Waste Management Treatment Technologies and Methods

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About the Book

Waste has been a major environmental issue everywhere since the industrial revolution. Besides the waste we create at home, school and other public places, there are also those from hospitals, industries, farms and other sources. A rising quality of life, and high rates of resource consumption patterns have had an unintended and negative impact on the urban environment - generation of wastes far beyond the handling capacities of urban governments and agencies. Cities are now grappling with the problems of high volumes of waste, the costs involved, the disposal technologies and methodologies, and the impact of wastes on the local and global environment.

But these problems have also provided a window of opportunity for cities to find solutions - involving the community and the private sector; involving innovative technologies and disposal methods; and involving behaviour changes and awareness raising. These issues have been amply demonstrated by good practices from many cities around the world. This book is divided in to four blocks. Block 1 deals with Waste Management Technologies, Block 2 deals with Water Security, Block 3 deals with Waste Management Banks, and finally, Block 4 deals with Reclamation and Remediation.

The assessment of environmental pollution is being extensively carried out to mitigate through interventions. The growth of urbanization and industrialization led to increase in deterioration of various components of environment including water resources. Several factors contributed to the development of science of environmental pollution in recent years, namely, the rapid strides in chemical, metallurgical and nuclear industries, vast use of fertilisers and pesticides in agriculture, deforestation; discharge of sewage and industrial wastes in oceans, rivers and groundwater streams and dumping of nuclear products in the underground pockets. The general sphere of course material on water security is the interaction between man and his environment at global scale and India in particular.

The book explains the basic issues of water availability globally and distribution in India's administrative State geographical territory and on watershed concept. Attention of communities have grown on water issues extending from quantitative to qualitative aspects with economic growth and pollution of aquatic resources became matter of discussion. The issues of water use; generation of wastewater leading to pollution; treatment of wastewater and scope of conventional and alternative technologies; and testing of water and wastewater for various uses impacting health of human beings and ecology at large are covered in this treatise.

The book shall be useful in understanding various aspects of water pollution and remediation techniques for securing water for its beneficial uses. The threat to maintain water resources widely covered under various blocks of this compendium on water security concept although presented with a over view of some problems that affect aquatic environments, such as eutrophication, are local in nature and can be solved at a local scale, provided sufficient financial and technical resources are made available, other problems are more regional or global and require efforts on the part of the international community to ameliorate conditions worldwide. For example, climate change and variability threaten the quality of aquatic ecosystems on a global scale, and requires international efforts to curb emissions of greenhouse gases that seem to be accelerating rates of climate change. It is thus the inter linking of various management modals can be developed to resolve the issues of quantity and quality aspects by business managers to revenue generation along with serving the requirement of one and all in the society.

In general, the significant increase of waste generation and its effects on sanitation, environmental, economical and social life associated with solid waste management suggest the researchers and society that the proper management of the waste through waste banks should be the very first priority for the community. The content of "Waste Management Banks" has been brought out incorporating key topics, latest advancements in the field of waste management banks which include waste to wealth, zero waste city, re-use and recycle methods with caselets. The contents are thoroughly reviewed and presented according to their needs. In the end, review questions, activity and references are provided. This course content includes 5 blocks which cover all the fundamental concepts of waste management banks include collection, separation, reuse, recycle and disposal of wastes.

Waste handling professionals, who are involved in collection, transport, processing, recycling or disposal of waste, are in direct contact with the waste, touching it or inhaling it and being at the risk of even ingesting it accidentally. However, even the most innocuous of wastes, such as the municipal solid waste generated from households, can have components with properties detrimental to the health and well-being of the individual as well as the environment, and create untold harm. For instance, are the everyday items like batteries, paints and insecticides that have been categorized as household/ domestic hazardous waste.

The hazards associated with other wastes coming from manufacturing industries (chemical), nuclear power plants (radioactive) or hospitals and healthcare institutions (biomedical) are several degrees more harmful and the exposure to such wastes – in the absence of adequate safety precautions – can lead to morbidity or even be fatal.

In addition, the contingency of accidental spillage, mishaps, and security lapses emerging from human error or mechanical failure, cannot be denied. Be it the Chernobyl tragedy or the Bhopal gas tragedy, the loss of life and property due to hazardous chemicals still haunts mankind's collective memory.

Hence, irrespective of whether it is the question of following day-to-day routine or remaining prepared for untold disasters, it is of the utmost importance for a waste management professional to understand the hazards associated with waste – not only to the individual but to the surrounding environment as well.

Acknowledgement

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Block 1

Waste Management Technologies

Swachhta Action Plan

सत्यमेव जयते

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MGNCRE

Where there is Rural Wellbeing
there is Universal Prosperity

Contents

Chapter1 Understanding Waste Management

Introduction

Waste has been a major environmental issue everywhere since the industrial revolution. Besides the waste we create at home, school and other public places, there are also those from hospitals, industries, farms and other sources. A rising quality of life, and high rates of resource consumption patterns have had an unintended and negative impact on the urban environment - generation of wastes far beyond the handling capacities of urban governments and agencies. Cities are now grappling with the problems of high volumes of waste, the costs involved, the disposal technologies and methodologies, and the impact of wastes on the local and global environment.

But these problems have also provided a window of opportunity for cities to find solutions - involving the community and the private sector; involving innovative technologies and disposal methods; and involving behaviour changes and awareness raising. These issues have been amply demonstrated by good practices from many cities around the world.

Objectives of the Block

- To know the concept of waste management & its importance and benefits.
- To understand the sources, types and composition of Municipal Solid Waste(MSW).

1.1 Meaning of Waste Management

Waste is anything your business intends to discard, or handles or produces and is not wanted or required. Disposing of waste can have a significant impact on the environment. Producing excessive amounts of waste is often a sign that your business processes may be inefficient. It is in your interests to identify ways of reducing the amount of waste your business generates.

The amount and type of waste you produce will depend largely on the type of business you operate. For example, manufacturing businesses tend to produce more waste than those in service industries.

Waste can be solid, liquid, or gaseous and each type has different methods of disposal and management. Waste management is now not about merely dumping the unwanted things in a random way but it has become a systematic process consisting of collection, transportation, proper disposal of garbage, sewage and other waste products. This also offers various solutions for recycling the items, putting the waste to productive use.

Waste management deals with all types of waste, including industrial, biological and household. In some cases waste can pose a threat to human health. Waste is produced by human activity, for example, the extraction and processing of raw materials. Waste management is intended to reduce adverse effects of waste on human health, the environment or aesthetics.

Waste management simply means the collection, transport, processing or disposal, managing and monitoring of waste materials to minimize its consequences on humans and environment. Waste management (or waste disposal) are the activities and actions required to manage waste from its inception to its final disposal. This includes the collection, transport, treatment and disposal of waste, together with monitoring and regulation of the waste management process.Waste management practices are not uniform among countries (developed and developing nations); regions (urban and rural areas), and residential and industrial sectors can all take different approaches.

A large portion of waste management practices deal with Municipal solid waste (MSW) which is the bulk of the waste that is created by household, industrial, and commercial activity.

There is a need for a complete rethinking of "waste" - to analyse if waste is indeed waste. A rethinking that calls for

- WASTE to become WEALTH
- REFUSE to become RESOURCE
- TRASH to become CASH

There is a clear need for the current approach of waste disposal that is focused on municipalities and uses high energy/high technology, to move more towards waste processing and waste recycling (that involves public-private partnerships, aiming for eventual waste minimization - driven at the community level, and using low energy/low technology resources. Some of the defining criteria for future waste minimization programmes will include deeper community participation, understanding economic benefits/recovery of waste, focusing on life cycles (rather than end-of-pipe solutions), decentralized administration of waste, minimizing environmental impacts, reconciling investment costs with long-term goals.

What is the Waste Management Hierarchy?

You can save money if you manage your waste well and choose the best waste management options for your business. You need to choose the best waste management options for dealing with each type of waste your business produces.

Waste Management Hierarchy

You should follow the waste management hierarchy when choosing a waste option. The waste hierarchy can help you to choose the least environmentally damaging option, in order

- Reduce - the most cost-effective option is to cut the amount of waste you produce in the first place.

- Reuse - products and materials can be reused by your own business or another organisation.
- Recycle and compost - these options ensure that benefit is still gained from goods and materials that have reached the end of their useful life.
- Recover energy - some facilities use waste to generate energy or produce biofuel.
- Dispose - the least sustainable option is to bury waste at landfill sites or burn it without recovering energy, as these do not lead to any benefit from the waste.

You must declare on your waste transfer note or hazardous waste consignment note that you have applied the waste management hierarchy.

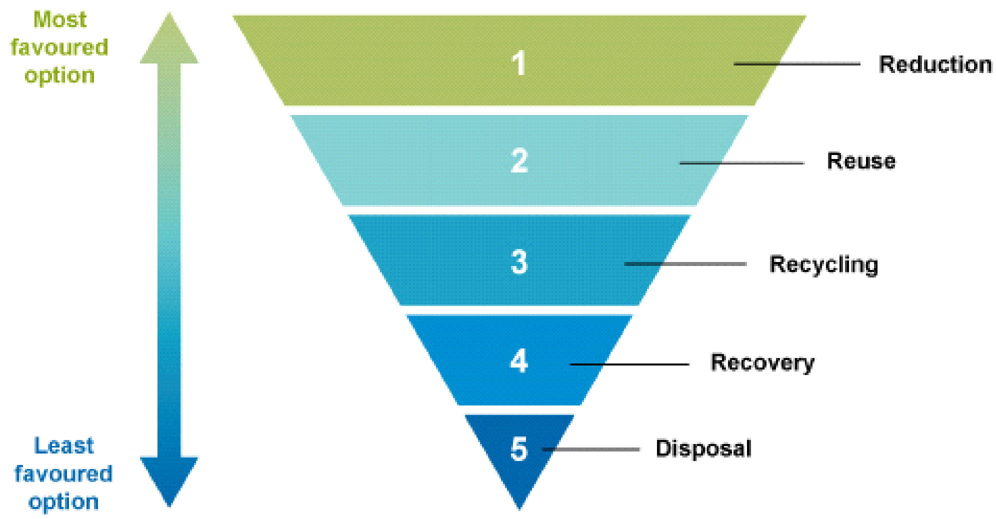

Figure 1.1 Waste management hierarchy (sourcewww.open.edu/openlearncreate)

When choosing a waste option for your business, you should consider

- what waste facilities are available near your business premises.
- the type of waste you have to dispose of.
- the cost or profit involved in dealing with your waste.
- the environmental impacts of disposing of your waste.
- You should select the best waste management option available as part of a co-ordinated plan to improve the way you deal with waste.
- Whichever waste management options you choose, you must comply with waste legislation and your duty of care for waste.
- What is waste (trash, garbage, rubbish, refuse)?

Difference between Trash and Garbage

Trash Solid waste from places like your attic, backyard or study. Trash items include paper and card boxes and the like.

Garbage This is waste from kitchen and bathroom. They also include waste from cooking food and from food storage facilities.

Waste are items we (individuals, offices, schools, industries, hospitals) don't need and discard. Sometimes there are things we have that the law requires us to discard because they can be harmful. Waste comes in infinite sizes—some can be as small as an old toothbrush, or as large as the body of a school bus.

Waste at Home

Everyone creates waste, although some people are very environmentally conscious and create very little. Likewise, some countries do a very good job creating less waste and managing the rest. Others are pretty horrible and have created huge environmental problems for the people and animals living there.

Waste Fact Did you know?

Europe creates about over 1.8 billion tonnes of waste each year. This means each person creates about 3.5tonnes on average.

Waste fact Did you know?

In 2010, Americans generated about 250 million tons of trash and recycled and composted over 85 million tons of this material, equivalent to a 34.1 percent recycling rate. On average, we recycled and composted 1.51 pounds out of our individual waste generation of 4.43 pounds per person per day. —EPA, USA.

All over the world, communities handle their waste or trash differently. Some common methods of managing their waste include landfilling, recycling and composting. Other communities strongly embark on waste reduction and litter prevention/control aimed at reducing the production of waste in the first place. Some communities also engage in waste-to-energy plants and hazardous waste disposal programs.

Importance of Waste Management

According to some research reports, every year, 62 million tonnes of waste is generating out of which only 28% of waste is recycled and 72% is left on the roads and the landfill areas for several years, which is fraught with hazardous consequences. Presently, most of the developing countries are facing almost similar situation. Therefore, segregating various kinds of wastes from the households, efficient waste collection systems, proper disposal, and sustainable recovery are very much needed processes in modern-day world.

Nothing is waste until it cannot be used anymore in any way. We generally see wastes piled up but do not think deep enough on how to use them. Today there are many innovations available in waste management like recycling wastes into usable products, generating methane or fuels, manufacturing new products for home/commercial usage such as fence posts, furniture and so on. Therefore, the importance of managing waste in a very effective way has enhanced many folds now-a-days.

What can be done to manage waste in a scientific way?

An effective strategy to dispose various wastes can offer many solutions for the various problems associated with waste materials. The most efficient way to deal the waste is to recycle and compost. It ensures there is gradual improvement of new and cost-effective facilities, which aims to encourage higher environmental protection standards.

Efficient management of Landfills : Most landfills lack proper on-site waste management thus contributing to some additional threats to the environment. After certain period, these landfills tend to leak and pollute ground water and other neighbouring environmental habitats making waste management a very difficult task. These landfills also generate potentially unsafe gases.

Most of the laws and regulation guiding the operations of landfills are often slack at monitoring and regulating the different types of wastes like medical waste, municipal waste, special waste or hazardous waste. This slackness of the laws contributes towards significant increases in toxicity and hazardous waste to a point where the landfill waste problems often lasts up to many decades.

Concept of 3R: Keeping the nature of waste generated by the households and industries in view, the three R's mantra of Reuse, Reduce and Recycle appears be more suitable to meet this challenge. Care should be taken to see that these options should be taken up under a well sustainable framework.

Zero Waste System: Industries can play a very significant role by streamlining the process of waste management for the entire organization through the one central system. Companies can deal effectively with hazardous waste regulations about the generation of their waste, its handling, transportation and safe disposal of the waste. In fact they can very well attain "zero waste to landfill" targets as part of sustainability initiatives.

More emphasis should be given to responsible resource use with an objective of avoidance, maximizing recycling and waste reduction methods. This involves techniques such as repair of broken things instead of buying new, purchasing and re-using second-hand items, and designing reusable and recyclable products.

Benefits of Waste Management

The benefits of managing wastes are very clear from the following

- Saving Natural Resources: It is a matter of serious concern for us when we see that many natural resources such as trees, gas, and water are diminishing very rapidly. We all know that paper, cupboards, paper cups, and many other products are made from trees. However, trees are cut down on a large scale every year and new trees are not replacing them at the rate they are cut. Therefore, we should think to recycle paper products so that there is no need of cutting new trees. It is also quite possible to reuse plastic and metal items. Some countries have established certain sites where people can bring and sell old newspapers, metal items or glass. These products are recycled and used again.

- Producing energy: Recycling is a great way to produce energy. By recycling something, we save energy because more energy is usually needed to produce a new item. For example, it is possible to get energy from recycling the waste. In Mukesh Ambani's house, garbage is used to create electricity. It is reported that electricity is generating from the waste by a special system in their house. First, the dry and wet wastes are separated, after which the electricity is generated. Electricity in such a large house is being produced by recycling the wastes.

- Reduce pollution: Recycling is a one of the most powerful tools to save nature and humanity. Making more people aware is a contribution in a better future. The more people start to manage their waste, the better planet we will have to live in. Apart from leaving a lot of waste, humanity pollutes the environment by producing various products. Factories considerably pollute the atmosphere with smoke by manufacturing processes. Recycling reduces pollution and helps save energy. Sounds like a win-win solution.

- Recycling Rubbish: Rubbish is a big problem for aquatic life too. A lot of rubbish is thrown away into the sea and ocean. There are large areas of waste called "waste islands," which are made of rubbish that has been accumulated in one place. Recycling rubbish is important for nature and humanity. Recycling begins with rubbish management. It means that paper items can be collected into a paper bin for paper waste, glass into a glass bin and so on.

Indian Scenario on Waste management

Under Indian scenario, the approach towards solid waste management is not scientific, at least for a common person. As the number of industries is increasing day by day due to a rapid increase in urbanization, this is eventually leading to the generation of municipal solid waste at a significantly high rate. In today's time, this problem has become so disturbing that a small rain creates conditions like floods in towns and cities.

If we look at the condition that was existing during few decades ago, it gives us an impression that it was far better than the present. During those days not only, the roads but even the streets of small towns used to be cleaned every day. Cleaning of drainages used to a part of everyday life and generally, no one would deliberately put garbage in the drainage. The silts and litter collected from the houses used to convert into organic fertilizers.

In this context, we can cite one example of a small city of Gujarat state – Bhavnagar to have a very good system of managing the drains. Bhavnagar is one of the few cities having underground drainage facilities ever since the time prior to independence. The old city of Bhavnagar had underground drainage system. These internal drainage works of the city came into practice since 1936 by Public Works Department of the state.

During olden days, people had a habit of shopping with a cloth bag. The goods purchased from the market used to be brought home usually in this bag. However, gradually the bag was replaced by a plastic bag. People started feeling ashamed to walk around with a cloth bag, as the use of plastic bags became the national habit. Now the use of plastic is growing due to continuous consumption of various commodities of day-to-day life.

Recommendations to Manage Waste Effectively/Solutions for Waste Management

We are moving from worse to worst in waste management because of the lack of laws and regulations in this regard. We do not have even a single city where the entire waste of the city is being managed in a scientific way. Identifying the sites where waste could be dumped and managed is becoming a great problem because of the resistance of the local people due to environmental considerations. In most of the towns, this waste ultimately finds its way on the banks of the rivers or on the periphery of water bodies. As a result, the surface water bodies are getting polluted. It is imperative that city planners consider this aspect in the planning stage itself.

Adequate consideration should be given to monitor the processes. There is a need to educate the public and plan in a proper way for waste management programs and implement into current waste management system. Some awareness programs also must be conducted to enhance the knowledge about managing the waste in an eco-friendly way. If these things are accomplished properly, we will be able to save money at individual as well as society level.

The concerned authorities should provide the introduction of certain programs and policy development about how efficiently we can do the waste management. It is not that everything eventually will decompose as this process results in many non-worthy by-products in the end. Most of the things we discard do not decompose. We unwittingly contribute to store them in a huge quantity at underground level. The time demands that waste management must be sustainable. Now a days, the proper management of solid wastes needs an economically affordable, socially accepted and environmentally friendly appropriate technology.

Recycling makes sense in most of the areas of our economy. In modern cities, wastewater is treated to use it again but when cooking oil starts solidifying in collection systems and eventually hamper the flow of wastewater, we have to deal with very high costs for repairs. Moreover, not all kinds of wastes are getting recycled. Only metals are recycled almost 100% into consumer goods. Glass and paper are at the second place but unfortunately, only less than 50% of plastics are being recycled. A very fruitful alternative to this problem could be to use bio-plastic, which tend to be more favourable to the environment.

Various communities from all walks of life whether urban or rural should be educated about the harmful impact of waste on infrastructure and public health through multimedia and how waste collection services can be improved to at local level. People should understand if they are not able to manage them, these waste materials might cause a serious hazard to human health as well as to the environment.

In fact, it is rarely better to simply throw something away than to reuse it or recycle it. We must always have in mind that our main and ultimate objective of waste management program is to keep the Earth clean and to conduct our activities in an eco-friendly way so that we can leave a more hygienic and healthier environment for future generations.

1.2 Sources of Solid Waste

Eight main sources of solid waste are as follows:

1. Municipal solid waste 2. Industrial solid waste 3. Mining solid waste 4. Fertilizers 5. Pesticides and Biocides 6. Excretory products of humans and livestock 7. Electronic wastes 8. Hospital Wastes.

1. Municipal Solid Waste

These are solid waste from home, offices, stores, schools, hospitals, hotels etc. These domestic solid wastes one usually, thrown in municipal garbage collecting cans or on road side open waste lands. They are collected by municipality vehicles to certain garbage disposal site. They are dumped over a large area of land which becomes the breeding ground of flies and rats. Usually they are not burnt to reduce the volume because burning would cause air pollution which is still more dangerous.

2. Industrial Solid Waste

Most of the toxic industrial waste are dumped on waste lands for slow and gradual decomposition. Some industries dump their effluents on barren land, road sides creating very unhygienic environment for the local population. Some of the effluents have heavy metals which pollute the ground water through seepage during the monsoon season. Some heavy metals have been found slowly accumulating on farmland soils. One such most toxic heavy metal is cadmium which is present in traces in some fertilizers.

3. Mining Solid Waste

They include mine dust, rock tailing, slack and slag. Open cast mining completely spoil the surrounding soil. Toxic chemicals and metals present in the mining wastes destroy vegetation and produce many deformities in animals and human beings.

4. Fertilizers

Chemical fertilizers increase soil fertility and gives better crop yield in lesser time. Shortly, the land becomes saline, acidic or alkaline and loses fertility.

5. Pesticides and Biocides

These toxic chemicals used in crop field which are not eco-friendly. They enter into crop and then into primary and secondary consumers. Even human beings are affected due to bio-magnification.

6. Excretory Products of Humans and Livestock

In underdeveloped and developing countries, the poor sanitary conditions aggravate soil pollution. The excreta of man and animals, digested sewage sludge used as manure pollute the soil. Several germs present in such wastes contaminate soil, vegetables, and water bodies causing severe health hazards.

7. Electronic Waste

The latest solid waste that has appeared in last twenty years commonly known as e-waste is no less harmful. Irreparable computer and electronic goods. Frequently, more efficient and user-friendly electronic items appear in the market thus discarding the old generation equipment which simply become garbages or solid wastes.

Over half of the e-wastes generated in developed countries are exported to developing countries where they ultimately increase the e-garbage proportions.

8. Hospital Waste

Hospitals generate hazardous wastes that contain disinfectants, other harmful chemicals and pathogenic microorganism. Such wastes require careful treatment and disposal. The use of incinerators is crucial for disposal of hospital wastes.

Table 1.1 Sources & Types of Solid Waste (Source: Franklin Association 1999)

Source of Municipal Solid Waste	Type of Solid Waste
Residential	Food waste, food container and packer, can, bottles, papers and newspapers, clothes, garden waste, e-waste, furniture waste
Commercial Centre (Office lot, small shape, restaurant)	Vary type of papers and boxes, food waste, food container and packer, can, bottles
Institutional (school, university, college, hospital)	Office waste, food waste, garden waste, furniture waste
Industry (factory)	Office waste, cafeteria waste, processing waste
City Centre (drainage and road)	Vary type of garden waste, construction waste, public waste

Every day, tonnes of solid waste is disposed of at various landfill sites. This waste comes from homes, offices, industries and various other agricultural related activities. These landfill sites produce foul smell if waste is not stored and treated properly. It can pollute the surrounding air and can seriously affect the health of humans, wildlife and our environment. The following are major sources of solid waste

Residential

Residences and homes where people live are some of the major sources of solid waste. Garbage from these places include food wastes, plastics, paper, glass, leather, cardboard, metals, yard wastes, ashes and special wastes like bulky household items like electronics, tyres, batteries, old mattresses and used oil. Most homes have garbage bins where they can throw away their solid wastes in and later the bin is emptied by a garbage collecting firm or person for treatment.

Industrial

Industries are known to be one of the biggest contributors of solid waste. They include light and heavy manufacturing industries, construction sites, fabrication plants, canning plants, power and chemical plants. These industries produce solid waste in form of housekeeping wastes, food wastes, packaging wastes, ashes, construction and demolition materials, special wastes, medical wastes as well as other hazardous wastes.

Commercial

Commercial facilities and buildings are yet another source of solid waste today. Commercial buildings and facilities in this case refer to hotels, markets, restaurants, go downs, stores and office buildings. Some of the solid wastes generated from these places include plastics, food wastes, metals, paper, glass, wood, cardboard materials, special wastes and other hazardous wastes.

Institutional

The institutional centers like schools, colleges, prisons, military barracks and other government centers also produce solid waste. Some of the common solid wastes obtained from these places include glass, rubber waste, plastics, food wastes, wood, paper, metals, cardboard materials, electronics as well as various hazardous wastes.

Construction and Demolition Areas

Construction sites and demolition sites also contribute to the solid waste problem. Construction sites include new construction sites for buildings and roads, road repair sites, building renovation sites and building demolition sites. Some of the solid wastes produced in these places include steel materials, concrete, wood, plastics, rubber, copper wires, dirt and glass.

Municipal Services

The urban centers also contribute immensely to the solid waste crisis in most countries today. Some of the solid waste brought about by the municipal services include, street cleaning, wastes from parks and beaches, wastewater treatment plants, landscaping wastes and wastes from recreational areas including sludge.

Treatment Plants and Sites

Heavy and light manufacturing plants also produce solid waste. They include refineries, power plants, processing plants, mineral extraction plants and chemicals plants. Among the wastes produced by these plants include, industrial process wastes, unwanted specification products, plastics, metal parts just to mention but a few.

Agriculture

Crop farms, orchards, dairies, vineyards and feedlots are also sources of solid wastes. Among the wastes they produce include agricultural wastes, spoiled food, pesticide containers and other hazardous materials.

Biomedical

This refers to hospitals and biomedical equipment and chemical manufacturing firms. In hospitals there are different types of solid wastes produced. Some of these solid wastes include syringes, bandages, used gloves, drugs, paper, plastics, food wastes and chemicals. All these require proper disposal or else they will cause a huge problem to the environment and the people in these facilities.

Municipal Sources of Waste

This includes trash or garbage from households, schools, offices, market places, restaurants and other public places. They include everyday items like food debris, used plastic bags, soda cans and plastic water bottles, broken furniture, grass clippings, product packaging, broken home appliances and clothing.

Waste Composition

Medical/Clinical Sources of Waste

Medical/clinical waste, normally refers to waste produced from health care facilities, such as hospitals, clinics, surgical theatre's, veterinary hospitals and labs. They tend to be classified as hazard waste rather than general waste. Items in this group include surgical items, pharmaceuticals, blood, body parts, wound dressing materials, needles and syringes

Agricultural Sources of Waste

Typically, this is waste generated by agricultural activities. These include horticulture, fruit growing, seed growing, livestock breeding, market gardens and seedling nurseries. Waste items in this group include empty pesticide containers, old silage wrap, out of date medicines and wormers, used tires, surplus milk, cocoa pods and corn husks.

End-of-life Automobiles

Automobile Scrap

When cars are old and not working again, where do they end up? Many people just leave them to rust in the fields, but there is a better way to deal with them. In many cities, these vehicles are sent to the plant, where all the removable parts are taken out for recycling. The rest is flattened up and shredded into pieces for recycling. The last bits that cannot be used again is sent to a landfill.

Industrial Sources of Waste

Since the industrial revolution, the rise in the number of industries manufacturing glass, leather, textile, food, electronics, plastic and metal products has significantly contributed to waste production. Take a look at the things in your home, every item there was probably manufactured and possibly, waste was produced as a result.

Construction/Demolition Sources of Waste

Construction waste is that resulting from the construction of roads and building. Sometimes old buildings and structures are pulled down (demolished) to make space for new ones. This is particularly common in old cities that are modernizing. This is called demolition waste. Waste items include concrete debris, wood, earth, huge package boxes and plastics from the building materials and the like.

Electronic Sources of Waste

This is waste from electronic and electrical devices. Think of DVD and music players, TV, Telephones, computers, vacuum cleaners and all the other electrical stuff in your home. These are also called e-waste, e-scrap, or waste electrical and electronic equipment (WEEE)

Some e-waste (like TV) contains lead, mercury, cadmium, and brominated flame retardants. These are harmful to humans and the environment. It is therefore important that the right authorities ensure the proper disposal of such waste.

There are several methods of managing all the various types of waste. Some of these methods cause additional harm to the environment, but not doing anything is not an option.

1.3 Types of Solid Waste

In a broad sense, waste can be classified into four major types as urban waste, industrial waste, biomass waste, and biomedical waste. With terms that are more specific, waste can be categorized as

- Solid Waste: Solid rubbish consists of number of items found in household along with some commercial as well as industrial locations.
- Liquid Waste: Households and industries generate liquid waste.
- Organic Waste: Consisting of organic material such as food, garden and lawn clippings organic waste includes animal and plant based material and degradable carbon such as paper, cardboard and timber, commonly found in household.
- Agricultural Waste: Waste generated by agriculture includes waste from crops and livestock.

- Bio-medical Waste: Bio-medical waste means any waste, which is generating during the diagnosis, treatment, or immunization of human beings or animals.
- Recyclable Rubbish Recyclable rubbish consists of all waste items that convert into products and use again as all types of metals, paper, and organic wastes.

Types/Methods/Techniques of Waste Management

Solid waste can be classified into different types depending on their source

a) Household waste is generally classified as municipal waste,

b) Industrial waste as hazardous waste, and

c) Biomedical waste or hospital waste as infectious waste.

Municipal Solid Waste

Municipal solid waste consists of household waste, construction and demolition debris, sanitation residue, and waste from streets. This garbage is generated mainly from residential and commercial complexes. With rising urbanization and change in lifestyle and food habits, the amount of municipal solid waste has been increasing rapidly and its composition changing. In 1947, cities and towns in India generated an estimated 6 million tonnes of solid waste, it was about 48 million tonnes in 1997 . More than 25% of the municipal solid waste is not collected at all; 70% of the Indian cities lack adequate capacity to transport it and there are no sanitary landfills to dispose of the waste. The existing landfills are neither well equipped nor well managed and are not lined properly to protect against contamination of soil and groundwater.

Garbage the four broad categories:

- Organic waste: kitchen waste, vegetables, flowers, leaves, fruits.
- Toxic waste: old medicines, paints, chemicals, bulbs, spray cans, fertilizer and pesticide containers, batteries, shoe polish etc.
- Recyclable paper, glass, metals, plastics.
- Soiled hospital waste such as cloth soiled with blood and other body fluids.

Over the last few years, the consumer market has grown rapidly leading to products being packed in cans, aluminium foils, plastics, and other such nonbiodegradable items that cause incalculable harm to the environment. In India, some municipal areas have banned the use of plastics and they seem to have achieved success. For example, today one will not see a single piece of plastic in the entire district of Ladakh where the local authorities imposed a ban on plastics in 1998. Other states should follow the example of this region and ban the use of items that cause harm to the environment. One positive note is that in many large cities, shops have begun packing items in reusable or biodegradable bags. Certain biodegradable items can also be composted and reused. In fact, proper handling of the biodegradable waste will considerably lessen the burden of solid waste that each city has to tackle.

There are different categories of waste generated, each take their own time to degenerate (as illustrated in the table below).

The type of litter we generate and the approximate time it takes to degenerate

Table 1.2 Type of litter & approximate time (Source: slideplayer.com/8987510)

Type of litter	Approximate time it takes to degenerate the litter
Organic waste such as vegetable and fruit peels, leftover foodstuff, etc.	A week or two.
Paper	10–30 days
Cotton cloth	2–5 months
Wood	10–15 years
Woollen items	1 year
Tin, aluminium, and other metal items Such as cans	100–500 years
Plastic bags	one million years?
Glass bottles	undetermined

Hazardous waste

Industrial and hospital waste is considered hazardous as they may contain toxic substances. Certain types of household waste are also hazardous. Hazardous wastes could be highly toxic to humans, animals, and plants; are corrosive, highly inflammable, or explosive; and react when exposed to certain things e.g. gases. India generates around 7 million tonnes of hazardous wastes every year, most of which is concentrated in four states Andhra Pradesh, Bihar, Uttar Pradesh, and Tamil Nadu. Household waste that can be categorized as hazardous waste include old batteries, shoe polish, paint tins, old medicines, and medicine bottles.

Hospital waste contaminated by chemicals used in hospitals is considered hazardous. These chemicals include formaldehyde and phenols, which are used as disinfectants, and mercury, which is used in thermometers or equipment that measure blood pressure. Most hospitals in India do not have proper disposal facilities for these hazardous wastes. In the industrial sector, the major generators of hazardous waste are the metal, chemical, paper, pesticide, dye, refining, and rubber goods industries. Direct exposure to chemicals in hazardous waste such as mercury and cyanide can be fatal.

Hospital Waste

Hospital waste is generated during the diagnosis, treatment, or immunization of human beings or animals or in research activities in these fields or in the production or testing of biologicals. It may include wastes like sharps, soiled waste, disposables, anatomical waste, cultures, discarded medicines, chemical wastes, etc. These are in the form of disposable syringes, swabs, bandages, body fluids, human excreta, etc. This waste is highly infectious and can be a serious threat to human health if not managed in a scientific and discriminate manner. It has been roughly estimated that of the 4 kg of waste generated in a hospital at least 1 kg would be infected.

Surveys carried out by various agencies show that the health care establishments in India are not giving due attention to their waste management. After the notification of the Bio-medical Waste (Handling and Management) Rules, 1998, these establishments are slowly streamlining the process of waste segregation, collection, treatment, and disposal. Many of the larger hospitals have either installed the treatment facilities or are in the process of doing so.

Generally, waste could be liquid or solid waste. Both of them could be hazardous. Liquid and solid waste types can also be grouped into organic, re-usable and recyclable waste.

Let us see some details below

Liquid Type

Waste can come in non-solid form. Some solid waste can also be converted to a liquid waste form for disposal. It includes point source and non-point source discharges such as storm water and wastewater. Examples of liquid waste include wash water from homes, liquids used for cleaning in industries and waste detergents.

Solid Type

Solid waste predominantly, is any garbage, refuse or rubbish that we make in our homes and other places. These include old car tyres, old newspapers, broken furniture and even food waste. They may include any waste that is non-liquid.

Hazardous Type

Hazardous or harmful waste are those that potentially threaten public health or the environment. Such waste could be inflammable (can easily catch fire), reactive (can easily explode), corrosive (can easily eat through metal) or toxic (poisonous to human and animals). In many countries, it is required by law to involve the appropriate authority to superwise the disposal of such hazardous waste. Examples include fire extinguishers, old propane tanks, pesticides, mercury-containing equipment (e.g, thermostats) and lamps (e.g. fluorescent bulbs) and batteries.

Organic Type

Organic waste comes from plants or animals sources. Commonly, they include food waste, fruit and vegetable peels, flower trimmings and even dog poop can be classified as organic waste. They are biodegradable (this means they are easily broken down by other organisms over time and turned into manure). Many people turn their organic waste into compost and use them in their gardens.

Recyclable Type

Recycling is processing used materials (waste) into new, useful products. This is done to reduce the use of raw materials that would have been used. Waste that can be potentially recycled is termed "Recyclable waste". Aluminium products (like soda, milk and tomato cans), Plastics (grocery shopping bags, plastic bottles), Glass products (like wine and beer bottles, broken glass), Paper products (used envelopes, newspapers and magazines, cardboard boxes) can be recycled and fall into this category.

16 Major Classification of Solid Waste

Some of the major various classification of solid waste are as follows 1. Municipal Waste 2. Domestic/ Residential Waste 3. Commercial Waste 4. Garbage 5. Rubbish 6. Institutional Waste 7. Ashes 8. Bulky Wastes 9. Street Sweeping 10. Dead Animals 10. Dead Animals 11. Construction and Demolition Wastes 12.Industrial Wastes 13. Hazardous Wastes 14.Sewage Wastes 15. Biomedical/Hospital Waste 16. Plastics.

Solid waste is the material generated from various human activities and which is normally disposed as useless and unwanted. A comprehensive classification of wastes is described below (Manual on Municipal Solid waste Management, 2000).

1. Municipal Waste

Municipal waste includes waste resulting from municipal activities and services such as street wastes, dead animals, market wastes and abandoned vehicles. However, the term is commonly applied in a wider sense to incorporate domestic wastes and commercial wastes.

2. Domestic / Residential Waste

This category of waste comprises the solid wastes that originate from single and multi-family house hold units. These wastes are generated as a consequence of house hold activities such as cooking, cleaning, repairs, hobbies, redecoration, empty containers packaging, clothing, old books, paper and old furnishings.

3. Commercial Waste

Commercial waste are solid wastes that originate in offices, wholesale and retail stores, restaurants, hotels, markets, warehouses and other commercial establishments. Some of these wastes are further classified as garbage and others as rubbish.

4. Garbage

Garbage is the term applied to animal and vegetable waste resulting from the handling, storage, sale, cooking and serving food. Such wastes contain putrescible organic matter, which produces strong odours and therefore attracts rats, flies and other vermin. It requires immediate attention in its storage, handling and disposal.

5. Rubbish

Rubbish is general term applied to solid wastes originating in households, commercial establishments and institutions, excluding garbage & ashes.

6. Institutional Waste

Institutional wastes are those arising from institutions such as schools, universities, hospitals and research institutes. It includes wastes, which are classified as garbage and rubbish, as well as wastes, which are considered to be hazardous to public health and to the environment.

7. Ashes

Ashes are the residues from the burning of wood, coal, charcoal, coke and other combustible materials for cooking and heating in houses, institutions and small industrial establishments. When produced in large quantities at power generation plants and factories, these wastes are classified as industrial wastes. Ashes consist of a fine powdery residue, cinders and clinker often mixed with small pieces of metal and glass.

8. Bulky Waste

Bulky household waste can't be accommodated in the normal storage containers of households. For this reason they require special collection. In developed countries residential bulky wastes include household furniture and "white goods" appliances such as stoves, washing machines and refrigerators, mattresses and springs, rugs, TV sets, water heaters, tyres, lawn mowers, auto parts, tree and brush debris, and so forth.

Commercial bulky wastes include packaging and containers in a wide range of sizes, including corrugated cardboard, and wood boxes, fiber, plastic and steel drums usually under 40 gallons (0.15m3), loose and bundled paper (office, printouts), bundles of textiles and plastics, bales of corrugated and paper, furniture and equipment, and flat and wire banding. Industrial bulky waste includes dunnage, including crates, cartons, pallets, skids; large and small steel, fibre, and plastic drums; bales and rolls of paper, plastics, and textiles; miscellaneous metal boxes, tubing, rod, punchings, and skeleton; wire, rope, and metal banding; and paper, textile, and plastic streamers (William D. Robinson, 1986).

9. Street Sweeping,

This term applies to wastes that are collected from streets, walkways, alleys, parks and vacant lots. In the more affluent countries, manual street sweeping has virtually disappeared but it still commonly takes place in developing countries, where littering of public places is a far more widespread and acute problem. Street wastes include paper, cardboard, plastic, dirt, dust, leaves and other vegetable matter.

10. Dead Animals

This is term applied to dead animals that die naturally or accidentally killed. This category does not include carcass and animal parts from slaughterhouses, which are regarded as industrial wastes. Dead animals are divided into 2 groups, large and small. Among the large animals are Horses, Cows, Goats, Sheep and the like. Small animals include dogs, cats, rabbits and rats. The reason for this differentiation is that large animals require special equipment for lifting and handling during their removal. If not collected promptly, dead animals are a threat to public health because they attract flies and other vermin as they putrefy. Their presence in public places is particularly offensive and emits foul smell from the aesthetic point of view.

11. Construction and Demolition Waste

Construction and demolition waste are the waste materials generated by the construction, refurbishment, repair and demolition of houses, commercial buildings and other structures. It mainly consists of earth, stones, concrete, bricks, lumber, roofing materials, plumbing materials, heating systems and electrical wires and parts of general municipal waste stream, but when generated in large amounts at building and demolition sites, it is generally removed by contractors for filling low lying areas and by urban local bodies for disposal at landfills. While retrievable items such as bricks, wood metal are recycled, the concrete and masonry waste accounting for 50% of the waste from construction and demolition activities, are not been currently recycled in India. Concrete and masonry waste can be recycled by sorting, crushing and sieving into recycled aggregates. These recycled aggregates can be used to make concrete for road construction and building material.

This category waste is complex due to the different types of building materials being used but in general may comprise of major components like Cement concrete, Bricks, Cement plaster, Steel (from RCC, door/ window frames, roofing support etc., Rubble, Stone (marble, granite, sand stone), Timber/wood and a few minor components like Conduits (iron, plastic), Pipes (GI, iron, plastic), Electrical fixtures (copper/ aluminium wiring, wooden baton, Bakelite, wire insulation, plastic switches), Panels (wooden, laminated), Others (Glazed tiles, glass panels).

12. Industrial Waste

In this category are the discarded solid material of manufacturing processes and industrial operations. They cover a vast range of substances which are unique to each industry. For this reason they are considered separately from municipal wastes. However, solid wastes from small industrial plants and ash from power plants are frequently disposed of at municipal landfills.

The major generators in the industrial solid wastes are the thermal power plants producing coal ash, the integrated Iron and steel mills producing blast furnace slag and steel melting slag, non-ferrous industries like aluminium, zinc, and copper producing red mud and tailings, sugar industries generating press mud, pulp and paper industries producing lime and fertilizer and allied industries producing gypsum.

13. Hazardous Wastes

Hazardous wastes may be defined as wastes of industrial, institutional or consumer origin which because of their physical, chemical or biological characteristics are potentially dangerous to human and the environment. In some cases although the active agents may be liquid or gaseous, they are classified as solid waste because they are confined in solid containers. Typical examples are solvents, paints and pesticides whose spent containers are frequently mixed with municipal wastes and become part of urban waste stream.

14. Sewage Waste

The solid by-products of sewage treatment are classified as sewage wastes. They are mostly organic and derive from the treatment of organic sludge from both the raw and treated sewage. The inorganic fraction of the raw sewage such as grit is separated at a preliminary stage of treatment, but because it entrains putrescible organic matter which may contain pathogens, must be buried/disposed off without delay.

The bulk of treated dewatered sludge is useful as a soil conditioner but invariably its use for this purpose is uneconomical. The solid sludge therefore enters the stream of municipal wastes unless special arrangements are made for its disposal.

15. Biomedical/Hospital Waste

Hospital waste is generated during the diagnosis, treatment, or immunization of human beings or animals or in research activities in these fields or in the production or testing of biological. It may include wastes like sharps, soiled waste, disposables, anatomical waste, cultures, discarded medicines, chemical wastes, etc.

These are in the form of disposable syringes, swabs, bandages, body fluids, human excreta, etc. This waste is highly infectious and can be a serious threat to human health if not managed in a scientific and discriminate manner. It has been roughly estimated that of the 4 kg of waste generated in a hospital at least 1 kg would be infected.

These wastes are categorized into 10 different categories as

- Human anatomical waste (tissues, organs, body parts etc.)
- Animal waste
- Microbiology and biotechnology waste, such as, laboratory cultures, microorganisms, human and animal cell cultures, toxins etc.
- Waste sharps such as, hypodermic needles, syringes, scalpels, broken glass etc
- Discarded medicines and cyto-toxic drugs
- Soiled waste, such as dressings, bandages, plaster casts, material contaminated with blood etc
- Solid waste (disposal items like tubes, catheters etc., excluding sharps)
- Liquid waste generated from any of the infected areas
- Incineration ash
- Chemical waste

Surveys carried out by various agencies show that the health care establishments in India are not giving due attention to their waste management. After the notification of the Bio-medical Waste (Handling and Management) Rules, 1998, these establishments are slowly streamlining the process of waste segregation, collection, treatment and disposal. Many of the larger hospitals have either installed the treatment facilities or are in the process of doing so.

16. Plastics

Plastics, due to their versatility in use and impact on environment can be grouped under a different category of solid waste. Plastic with its exclusive qualities of being light yet strong and economical, has invaded every aspect of our day-to-day life.

1.4 Composition of Solid Waste

The composition of municipal solid waste varies greatly from municipality to municipality and it changes significantly with time. In municipalities which have a well developed waste recycling system, the waste stream mainly consists of intractable wastes such as plastic film and non-recyclable packaging materials.

- Composition is the term used to describe the individual components that make up a solid waste stream and their relative distribution.
- Information on the composition of solid wastes is important in evaluating equipment needs, systems and management programme and plans.
- The residential and commercial portion makes up about 50 to 75 percent of total MSW generated in a community.
- The actual percentage distribution will depend on
    - The extent of construction and demolition activities.
    - The extent of the municipal services provided.
    - The types of water and wastewater treatment process that are used.

Table 1.3 Composition of municipal solid waste (Source: slideplayer.com/slide/6288311)

Typical Physical Composition of Residential MSW

Component	Percent by Weight		Moisture percent	
	Range	Typical	Range	Typical
Organic				
Food wastes	6 – 26	15	50 – 80	70
Paper	25 – 45	40	4 – 10	6
Cardboard	3 – 15	4	4 – 8	5
Plastics	2 – 8	3	1 – 4	2
Textiles	0 – 4	2	6 – 15	10
Rubber	0 – 2	0.5	1 – 4	2
Leather	0 – 2	0.5	8 – 12	10
Yard wastes	0 – 20	12	30 – 80	60
Wood	1 – 4	2	15 – 40	20
Misc. organics				
Inorganics				
Glass	4 – 16	8	1 – 4	2
Tin cans	2 – 8	6	2 – 4	3
Aluminum	0 – 1	1	2 – 4	2
Other metal	1 – 4	2	2 – 6	3
Dirt, ash etc	0 – 10	4	6 – 12	8

Waste composition depends on a wide range of factors such as food habits, cultural traditions, climate and income (Srivastava et al., 2014; Patel et al., 2014; Naveen et al., 2013; Gupta et al.,2013; Kumar et al., 2009). Many categories of municipal solid waste are found such as food waste, rubbish, commercial waste, institutional waste, street sweeping waste, industrial waste, construction and demolition waste, and sanitation waste. Municipal solid waste contains compostable organic matter (fruit and vegetable peels, food waste), recyclables (paper, plastic, glass, metals, etc.), toxic substances (paints, pesticides, used batteries, medicines), and soiled waste (bloodstained cotton, sanitary napkins, disposable syringes) (Kaushal et al., 2012; Upadhyay et al., 2012; Reddy and Galab, 1998). Of these papers, plastics, yard debris, food waste, wood, textiles, disposable diapers, bones, leather and other organics are combustible materials although glass, metal and aluminium are non-combustible materials (Srivastava et al., 2014; Denison and Ruston, 1990). The composition of municipal solid waste at generation sources and collection points was determined on a wet weight basis and it consists mainly of a large organic fraction (40%–60%), ash and fine earth (30%–40%), paper (3%–6%) and plastic, and glass and metals (each less than 1%). The C/N ratio ranges between 800 and 1000 kcal/kg (Sharholy et al., 2008)

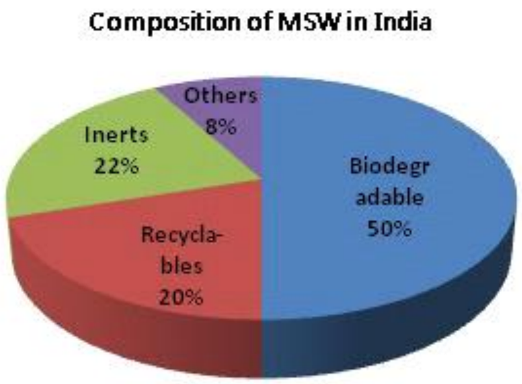

Figure 1.2 Composition of Indian Municipal Solid Waste (www.eai.in/ref/ae/wte/typ/msw)

Contents

1. Composition of MSW

2. Composition of Recyclables and Informal Recycling

1. Composition of MSW

A major fraction of urban MSW in India is organic matter (51%). Recyclables are 17.5 % of the MSW and the rest 31% is inert waste. The average calorific value of urban MSW is 7.3 MJ/kg (1,751 Kcal/kg) and the average moisture content is 47% (Table 6). It has to be understood that this composition is at the dump and not the composition of the waste generated. The actual percentage of recyclables discarded as waste in India is unknown due to informal picking of waste which is generally not accounted. Accounting wastes collected informally will change the composition of MSW considerably and help estimating the total waste generated by communities.

The large fraction of organic matter in the waste makes it suitable for aerobic and anaerobic digestion. Significant recyclables percentage after informal recycling suggests that efficiency of existing systems should be increased. Recycling and composting efficiency are greatly reduced due to the general absence of source separation. Absence of source separation also strikes centralized aerobic or anaerobic digestion processes off the list. Anaerobic digestion is highly sensitive to feed quality and any impurity can upset the entire plant. Aerobic digestion leads to heavy metals leaching into the final compost due to presence of impurities and makes it unfit for use on agricultural soils. In such a situation the role of waste to energy technologies and sanitary land filling increases significantly. This is due to the flexibility of waste-to-energy technologies in handling mixed wastes. Sanitary landfilling needs to be practiced to avoid negative impacts of open dumping and open burning of wastes on public health, and on air, water and land resources. Therefore, increasing source separation rates is always the long term priority.

2. Composition of Recyclables and Informal Recycling

A significant amount of recyclables are separated from MSW prior to and after formal collection by the informal recycling sector. The amount of recyclables separated by the informal sector after formal collection is as much as 21%. The amount of recyclables separated prior to collection is generally not accounted for by the formal sector and could be as much as four times the amount of recyclables separated after formal collection. Comparing the percentage of recyclables in MSW in metro cities with that in smaller cities clearly shows the increased activity of informal sector in metros and other large cities. Increased presence of informal sector in large cities explains the huge difference in recyclables composition between large and small cities, observed by PerinazBhada, et al. In metro cities, which generally have a robust presence of informal recycling sector, the amount of recyclables at the dump is 16.28%, whereas in smaller cities where the presence of informal sector is smaller, the composition of recyclables is 19.23%. The difference of 3% in the amount of recyclables at the dump indicates the higher number of waste pickers and their activity in larger cities.

Following major categories of waste are generally found in MSW of India

- Biodegradable Waste: Food and kitchen waste, green waste (vegetables, flowers, leaves, fruits)and paper.
- Recyclable Material: Paper, glass, bottles, cans, metals, certain plastics, etc.
- Inert Waste Matter: C&D, dirt, debris.
- Composite waste: Waste clothing, Tetra packs, waste plastics such as toys.
- Domestic Hazardous Waste (also called "household hazardous waste") and toxic waste

Waste medicine, e-waste, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and pesticide containers, batteries, and shoe polish. MSW in India has approximate 40–60% compostable, 30–50% inert waste and 10% to 30% recyclable. Analysis carried out by NEERI reveals that in totality Indian waste consists of Nitrogen content (0.64 ± 0.8) %, Phosphorus (0.67 ± 0.15)%, Potassium (0.68 ± 0.15)%, and C/N ration (26 ± 5) %.

Determination of the Composition of MSW in the Field

- Determination of the composition is not an easy task because the heterogeneous nature of solid wastes.
- More generalized field procedures based on common sense and random sampling techniques have evolved.
- The procedure for residential MSW can be summarized as following.
- The load is first quartered.

- One part is then selected for additional quartering unit a sample size of about 200 lb is obtained.
- It is important to maintain the integrity of each selected quarter regardless of the odour and physical decay.
- Make sure that all the components are measured.
- The field procedure for component identification for commercial and industrial waste involves the analysis of representative waste samples taken directly from the source, not from a mixed waste load in a collection vehicle. Due to the fact that these wastes are so variable.

Future Changes in Waste Composition

In terms of solid waste management planning, knowledge of future trends in the composition of solid waste and quantities are of great importance.

Food Waste

The quantity of residential food waste collected has changed significantly over the years as a result of technical advances and change in public health. Food processing and packaging industry and the use of kitchen food waste grinders shave affected the quantity of food waste. The percentage of food waste, by weight, has decreased from about 14% in the early 60s to about 9% in 1992.

Paper and Cardboard

The percentage of paper and cardboard found in MSW has increased greatly over the past half century, rising from about 20% in the early 1940s to about 40% in 1992. If the postal rate for bulk mail were increased to first class mail, a significant reduction would occur in the amount of paper collected for disposal.

Yard Waste

The percentage of yard waste has also increased significantly, due primarily to passage of laws that prohibit burning of yard wastes. By weight, yard waste currently accounts for about 16-24% of the waste stream. Environmental conditions such as droughts have also affected the quantities of yard wastes collected in certain locations.

Plastics

The percentage of plastics in solid waste has increased significantly during the past 50 years. The use of plastics has increased from almost non- measurable quantities in the early 1940s to 7% in 1992. It is anticipated the use of plastic will continue to increase, but at a slower rate than during the past 25 years.

1.5 Types of Materials Recovered from MSW

The types of materials recovered from MSW are

- Aluminium
- Paper
- Plastics
- Glass
- Ferrous Metals (Iron and Steel)
- Non ferrous metals
- Yard waste collected separately
- Construction and demolition wastes

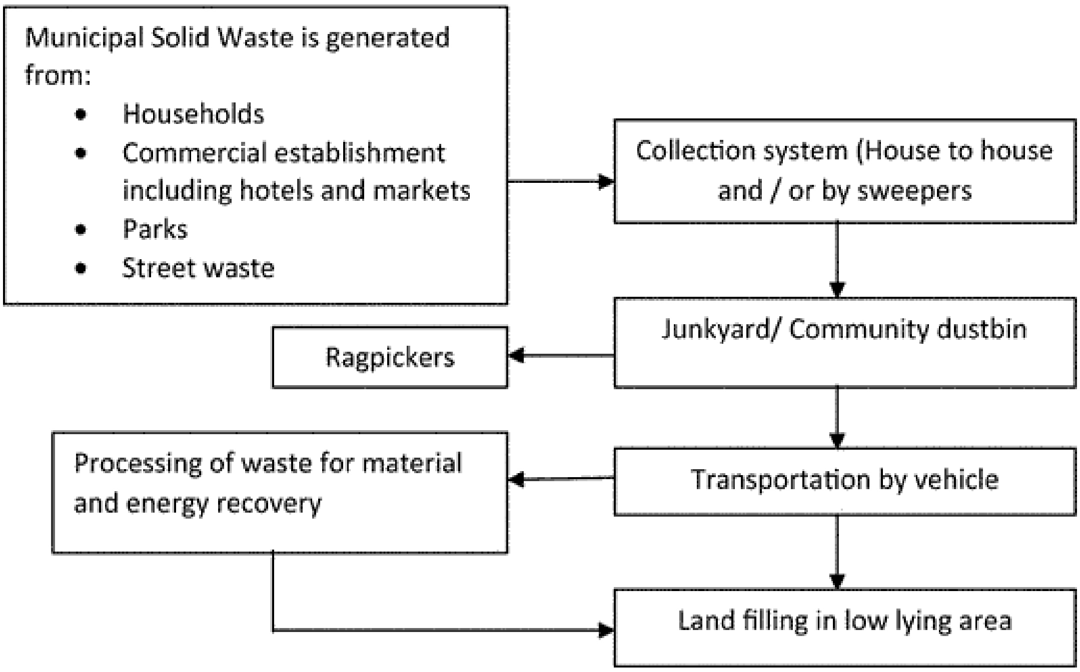

Fig 1.3 Flow chart of existing MSW Management system in India (www.researchgate.net/figure)

Recycling is the best way to solve solid waste management problem. This process exists in all cities. However, the recycling system differs from developing countries and developed countries. Developed countries have well organized source separation and recycling system while in the developing countries the system of recycling is not effective because it is still in the hands of informal sectors.

The major types of recyclable wastes recovered included paper, plastics, ferrous metal and non-ferrous metal, which accounted for about 97% of the waste recovered. The remaining 3% include electrical & electronic equipment, wood, textile, rubber tyres and glass. Following major categories of waste are generally found in MSW of India:

Biodegradable Waste Food and kitchen waste, green waste (vegetables, flowers, leaves, fruits) and paper. Recyclable Material Paper, glass, bottles, cans, metals, certain plastics, etc.

Municipal Solid Waste management is a major environmental issue in India. Due to rapid increase in urbanization, industrialization and population, the generation rate of municipal solid waste in Indian cities and towns is also increased. Mismanagement of Municipal Solid Waste can cause adverse environmental impacts, public health risks and other socio-economic problems.

Resource recovery is using wastes as an input material to create valuable products as new outputs. The aim is to reduce the amount of waste generated, therefore reducing the need for landfill space and also extracting maximum value from waste. Resource recovery delays the need to use raw materials in the manufacturing process. Materials found in municipal solid waste can be used to make new products. Plastic, paper, aluminium, glass and metal are examples of where value can be found in waste.

Resource recovery goes further than just the management of waste. Life-cycle analysis (LCA) can be used to compare the resource recovery potential of different treatment technologies. Improvements to administration, source separation and collection, reuse and recycling are important. For example, organic materials can be treated with anaerobic digestion and turned into energy, compost or fertilizer.

Resource recovery can also be an aim in the context of sanitation. Here, the term refers to approaches to recover the resources that are contained in wastewater and human excreta (urine and faeces). The term "toilet resources" has come into use recently. Those resources include nutrients (nitrogen and phosphorus), organic matter, energy and water. This concept is also referred to as ecological sanitation. Separation of waste flows can help make resource recovery simpler. Examples include keeping urine separate from faeces (as in urine diversion toilets) and keeping greywater and blackwater separate in municipal wastewater systems.

The following resources can be recovered

Water In many water-scarce areas there are increasing pressures to recover water from wastewater. In 2006, the World Health Organization, in collaboration with the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Environment Program (UNEP), developed guidelines for safe use of wastewater. In addition, many national governments have their own regulations regarding the use of recovered water. Singapore for example aims to recover enough water from its wastewater systems to meet the water needs of half the city. They call this NEWater. Another related concept for wastewater reuse is sewer mining.

Energy: The production of biogas from wastewater sludge is now common practice at wastewater treatment plants. In addition, a number for methods have been researched regarding use of wastewater sludge and excreta as fuel sources.

Fertilizing nutrients: A human excreta contains nitrogen, phosphorus, potassium and other micronutrients that are needed for agricultural production. These can be recovered through chemical precipitation or stripping processes, or simply by use of the wastewater or sewage sludge. However, reuse of sewage sludge poses risks due to high concentrations of undesirable compounds, such as heavy metals, environmental persistent pharmaceutical pollutants and other chemicals. Since the majority of fertilizing nutrients are found in excreta, it can be useful to separate the excreta fractions of wastewater (e.g. toilet waste) from the rest of the wastewater flows. This reduces the risk for undesirable compounds and reduces the volume that needs to be treated before applying recovered nutrients in agricultural production.

Other methods are also being developed for transforming wastewater into valuable products. Growing Black Soldier Flies in excreta or organic waste can produce fly larvae as a protein feed. Other researchers are harvesting fatty acids from wastewater to make bioplastics.

Types of Materials Recovered from Municipal Solid Waste

- Biodegradable waste food and kitchen waste, green waste, paper (most can be recycled although some difficult to compost plant material may be excluded)
- Recyclable materials paper, cardboard, glass, bottles, jars, tin cans, aluminium cans, aluminium foil, metals, certain plastics, fabrics, clothes, tyres, batteries, etc.
- Inert waste construction and demolition waste, dirt, rocks, debris.
- Electrical and electronic waste (WEEE) - electrical appliances, light bulbs, washing machines, TVs, computers, screens, mobile phones, alarm clocks, watches, etc.
- Composite wastes: waste clothing, Tetra Packs, waste plastics such as toys.
- Hazardous waste including most paints, chemicals, tyres, batteries, light bulbs, electrical appliances, fluorescent lamps, aerosol spray cans, and fertilizers.
- Toxic waste including pesticides, herbicides, and fungicides.
- Biomedical waste -expired pharmaceutical drugs, etc.

Activity

Play your part!

Reduce, re-use and recycle. Efficient and effective waste management is best achieved at household levels. If every person gets involved, we can have a powerful effect on our environment in a positive way.

Many times, people want to do the right things but they feel they are alone, and their actions will not make any difference — YES IT WILL!!

There are millions of great teens like you who appreciate the magnitude of the waste problem and are doing the right things to help. But we can do more and get others who are not doing well to do better.

Here is what you can do!

Reduce creating waste

The next time you change the waste-bin bag, take a look inside it. Is there anything that could have not ended up there? Probably. Try cutting the waste you produce at home into half. For example,

Use proper towels and ceramic plates at home instead of paper towels, disposable spoons and paper plates.

Get your own shopping bag instead of bringing home plastic bags each time you go grocery shopping.

Use old post package boxes to send parcels instead of buying new ones.

More on waste reduction

Re-use things that end up as waste

There are things that can be used over and over again package boxes, gift wrappers, clothing, furniture and even playing toys. If even you have outgrown them, you can give it out to someone who has a need for it. Do not be too quick to throw them away.

To do Activity

Overview

In this activity, students will learn about the 4Rs hierarchy by watching a video of students demonstrating ways to practice the 4Rs. Working in groups, they will use 4Rs pictographs to brainstorm ways to practice the 4Rs.

Objectives

Students will

1. Explain the need for each of the 4Rs.

2. Give at least two ways to practice of each of the 4Rs, i.e. Reduce, Reuse, Recycle and Rot (Compost).

Teacher Background

The 4Rs (Reduce, Reuse,Recycle and Rot/Compost) are organized in a hierarchy, or order of importance. The first goal is to reduce the amount of waste we generate. If we use less stuff, we reduce the amount of waste produced. Some ways to reduce waste include buying products with minimal packaging, using a cloth bag instead of paper or plastic and buying durable products with a longer life span. When waste does occur, the next level in the hierarchy is to reuse items. The reuse of items does not require the expense of energy or newmaterials because the manufacturing process is not involved. Some ways to reuse items include using both sides of a piece of paper, saving and using plastic or paper grocery bags for future visits and donating unwanted items such as clothing, books or toys to a charity.

If waste items cannot be reused, the next level is recycling. For example, paper can be recycled to produce new paper. Glass can be recycled to produce new bottles or kitchen tile. Recycling conserves natural resources, reduces air and water pollution and saves energy. Finally, organic materials (originally living plants or animals) that cannot be reused or recycled can be decomposed (rot) to produce compost, a rich soil amendment that helps plants grow.

Materials

Students

- "4Rs Pictographs" with labels (one set per group of four)
- "Kids Doing the 4Rs" worksheet (one per student)
- Teacher
- Doing the 4Rs Reduce, Reuse,Recycle, Rot video
- "4Rs Pictographs" (without labels) overheads
- Rubric overhead
- Rubrics (one per student)

Preparation

Be prepared to divide the class into groups of four for part of the activity.

Discussion

- Ask students whether they can name the 4Rs. Write them on the board.
- Explain that the 4Rs are arranged in a hierarchy of importance, and guide them to list in the correct hierarchy (Reduce, Reuse, Recycle, Rot/Compost). Give another example of a hierarchy.
- Show an overhead of the lesson rubric, and review the expectations for this lesson.

Procedure

- Before showing the video, inform the students that they will be looking for examples of students practicing the 4Rs.
- Ask them to write down several examples for each of the 4Rs while they watch the video.
- Show the video Doing the 4Rs.
- Organize the students into groups of four. Pass out one set of the "4Rs Pictographs" to each group.
- Ask each group to cut out the pictographs.

- Provide a definition for each of the four pictographs and have the groups identify which pictograph represents each of the 4Rs. Ask them to write the name of each pictograph below the picture.

- Have them place the 4Rs pictographs in the correct hierarchy.

- Have them brainstorm examples of 4R practices shown in the video.

Wrap-Up

- Put up the “4Rs Pictographs” overheads one at a time.Have groups name and provide a definition for the pictograph and provide examples of how to practice that particular R.

- Ask students to address why each of the 4Rs is important.

- Pass out “Kids Doing the 4Rs” worksheet to each student. Have students write down two examples for each of the 4Rs that they would like to implement at home or school.

Final Assessment Idea

Have students draw or create their own pictograph showing one way to practice each of the 4Rs at home or school. In groups, have them present their pictographs and the group members can choose which of the 4Rs each pictograph represents.

Summary

In Chapter 1, you have learnt that

- Wastes are items we (individuals, offices, schools, industries, hospitals) don’t need and discard.

- Waste management simply means the collection, transport, processing or disposal, managing and monitoring of waste materials to minimize its consequences on humans and environment.

Eight main sources of solid wastes are as follows:

1. Municipal solid wastes 2. Industrial Solid Wastes 3. Mining solid wastes 4. Fertilizers 5. Pesticides and Biocides 6. Excretory products of humans and livestock 7. Electronic wastes 8. Hospital Wastes.

- In a broad sense, waste can be classified into four major types as urban waste, industrial waste, biomass waste, and biomedical waste.
  The composition of municipal solid waste varies greatly from municipality to municipality and it changes significantly with time.

- The types of materials recovered from MSW are

- Aluminium
- Paper
- Plastics
- Glass Ferrous Metals (Iron and Steel)
- Non ferrous metals
- Yard waste collected separately
- Construction and demolition wastes

However, the recycling system differs from developing countries and developed countries.

Model Questions

1. What is the importance of waste management in present scenario?
2. What are the first few steps to initiate a waste management programme in your locality?
3. What are the different types of waste?

Suggested Reading

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Chapter 2 Properties of Municipal Solid Waste & Characteristics of Hazardous solid waste

Introduction

The properties of Municipal solid waste describe the physical, chemical & biological properties associated with MSW and perform calculations using properties.

Objectives

- To introduce the reader to the physical, chemical & biological properties of Municipal solid waste.
- To know the all transformations that can affect the form and composition of Municipal solid waste.
- To find the characteristics of hazardous solid waste & its harmful effects.

2.1 Physical Properties of MSW

This includes the determination of percent contents of various ingredients of the solid waste.

- Bulk Density is generally calculated.
- Function of location, season, storage time, equipment used, processing (compaction, shredding, etc.)
- Used in volume calculations.

The major physical properties measured in waste are (1) density, (2) size distribution of components, and (3) moisture content. Other characteristics which may be used in making decision about solid waste management are (1) colour, (2) voids, (3) shape of components, (4) optical property, (5) magnetic properties and (6) electric properties. Optical property can be used to segregate opaque materials from transparent substances which would predominately contain glass and plastic. Magnetic separators are designed based on the magnetic characteristics of the waste. Moisture content is essential for leachate calculation and composting. Density is used to assess volume of transportation vehicle and size of the disposal facility. Shape can be used for segregation as flaky substance will behave differently compared to non-flaky substance.

Density of waste, i.e. its mass per unit volume (kg/m3). It is a critical factor in the design of a Solid waste management system i.e. the design of sanitary landfills, storage, types of collection and transport vehicles etc. For an efficient operation of landfill, compaction of wastes to optimum density is essential.

- Any normal compaction equipment can achieve reduction in volume of wastes by 75%, which increases an initial density from 100kg/m3 to 400kg/m3.
- Municipal solid wastes as delivered in compaction vehicles have been found to have an average density of about 300 kg/m3.
- A waste collection vehicle can drag four times the weight of waste in its compacted state than when it is un- compacted.

Important physical characteristics of MSW include specific weight, moisture content, particle size and size distribution, field capacity and compacted waste porosity. The discussion is limited to an analysis of residential, commercial and some industrial solid wastes.

Specific Weight

Specific weight is defined as the weight of a material per unit volume (e.g., lb/ft3. lb/yd3). Specific weight expressed as lb/yd3 is commonly referred to in the solid waste literature incorrectly as density. Because the specific weight of MSW is often reported as loose, as found in containers, uncompacted, compacted, and the like, the basis used for the reported values should always be noted. Specific weight data are often needed to assess the total mass and volume of waste that must be managed. Typical specific weights for various wastes as found in containers, compacted or uncompacted. Because the specific weights of solid wastes vary markedly with geographic location, season of the year and length of time in storage, great care should be used in selecting typical values. Municipal solid wastes as delivered in compaction vehicles have been found to vary from 300 to 700 lb/yd3; a typical value is about 500 lb/yd3.

Moisture Content

The moisture content of solid wastes usually is expressed in one of two ways. In the wet-weight method of measurement, the moisture in a sample is expressed as a percentage of the wet weight of the material; in the dry-weight, it is expressed as a percentage of the dry weight of the material. The wet- weight method is used most commonly in the field of solid waste management. In equation form, the wet - weight moisture content is expressed as follows

M=(A-B)/A x100
Where
M=moisture content,%
A=initial weight of sample as delivered, lb(kg)
B= weight of sample after drying at 105 degree C, lb(kg)
The moisture content will vary from 15-40 % depending on the composition of the wastes, the season of the year and the humidity and weather conditions, particularly rain.

- Moisture increases the weight of solid wastes and thereby, the cost of collection and transport.
- It is a critical determinant in the economic feasibility of waste treatment by incineration because wet waste consumes energy for evaporation of water and in raising the temperature of water vapour.

Particle Size and Distribution

The size and size distribution of the component materials in solid wastes are an important consideration the recovery of materials, especially with mechanical means such as trammel screens and magnetic separators. It plays a significant role in the design of mechanical separators and shredders. The size of a waste component may be defined by one or more of the following measures:

$S_c=L$

$S_c=((L+w)/2)$

$S_c=((L+w+h)/3)$

$S_c=(L \text{ x } w)^{(1?2)}$

$S_c=(Lxwxh)^{(1?3)}$

Where

S_c= size of component, in(mm)

L=length, in(mm)

w=width, in(mm)

h=height, in(mm)

- The major means of controlling particle size is through shredding.
- Shredding increases homogeneity increases the surface area/volume ratio and reduces the potential of liquid flow paths through the waste.
- Particle size will also influence waste packing densities.
- Particle size reduction could increase biogas production through the increased surface area available to degradation by bacteria.
- Optical property can be used to separate opaque materials from transparent substances which majorly contains glass and plastic.
- Shape can be used for segregation as flaky substance will behave differently compared to non-flaky substance.
- Magnetic separators are designed based on the magnetic characteristics of the waste.

Field Capacity

The field capacity of solid waste is the total amount of moisture that can be retained in a waste sample subject to the downward pull of gravity. The field capacity of waste materials is of critical importance in determining the formation of leachate in landfills. Water in excess of the field capacity will be released as leachate.

Table2.1 Physical properties of MSW

Table 3.4 : Physical Characteristics of Municipal Solid Wastes in Indian Cities

Population Range (in million)	Number Of Cities Surveyed	Paper	Rubber, Leather And Synthetics	Glass	Metals	Total compostable matter	Inert
0.1 to 0.5	12	2.91	0.78	0.56	0.33	44.57	43.59
0.5 to 1.0	15	2.95	0.73	0.35	0.32	40.04	48.38
1.0 to 2.0	9	4.71	0.71	0.46	0.49	38.95	44.73
2.0 to 5.0	3	3.18	0.48	0.48	0.59	56.67	49.07
> 5	4	6.43	0.28	0.94	0.80	30.84	53.90

All values in table 3.4 are in percent, and are calculated on net weight basis

Source : Background material for Manual on SWM, NEERI, 1996

Physical properties in brief-

Moisture Content

Moisture content is a critical determinant in the economic feasibility of waste treatment by incineration since energy must be supplied for evaporation of water and in raising the temperature of the water vapour.

Moisture content also plays an important role in other processing methods such as composting and anaerobic digestion.

Particle Size

The measurement of the size distribution of particles in the waste stream is important because of its significance in the design of mechanical separators and shredders. The results of the analysis are expressed in the manner used for the particle analysis of soils namely a plot of particles size against % less than a given value.

Density

Knowledge of the density of waste i.e. mass per unit volume is essential for the design of all elements of the solid waste management system. For example, in high income countries, considerable benefit is derived through the use of compaction vehicles on collection routes because the waste is typically of low density. However, in India and other developing countries such as Thailand, Indonesia etc. due to higher initial density the compaction ratio obtained rarely exceeds 1.5.

Field Capacity

Field capacity of solid waste is total amount of moisture that can be retained in waste sample subject to downward pull of gravity. Field capacity of critically important in determining the formation of leachate in landfills. Water excess of field capacity can be released as leachate and field capacity varies with degree of applied pressure and state of decomposed moisture of waste. Permeability The Hydraulic conductivity of compacted waste is an important physical property to a large extent governs movement of liquid and gases in landfill.

2.2 Chemical Properties of MSW

Chemical properties of MSW are very important in evaluating the alternative processing and recovery options. Knowledge of the classification is essential for the proper understanding of the behaviour of waste, as it moves through the waste management system.

- Used primarily for combustion and waste to energy (WTE) calculations but can also be used to estimate biological and chemical behaviours.
- Waste consists of combustible (i.e. paper) and non-combustible materials (i.e. glass).

Important chemical properties measured for solid waste are (1) moisture (water content can change chemical and physical properties), (2) volatile matter, (3) ash, (4) fixed carbon, (5) fusing point of ash, (6) calorific value, (7) percent of carbon, hydrogen, oxygen, sulphur and ash. Proximate analysis of waste aims to determine moisture, volatile matter, ash and fixed carbon. Ultimate analysis of waste aims to analyse percent of carbon, hydrogen, oxygen, sulphur and ash.

Solid waste production is a function of land use as well as its composition is inversely proportional to the possible soil damage and bacterial contamination of the environment (Achudume and Olawale 2009; Lober 1996; Omuta 1999; Shakibaie et al. 2009). Wet waste will host more bacteria compared to dry waste. The nutrition in waste also acts as a key factor which decides population balance of species in the waste and immediate environment. Toxic elements discourage multi-cellular organism in the waste. But micro-organisms may still persist at places which may favour some species of micro organism. Saprophytes and fungi will flourish in decomposable matter.

Chemical properties includes-

- Lipids
- Carbohydrates
- Proteins
- Natural fibres
- Synthetic organic material (plastics)
- Non-combustibles
- Heating value
- Ultimate analysis
- Proximate analysis

Lipids- This class of compounds includes fats, oils and grease and the principal sources of lipids are garbage, cooking oils and fats.

Lipids have high heating values, about 38,000 KJ/Kg, which makes them suitable for energy recovery. Since lipids become liquid at temperatures slightly above ambient, they add to the liquid content during waste decomposition. Though they are biodegradable, the rate of biodegradation is relatively slow because lipids have a low solubility in water.

Carbohydrates- These are found primarily in food and yard wastes, which emcompass sugar and polymer of sugars (e.g., Starch, cellulose, etc.) with general formula (CH2O) X. Carbohydrates are readily biodegraded to products such as carbon dioxide, water and methane. Decomposing carbohydrates attract flies and rats and therefore, should not be left exposed for long duration.

Proteins - There are compounds containing carbon, hydrogen, oxygen and nitrogen and consist of an organic acid with a substituted amine group (NH2). They are mainly found in food and garden wastes. The partial decomposition of these compounds can result in the production of amines that have unpleasant odours.

Natural Fibres - They are found in paper products, food and yard wastes that are resistant to biodegradation. They are a highly combustible solid waste, having a high proportion of paper and wood products, they are suitable for incineration.

Synthetic organic material (Plastics) - They are highly resistant to biodegradation and therefore, are objectionable and of special concern in Solid waste management. Plastics have a high heating value, about 32,000 KJ/Kg, which makes them very suitable for incineration.

Information on the chemical composition of the components that constitute MSW is important in evaluating alternative processing and recovery options. For example, the feasibility of combustion depends on the chemical composition of the solid wastes. If solid wastes are to be used as fuel, the four most important properties to be known are

Proximate analysis

Fusing point of ash

Ultimate analysis (major elements)

Energy content

Proximate Analysis

- Proximate analysis for the combustible components of MSW includes the following tests.
- Moisture (loss of moisture when heated to 105 degree C for 1 h).
- Volatile combustible matter (additional loss of weight on ignition at 950 degree C in a covered crucible).
- Fixed carbon (combustible residue left after volatile matter is removed).
- Ash (weight of residue after combustion in an open crucible).

Fusing Point of Ash

The fusing point of ash is defined as that temperature at which the ash resulting from the burning of waste will form a solid (clinker) by fusion and agglomeration. Typical fusing temperatures for the formation of clinker from solid waste range from 2000 to 2200 degree F.

Ultimate Analysis of Solid Waste Components

The ultimate analysis of a waste component typically involves the determination of the percent

C(Carbon), H(Hydrogen), O(Oxygen), N(Nitrogen), S(Sulphur) and ash. Because of the concern over the emission of chlorinated compounds during combustion, the determination of halogens is often included in an ultimate analysis. The results of the ultimate analysis are used to characterize the chemical composition of the organic matter in MSW. They are also used to define the proper mix of waste materials to achieve suitable C/N ratios for biological conversion processes.

Energy Content of Solid Waste Components

The energy content of the organic components in MSW can be determined

- By using a full scale boiler as a calorimeter
- By using a laboratory bomb calorimeter
- By calculation, if the elemental composition is known

Table 2.2 Chemical properties of MSW

Table 3.5 : Chemical Characteristics of Municipal Solid Wastes in Indian Cities

Population range (in million)	No. of Cities surveyed	Moisture %	Organic matter %	Nitrogen as Total Nitrogen %	Phosphorous as P_2O_5 %	Potassium as K_2O %	C/N Ratio	Calorific value* in kcal/kg
0.1-0.5	12	25.81	37.09	0.71	0.63	0.83	30.94	1009.89
0.5-1.0	15	19.52	25.14	0.66	0.56	0.69	21.13	900.61
1.0-2.0	9	26.98	26.89	0.64	0.82	0.72	23.68	980.05
2.0-5.0	3	21.03	25.60	0.56	0.69	0.78	22.45	907.18
> 5.0	4	38.72	39.07	0.56	0.52	0.52	30.11	800.70

All values, except moisture, are on dry weight basis.
*Calorific value on dry weight basis

Source : Background material for Manual on SWM, NEERI, 1996.

Chemical Properties in Brief

pH A 5 gm portion of the powdered sample is mixed with 50 ml of distilled water by stirring and pH is then measured by a pH meter. The pH of fresh solid waste is normally around 7. During decomposition it tends to become acidic and stabilized solid waste has an alkaline pH. Organic content A 10 gm portion of the dried ground sample is placed in a silica dish and slowly heated in an electric furnace to 700 degree Celsius for 30 min. The residue is weighed and the loss of weight represents the organic content and is expressed as percent by weight. The knowledge of organic content helps assess the feasibility of biological processing-composting and anaerobic digestion.

Carbon Content

The carbon is determined by using the New Zealand formula in which the percent organic matter is divided by 1.724. Nitrogen content Total nitrogen is obtained by Kjeldahl method and the phosphorous and potassium are estimated by using phosphomolybdic and flame photometric method. Nitrogen, phosphorous and potash values are important in composting.

Toxicity

Toxicity characteristics include heavy metals, pesticides, insecticides etc. Heavy metals are present in municipal solid waste due to the waste from small scale industries. As some of the heavy metals leach out, testing for heavy metals is often carried out. Toxicity Characteristics Leaching Procedure (TCLP) test is invariably carried out if the waste is suspected to be toxic in nature.

2.3 Biological Properties of Municipal Solid Waste

The most important biological characteristic of the organic fraction of MSW is that almost all the organic components can be converted biologically to gases and relatively inert organic and inorganic solids.

- The production of odours and the generation of flies are also related to the putrescible nature of the organic materials. The organic fraction of MSW (excluding plastics, rubber and leather) can be classified as:
- Water-soluble constituents - sugars, starches, amino acids and various organic acids
- Hemi cellulose - a product of 5 and 6-carbon sugars
- Cellulose - a product of 6-carbon sugar glucose
- Fats, oils and waxes - esters of alcohols and long-chain fatty acids
- Lignin - present in some paper products
- Lignocellulose - combination of lignin and cellulose
- Proteins - amino acid chains

Volatile solids (VS) content, determined by ignition at 550 degree C, is often used as a measure of the biodegradability of the organic fraction of MSW. The use of VS in describing the biodegradability of the organic fraction of MSW is misleading, as some of the organic constituents of MSW are highly volatile but low in biodegradability (e.g., newsprint and certain plant trimmings). Alternatively, the lignin content of a waste can be used to estimate the biodegradable fraction, using the following relationship

$BF=0.83- 0.028LC$

Where

- BF= biodegradable fraction expressed on a volatile solids (VS) basis
- 0.83=empirical constant
- 0.028=empirical constant
- LC=lignin content of the VS expressed as a percent of dry weight

The biodegradability of several of the organic compounds found in MSW, based on lignin content. Wastes with high lignin contents, such as newsprint, are significantly less biodegradable than the other organic wastes found in MSW. The rate at which the various components can be degraded varies markedly. For practical purposes, the principal organic waste components in MSW are often classified as rapidly and slowly decomposable.

Production of Odours

Odours can develop when solid wastes are stored for long periods of time on-site between collections, in transfer stations and in landfills. The development of odours in on-site storage facilities is more significant in warm climates. Typically, the formation of odours results from the anaerobic decomposition of the readily decomposable organic components found in MSW. For example, under anaerobic (reducing) conditions, sulphate can be reduced to sulphide

(S-2), which subsequently combines with hydrogen to form H2S.

The black colour of solid wastes that have undergone anaerobic decomposition in a landfill is primarily due to the formation of metal sulphides. If were not for the formation of a variety of sulphides, odour problems at landfills could be quite significant.

The biochemical reduction of an organic compound containing a sulphur radical can lead to the formation of malodorous compounds such as methyl mercaptan and amino butyric acid. The methyl mercaptan can be hydrolyzed biochemically to methyl alcohol and hydrogen sulphide

? CH?_3SH+H_2 0??CH?_4 0H+H_2 S

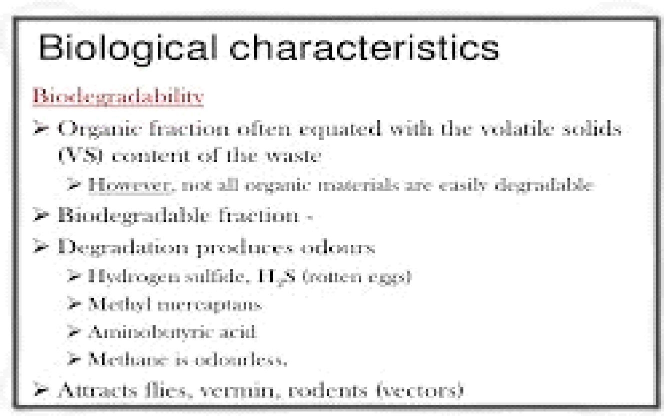

Fig 2.1 Biological properties of MSW (Source: www.slideshare.net/biological characteristics)

Solid waste can host an array of insects, arthropod and annelids. The examples of insects include cockroaches, dung beetles, ants, termites, mosquitoes, honey bees and house flies. Some of the arthropods in solid waste are spiders and scorpions.

Annelids in solid waste include centipede, millipede and earthworm. In some of the waste dumps adjacent to forest area attract wild life as well. While herbivores are attracted towards vegetables and food carnivores are attracted towards hospital waste and other animals which come to eat solid waste. Solid waste dumps attract and host rats, lizards, snakes and street dogs depending on the food available. Due to the absence of agricultural land honey bees in urban area are attracted to left over sweet drinks in trash for collecting nectar.

Micro-organisms play an important role in the decomposition of decomposable fraction of solid waste. Thermophilic bacteria would breakdown of proteins and other easily biodegradable material. Fungi and actinomycetes would degrade complex organic matter like cellulose and lignin. Streptomyces and micromonospora species are commonly observed actinomycetes in compost. Thermonomyces sp., asperigallus and penicillium dupontii fumigatus are common fungi observed in compost. Most of these organisms will be present in municipal solid waste even before composting (CPHEEO 2000).

Biodegradability of MSW

- The most important biological characteristic of the organic fraction of MSW is that almost all the organic components can be converted biologically to gases and relatively inert organic and inorganic solids.
- The production of odours and the generation of flies are also related to the putrescible nature of the organic materials. These will be discussed when talking about landfill processes.
- Volatile solids (VS), determined by ignition at 550 Degree C, is often used as a measure of the biodegradability of the organic fraction of MSW.
- Some of the organic constituents of MSW are highly volatile but low in biodegradability (e.g. Newsprint) due to lignin content.
- The rate at which the various components can be degraded varies markedly. For practical purposes, the principal organic waste components in MSW are often classified as rapidly and slowly decomposable.

2.4 Transformation of Municipal Solid Waste

Physical Transformations

The principal physical transformations that may occur in the operation of solid waste management systems include

Component separation,

Mechanical volume reduction and

Mechanical size reduction.

Physical transformations do not involve a change in phase (e.g., solid to gas), unlike chemical and biological transformation processes.

Component Separation

Component separation is the term used to describe the process of separating, by manual and/or mechanical means. Component separation is used to transform a heterogeneous waste into a number of more-or-less homogeneous components. Component separation is a necessary operation in the recovery of reusable and recyclable materials from MSW, in the removal of contaminants from separated materials to improve specifications of the separated material, in the removal of hazardous wastes from MSW and where energy and conversion products are to be recovered from processed wastes.

Mechanical Volume Reduction

Volume reduction (sometimes known as densification) is the term used to describe the process whereby the initial volume occupied by waste is reduced, usually by the application of force or pressure.

In most cities, the vehicles used for the collection of solid wastes are equipped with compaction mechanisms to increase the amount of waste collected per trip. Paper, cardboard, plastics and aluminium and tin cans removed from MSW for recycling are baled to reduce storage volume, handling costs and shipping costs to processing centers. At disposal sites solid wastes are compacted to use the available land effectively.

Mechanical Size Reduction

Size reduction is the term applied to the transformation processes used to reduce the size of the waste materials. The objective of size reduction is to obtain a final product that is reasonably uniform and considerably reduced in size in comparison with its original form. Size reduction does not necessarily imply volume reduction. In some situations, the total volume of the material after size reduction may be greater than that of the original volume. In practice, the term shredding, grinding and milling are used to describe mechanical size-reduction operations.

2.4.2 Chemical Transformations

Chemical transformations of solid waste typically involve a change of phase (e.g., solid to liquid, solid to gas, etc.) to reduce the volume and /or to recover conversion products, the principle chemical processes used to transform MSW include

- Combustion(chemical oxidation),
- Pyrolysis and
- Gasification.
- All three of these processes are often classified as thermal processes.

Combustion (chemical oxidation) : Combustion is defined as the chemical reaction of oxygen with organic materials to produce oxidized compounds accompanied by the emission of light and rapid generation of heat. In the presence of excess air and under ideal conditions, the combustion of the organic fraction of MSW can be represented by the following equation

Organic matter+excessair?N_2+CO?_2+H_2O+O_2+ash+heat

Excess air is used to ensure complete combustion. The end products derived from the combustion of MSW, equation includes hot combustion gases-composed primarily of nitrogen (N2), carbon dioxide (CO2), water (H2O), oxygen(O2)and non-combustible residue. In practice, small amounts of ammonia (NH3). Sulphur dioxide (SO2), Nitrogen oxides (NOx) and trace gases will also be present, depending on the nature of the waste materials.

Pyrolysis: Because most organic substances are thermally unstable, they can be split, through a combination of thermal cracking and condensation reactions in an oxygen-free atmosphere, into gaseous, liquid and solid fractions. In contrast with the combustion process, which is highly exothermic, the pyrolytic process is highly endothermic. For this reason, destructive distillation is often used as an alternative term for pyrolysis. The characteristics of the three major component fractions resulting from the pyrolysis of the organic portion of MSW are

A gas stream containing primarily Hydrogen (H2). Methane(CH4), Carbon monoxide(CO), Carbon dioxide(CO2) and various other gases, depending on the organic characteristics of the waste material being pyrolyzed; A tar and/or oil stream that is liquid at room temperature and contains chemicals such as acetic acid, acetone and metham and a char consisting of almost pure carbon plus any inert material that may have entered the process.

Gasification: The gasification process involves partial combustion of a carbonaceous fuel so as to generate a combustible fuel gas rich in carbon monoxide, hydrogen and some saturated hydrocarbons, principally methane. The combustible fuel gas can then be combusted in an internal combustion engine or boiler. When a gasifier is operated at atmospheric pressure with air as the oxidant, the end products of the gasification process are

A low-Btu gas typically containing Carbondioxide (CO2), Carbon monoxide (CO), Hydrogen (H2), Methane(CH4) and Nitrogen(N2); A char containing carbon and the inerts originally in the fuel and condensable liquids resembling pyrolytic oil.

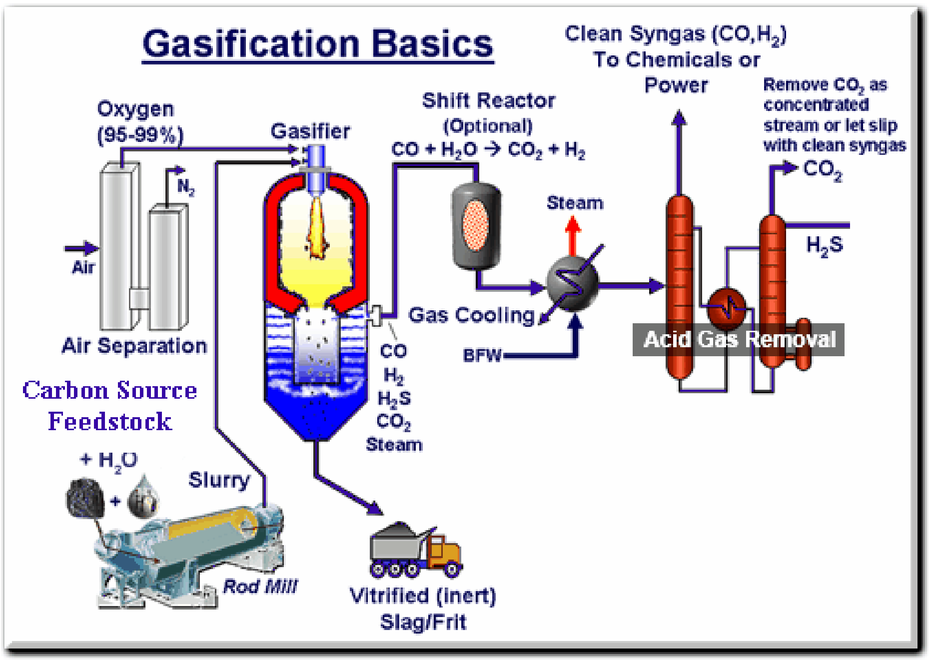

Fig 2.2 Gasification basics (source http//www.waste2energyworld.com)

Biological Transformations

The biological transformations of the organic fraction of MSW may be used to reduce the volume and weight of the material; to produce compost, a humus-like material that can be used as a soil conditioner; and to produce methane. The principal organisms involved in the biological transformations of organic wastes are bacteria, fungi, yeasts and actinomycetes. These transformations may be accomplished either aerobically or anaerobically depending on the availability of oxygen. The principal differences between the aerobic and anaerobic conversion reactions are the nature of the end products and the fact oxygen must be provided to accomplish the aerobic conversion. Biological processes that have been used for the conversion of the organic fraction of MSW include aerobic composting, anaerobic digestion and high-solids anaerobic digestion.

Aerobic Composting

The organic fraction of MSW will undergo biological decomposition. The extent and the period of time over which the decomposition occurs will depend on the nature of the waste, the moisture content, the available nutrients and other environmental factors. Yard wastes and the organic fraction of MSW can be converted to a stable organic residue known as compost in a reasonably short period of time. Composting the organic fraction of MSW under aerobic conditions can be represented by the following equation

Organic matter+ O_2+nutrients? new cells+Resistant organic matter+?CO?_2+H_2 O+?NH?_3+?SO?_2+heat

In equation, the principal end products are new cells, resistant organic matter, carbon dioxide, water, ammonia and sulphate. Compost is the resistant organic matter that remains. The resistant organic matter usually contains a high percentage of lignin, which is difficult to convert biologically in a relatively short time. Lignin, found most commonly in newsprint, is the organic polymer that holds together the cellulose fibres in trees and certain plants.

Anaerobic Digestion

The biodegradable portion of the organic fraction of MSW can be converted biologically under anaerobic conditions to a gas containing carbon dioxide and methane (CH4). This conversion can be represented by the following equation

Organic matter+H_2 O+nutrients? new cells+ Resistant organic matter+?CO?_2+?CH?_4+?NH?_3+H_2S+heat

Thus, the principal end products are carbon dioxide, methane, ammonia, hydrogen sulphide and resistant organic matter. In most anaerobic conversion processes carbon dioxide and methane constitute over 99 percent of the total gas produced.

Importance of Transformation

Typically waste transformations are used

1. To improve the efficiency of solid waste management systems.

2. To recover reusable and recyclable materials.

3. To recover conversion products and energy.

The organic fraction of MSW can be converted to usable products and ultimately to energy in a number of ways including

1. Combustion to produce steam and electricity.

2. Pyrolysis to produce a synthetic gas, liquid or solid fuel, and solids.

3. Gasification to produce a synthetic fuel.

4. Biological conversion to produce compost.

5. Bio digestion to generate methane and to produce a stabilized organic humus.

2.5 Characteristics of Hazardous Solid Waste & its Harmful Effects

The terms "hazard" and "risk" are often interchanged, and thought to have similar meanings to most of us. In reference to chemicals though, the terms are quite different.

Hazard – refers to the inherent properties of a chemical substance that make it capable of causing harm to a person or the environment.

Risk – is the possibility of harm arising from a particular exposure to a chemical substance, under specific conditions.

To understand risk, we need to know both what the inherent hazard is and the degree of exposure. With every hazardous material, there is a risk of potential harm being done, which is increased by how much of the hazardous material is exposed to certain things. An example being hydrofluoric acid, this chemical is used in pharmaceuticals which is generally a safe practice, however, if someone working with this acid accidentally gets it on themselves, it will likely cause 3rd degree burns. Potential exposure to the chemical is high if the chemical is handled with bare hands without proper personal protection equipment (PPE). This creates a high-risk situation.

Once we understand the risk of something, we can then either reduce it or manage it. Many businesses are not able to reduce the amount of waste they create so they must look to manage it. In the example above, a way to reduce the hazard is to handle the chemical properly and the person handling it wears the proper personal protection equipment, which lowers the risk of burns. If a chemical is no longer needed for production, another way to lower the exposure risk is to look for the best environmental waste disposal method to minimize the impact on humans and the environment.

How Chemicals Move Throughout the Environment

The different ways a person can come into contact with hazardous chemicals are called exposure pathways. There are three basic exposure pathways inhalation, ingestion, and dermal (skin) contact. Since chemicals can move through air, soil and water, they can be found in the air we breathe, the soil our plants grow in, water we drink, and the food we eat. Some common ways a person may be exposed to hazardous chemicals include

Water – Exposure can occur when people drink, shower, bath, or swim in contaminated groundwater or surface water. If someone goes swimming in waters that have been polluted by chemicals, they may not realize it until they're having a reaction.

Soil, Sediment, or Dust – Exposure can occur if contaminated soil, sediment or dust is inhaled or makes direct contact with skin. This form of exposure is very common in children and is currently a huge problem in Imperial County, California.

Air – Exposure can occur when people breathe in hazardous chemical vapors or air that is contaminated by hazardous chemicals or dust.

Food – Exposure can occur when people eat certain foods that have been contaminated. Food contamination can occur if the food has come into contact with hazardous chemicals either through water, or in secondary consumers being contaminated by primary consumers

When it comes to hazardous waste disposal and management, understanding the waste your organization generates is imperative. Hazardous waste is heavily regulated, and thus cannot just be tossed out with your everyday trash. To know if your organization is handling hazardous waste, the first step is to assess its characteristics.

When categorizing hazardous waste, the EPA breaks it down by four characteristics

- Ignitability or something flammable
- Corrosivity, or something that can rust or decompose
- Reactivity, or something explosive
- Toxicity, or something poisonous

These high level categories each have their own characteristics that further help you as a generator define with what your are dealing.

Ignitability

There are three types of ignitable forms

- Liquids with a flash point–the lowest temperature at which fumes above waste ignite–of 60 degrees Celsius or 140 degrees Fahrenheit. Examples include alcohol, gasoline, and acetone.
- Solids that spontaneously combust.
- Oxidizers and compressed gasses.

Corrosivity

Corrosive substances, such as hydrochloric acid, nitric acid, and sulphuric acid, have the ability eat through containers, causing the leakage of harmful materials. A corrosive is anything liquid with a pH of less than or equal to 2 or greater than or equal to 12.5, or has the ability to corrode steel. Everyday example of corrosives includes battery acid and rust removers.

Reactivity

Given their instability, reactive wastes can be very dangerous. The EPA recognizes that there are too many conditions and situations to identify all types of reactive materials. However, they use the following as guidelines to assist generators

- Unstable, and routinely experiences violent change without detonating
- Potential for explosive mixture or violent reaction when combined with water
- Toxic gasses are released when mixed with water

Toxicity

Poisonous materials pose a threat to our groundwater, which can have long term effects to human health and the environment. This is different from the first three characteristic groups, which the EPA views as containing immediate and firsthand dangers. There are 60 contaminants on the toxicity characteristics list. These contaminants are identified solely through a test method called Toxicity Characteristic Leaching Procedure or TCLP.

As a generator of any the above, you have two options to determine which characteristics above best define the waste you generate test it, or use applied knowledge from previous company records or industry data and studies.

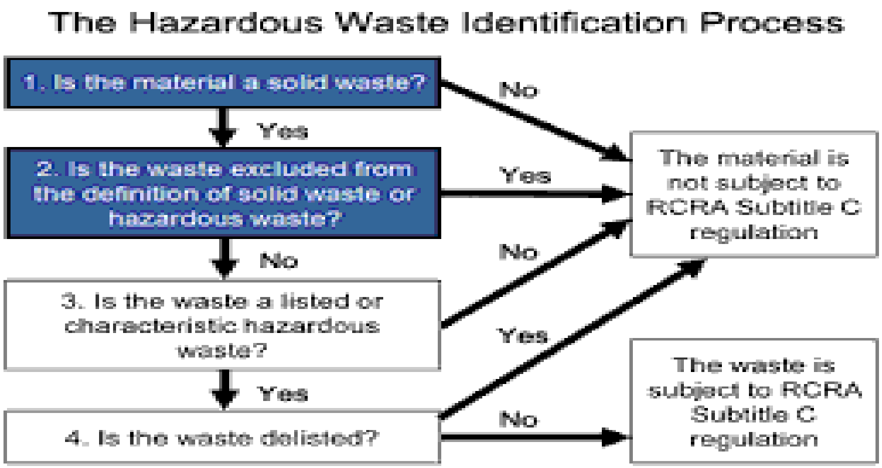

Fig 2.3 Hazardous waste process(sourcewww.epa.gov/hw)

Physical Treatment of Hazardous Waste

This includes processes that separate components of a waste stream or change the physical form of the waste without altering the chemical structure of the constituent materials. Physical treatment techniques are often used to separate the materials within the waste stream so that they can be reused or detoxified by chemical or biological treatment or destroyed by high-temperature incineration. These processes are very useful for separating hazardous materials from an otherwise non-hazardous waste stream so that they may be treated in a more concentrated form, separating various hazardous components for different treatment processes, and preparing a waste stream for ultimate destruction in a biological or thermal treatment process.

Physical treatment processes are important to most integrated waste treatment systems regardless of the nature of the waste materials or the ultimate technologies used for treatment or destruction.

The physical processes that are commonly used in waste treatment operations are as follows

- Screening is a process for removing particles from waste streams, and it is used to protect downstream pre-treatment processes.
- Sedimentation is a process for removing suspended solid particles from a waste stream. Sedimentation is usually accomplished by providing sufficient time and space in special tanks or holding ponds for settling. Chemical coagulating agents are often added to encourage the settling of fine particles.
- Flotation is a process for removing solids from liquids by floating the particles to the surface by using tiny air bubbles. Flotation is useful for removing particles too small to be removed by sedimentation.
- Filtration is a process for separating liquids and solids by using various types of porous materials. There are many types of filters designed to achieve various levels of separation.
- Centrifugation is a process for separating solid and liquid components of a waste stream by rapidly rotating a mixture of solids and liquids inside a vessel. Centrifugation is most often used to dewater sludges.
- Dialysis is a process for separating components in a liquid stream by using a membrane. Components of a liquid stream will diffuse through the membrane if a stream with a greater concentration of the component is on the other side of the membrane. Dialysis is used to extract pure process solutions from mixed waste streams.
- Electrodialysis is an extension of dialysis. This process is used to separate the components of an ionic solution by applying an electric current to the solution, which causes ions to move through the dialysis membrane. It is very effective for extracting acids and metal salts from solutions.
- Reverse osmosis separates components in a liquid stream by applying external pressure to one side of a membrane so that solvent will flow in the opposite direction.
- Ultrafiltration is similar to reverse osmosis, but the separation begins at higher molecular weights. The result is that dissolved components with low molecular weights will pass through the membrane with the bulk liquid while the higher-molecular-weight components become concentrated through the loss of solvent. Ultrafiltration systems can handle much more corrosive fluids than reverse-osmosis units.

- Distillation is a process for separating liquids with different boiling points. The mixed-liquid stream is exposed to increasing amounts of heat, and the various components of the mixture are vapourised and recovered. The vapour may be recovered and re-boiled several times to effect a complete separation of components.

- Solvent extraction is a process for separating liquids by mixing the stream with a solvent which is immiscible with part of the waste but which will extract certain components of the waste stream. The extracted components are then removed from the immiscible solvent for reuse or disposal.

- Evaporation is a process for concentrating non-volatile solids in a solution by boiling off the liquid portion of the waste stream. Evaporation units are often operated under some degree of vacuum to lower the heat required to boil the solution.

- Adsorption is a process for removing low concentrations of organic materials on the surface of a porous material, usually activated carbon. The carbon is replaced and regenerated with heat or a suitable solvent when its capacity to attract organic substances is reduced.

Chemical Treatment of Hazardous Waste

Chemical treatment processes alter the chemical structure of the constituents of the waste to produce either an innocuous or a less hazardous material. Chemical processes are attractive because they produce minimal air emissions, they can often be carried out on the site of the waste generator, and some processes can be designed and constructed as mobile units.

The five chemical treatment operations commonly used in treating wastes are as follows:

- Neutralisation is a process for reducing the acidity or alkalinity of a waste stream by mixing acids and bases to produce a neutral solution. This has proven to be a viable waste management process.

- Precipitation is a process for removing soluble compounds contained in a waste stream. A specific chemical is added to produce a precipitate. This type of treatment is applicable to streams containing heavy metals.

- Ion exchange is used to remove from solution ions derived from inorganic materials. The solution is passed over a resin bed, which exchanges ions for the inorganic substances to be removed. When the bed loses its capacity to remove the component, it can be regenerated with a caustic solution.

- De-chlorination is a process for stripping chlorine atoms from chlorinated compounds such as polychlorinated biphenyls (PCBs). One of the processes uses a metallic sodium reagent to break the chlorine bond.

- Oxidation-reduction is a process for detoxifying toxic wastes in which the chemical bonds are broken by the passage of electronics from one reactant to another.

Biological Treatment of Hazardous Waste

Biological waste treatment is a generic term applied to processes that use micro-organisms to decompose organic wastes either into water, carbon dioxide, and simple inorganic substances, or into simpler organic substances, such as aldehydes and acids. Typically, the micro-organisms used in a biological process are present in the incoming waste. In some instances, micro-organisms that were developed to attack specific compounds are injected into a waste stream.

The purpose of a biological treatment system is to control the environment for micro-organisms so that their growth and activity are enhanced, and to provide a means for maintaining high concentrations of the micro-organisms in contact with the wastes. Since biological treatment systems do not alter or destroy inorganic substances, and high concentrations of such materials can severely inhibit decomposition activity, chemical or physical treatment may be required to extract inorganic materials from a waste stream prior to biological treatment.

There are five principal types of conventional biological treatment. Treatment with activated sludge involves exposing waste to a biological sludge that is continuously extracted from the clarified waste stream and recycled. In the aerated lagoon method, waste is agitated with air in large enclosures to increase oxygen-dependent biological oxidation. In treatment using trickling filters, wastes are allowed to trickle through a bed of rocks coated with micro-organisms that alter the waste components by using them as food. Waste stabilisation ponds are ponds in which wastes are allowed to decompose over long periods of time, aeration is provided only by wind action. Anaerobic digestion is a method for decomposing organic matter by using anaerobic organisms in closed vessels in the absence of air; methane may be produced in the process.

Incineration and Pyrolysis of Hazardous Waste

Incineration and Pyrolysis techniques reduce the volume or toxicity of organic wastes by exposing them to high temperatures. When organic chemical wastes are subjected to temperatures of 800-3000°F (430-1700°C), they break down into simpler and less toxic forms.

If the wastes are heated in the presence of oxygen, combustion occurs, and the process is known as incineration. Incineration systems are designed to accept specific types of materials; they vary according to feed mechanisms, operating temperatures, equipment design, and other parameters. The main products from complete incineration include water, carbon dioxide, ash, and certain acids and oxides, depending upon the waste in question.

If the wastes are exposed to high temperatures in an oxygen-starved environment, the process is known as Pyrolysis. The products of this process are simpler organic compounds, which may be recovered or incinerated, and a char or ash.

Hazardous waste incineration and Pyrolysis systems include single-chamber liquid systems, rotary kilns, and fluidised-bed incineration systems. In a single-chamber liquid system a brick-lined combustion chamber contains liquids that are burned in suspension; in addition to being the primary parts of an incineration system, these units are used as afterburners for rotary kilns.

A rotary kiln is a versatile large refractory-lined cylinder capable of burning virtually any liquid or solid organic waste, the unit is rotated to improve turbulence in the combustion zone. Fluidised-bed incineration uses a stationary vessel within which solid and liquid wastes are injected into a heated, extremely agitated bed of inert granular material; the process promotes rapid heat exchange and can be designed to scrub off the gases.

Solidification and Stabilisation of Hazardous Waste

Solidification and stabilisation are treatment systems designed to accomplish one or more of the following —improve handling and the physical characteristic of the waste; decrease the surface area across which transfer or loss of contained pollutants can occur; and limit the solubility of, or detoxify, any hazardous constituents contained in the wastes.

In solidification these results are obtained primarily, but not exclusively, via the production of a monolithic block of treated waste with high structural integrity. Stabilisation techniques limit the solubility or detoxify waste contaminants even though the physical characteristics of the waste may not be changed. Stabilisation usually involves the addition of materials that ensure that the hazardous constituents are maintained in their least soluble or least toxic form.

Disposal of Hazardous Waste

Ultimately, after all treatment is completed, there remains an inorganic valueless residue that must be disposed of safely. There are five options for disposing of hazardous waste as follows

(i) Underground injection wells are steel and concrete-encased shafts placed deep below the surface of the earth into which hazardous wastes are deposited by force and under pressure. Some liquid waste streams are commonly disposed of in underground injection wells.

(ii) Surface impoundment involves natural or engineered depressions or diked areas that can be used to treat, store, or dispose of hazardous waste. Surface impoundments are often referred to as pits, ponds, lagoons, and basins.

(iii) Landfills are disposal facilities where hazardous waste is placed in or on land. Properly designed and operated landfills are lined to prevent leakage and contain systems to collect potentially contaminated surface water run-off. Most landfills isolate wastes in discrete cells or trenches, thereby preventing potential contact of incompatible wastes.

(iv) Land treatment is a disposal process in which hazardous waste is applied onto or incorporated into the soil surface. Natural microbes in the soil break down or immobilise the hazardous constituents. Land treatment facilities are also known as land application or land farming facilities.

(v) Waste piles are non-containerised accumulations of solid, non-flowing hazardous waste. While some are used for final disposal, many waste piles are used for temporary storage until the waste is transferred to its final disposal site.

Of the hazardous waste disposed of on land, nearly 60% is disposed of in underground injection wells, approximately 35% in surface impoundments, 5% in landfills; and less than 1% in waste piles or by land application.

To do Activity

Reuse or Recycle Which Comes First?

Introduction

In this activity, students will explore the 4Rs hierarchy by looking at the benefits of reusing a plastic bottle before recycling it. They will work in pairs to identify the amount of energy required to manufacture a water bottle and compare the amount of energy necessary to manufacture, reuse or recycle a plastic bottle.

Teacher Background

Reuse and recycling are quite different, but are often considered the same practice. Recycling involves the process of taking a product, deconstructing it and using the materials in remanufacturing a new product. A product that gets recycled may not always get remanufactured into the same product again. Recycling products conserves the resources and energy used during the early parts of the manufacturing process; however, the process of remanufacturing recycled products still requires energy and resources. Reuse involves the process of taking a product or material in its current form and using it for the same or different purpose without changing its original form. The practice of reuse reduces solid waste, conserves even more non-renewable resources, and reduces emissions such as carbon dioxide released during the manufacturing process. Reusing items also saves money and landfill space, creates local jobs and keeps resources in our local economy.

Materials

Students

"Energy of Making Plastic" worksheet

Teacher

- "Making Plastic" overhead
- "Energy of Making Plastic" worksheet overhead
- "Energy of Making Plastic" worksheet answers
- Plastic soda or water bottle
- Rubric overhead
- Rubrics (one per student)

Preparation

Be prepared to put students into pairs for part of the activity.

Discussion

- Explain that many of the things we use everyday are made, or "manufactured," in factories using some kind of raw material. Ask the students what paper is manufactured from. Explain that the process of making things for people to use has several steps Draw T-chart on board as shown below and fill in first column only Manufacturing Steps Manufacturing a Plastic Bottle Collecting raw materials Drilling for oil.

Cleaning materials Cleaning or refining the oil ("refining"),Making item Making oil into plastic, shaping plastic into bottles,filling bottles with a drink. Packing Packed bottles into boxes. Transporting to store transport to stores in trucks trains, boats. Selling to Customer Store sells bottles.Use of Product Purchase bottle and use it.

- Explain another example of something that is manufactured such as a plastic bottle. Ask the students what the bottle is made from. Show a clear plastic bottle. Explain that plastic bottles are made from black, liquid oil that is pumped out of the ground. The atoms in the oil are rearranged and combined with other things during manufacture to make plasticsolid but a little flexible, fairly clear. Show the overhead "Making Plastic." Complete the T-chart by writing down the steps to manufacturing a plastic bottle.

- Ask students what they might do with a plastic bottle when they're finished drinking the contents? Record their answers on the board. Ask the students if they can think of ways to use the bottle again. Explain that there is an important step in the 4Rs hierarchy that comes before recycling Reuse. When we reuse something, it is used for a new purpose. When we're finally done with it, we can still recycle the bottle. When the bottle gets recycled, it will go back to the manufacturing part of our process to get made into a new thing, instead of having to pump more oil and make more plastic. Refer to T-chart and draw a line labelled recycling connecting back into manufacturing from bottom.

- Ask students to name items they often recycle but do not reuse. Write the names of these items on the board. Why do people use some things only once before recycling? Examine some of the reasons that people do not reuse items before recycling; i.e., convenience, durability, accessibility to purchasing a new item, cost, it can't be refilled, it's dirty, etc.

- Ask students to define reuse (to use again) and write their definition on the board. Then ask them to define recycle (making something old into something new, the process of remanufacturing used materials into new products).

- Tell the students that they will learn why reuse is so important and why it comes before recycling in the 4Rs hierarchy by looking at how much energy is saved by reusing a plastic bottle before it is recycled.

- Post the overhead of the rubric, and review with the class the expectations for this lesson.

Procedure

- Explain that if a bottle is reused to carry water or something else instead of buying a new one, we save natural resources and energy.

- Ask the student to consider how much energy might be saved by reusing a bottle. Define energy the capacity for doing work. Explain that energy is stored in food, batteries, and different fuels like gas. Energy is carried by electricity, waves of water or sound, and moving objects. Have the students discuss different ways that they use energy and identify where it comes from.

- Ask the students to describe where is energy might be used to make a plastic bottle? Show the overhead "Energy of Making Plastic." Discuss and circle the different energy sources and inputs required to manufacture and transport a plastic product.

- Have the students describe where is energy used if a plastic bottle is reused? Where is energy used if you buy a new bottle made from recycled plastic? Is the energy required to reuse a product different from the type of energy used to remanufacture a new product from recycled material? Discuss the differences.

- Tell the students that they will work with a partner to compare the amount of energy required to make a new plastic bottle, reuse a bottle and recycle a bottle.

- Assign the students to work in pairs. Hand out a worksheet "Energy of Making Plastic" to each pair of students. Model how to complete the worksheet.

Wrap-Up

- Come back together as a class and discuss their findings with a series of questions, for example

  - How many energy units are required to reuse a plastic bottle versus buying a new bottle made from recycled plastic?

  - If you reuse a plastic bottle before recycling it, how many energy units are you saving? (A bottle's worth of energy for each time you reuse it.)

  - Which action conserves more natural resources reusing or recycling?

  - Did anyone think of some other things that are saved when you reuse, besides energy?

(Go back to the overhead "Making Plastic" to discuss other resource inputs and pollution outputs. An interesting fact toshare is that local environmental scientists have figured out that it takes more water to make the bottle than a plastic water bottle actually contains for you to drink. The process of moving the materials and bottles around and manufacturing thebottles produces both air and water pollution. Time, money, and landfill space are other savings associated with reuse.)

- Ask students to describe other things that people throw away that could be reused?

- Explain when an item such as a plastic bottle is reused, all of the resources and energy required to make plastic and manufacture and transport a new bottle are conserved. Even if the new bottle was recycled, energy and resources are still required to transform the recycled plastic into a new product—so reuse before you recycle!

Final Assessment Idea

Have students write a paragraph describing why reuse is placed before recycling in the 4Rs hierarchy, citing at least three benefits of reusing something before it is recycled or thrown away.

Have them describe one specific example of an item from home that can be reused before it is recycled.

Summary

- Physical characteristics of MSW include specific weight, moisture content, particle size and size distribution, field capacity and compacted waste porosity.
- Chemical properties measured for solid waste are (1) moisture (water content can change chemical and physical properties), (2) volatile matter, (3) ash, (4) fixed carbon, (5) fusing point of ash, (6) calorific value, (7) percent of carbon, hydrogen, oxygen, sulphur and ash.
- The most important biological characteristic of the organic fraction of MSW is that almost all the organic components can be converted biologically to gases and relatively inert organic and inorganic solids.
- All transformations can affect the composition of MSW.
- When it comes to hazardous waste disposal and management, understanding the waste your organization generates is imperative.

Model Questions

1. What are the characteristics of solid waste?
2. How to accelerate the biodegradation of Municipal solid waste?
3. Explain Hazardous waste & its harmful effects.

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Chapter 3 Solid Waste Generation and Collection

Introduction

Solid waste collection means the act of removing solid waste from the premises of a primary generating source to a place of solid waste disposal. The solution to many of the problems of solid waste management is the careful selection and operation of solid waste collection equipment that is efficient and yet responsive to the physical and socio-economic conditions of the various neighbourhoods in which service is supplied.

Objectives

- To find out the quantities of solid waste generation and collection.
- To know the methods used to measure solid waste quantities.
- To understand the factors affecting solid waste generation rate.

3.1 Quantities of Solid Waste

The management of municipal solid waste in India has surfaced or continued to be a severe problem not only because of environmental and aesthetic concerns but also because of the enormous quantities generated every day. Even though only 31% of Indian population resides in urban areas, this population of 377million (Census of India, 2011) generates a gigantic 1,43,449 metric tonnes per day of municipal solid waste, as per the Central Pollution Control Board (CPCB), 2014-15 and these figures increase every day with an increase in population. To further add to the problem, the total number of towns (statutory and census) in the country have also increased from 5,161 in 2001 to 7,936 in 2011, thus increasing the number of municipal waste generation by 2,775 within a decade.

The management of municipal solid waste is one of the main functions of all Urban Local Bodies (ULBs) in the country. All ULBs are required to meticulously plan, implement and monitor all systems of urban service delivery especially that of municipal solid waste. With limited financial resources, technical capacities and land availability, urban local bodies are constantly striving to meet this challenge.

The quantity and composition of MSW generated in the ULB determine collection, processing, and disposal options that could be adopted. They are dependent on the population, demographic details, principal activities in the city or town, income levels, and lifestyle of the community. Waste generation is strongly dependent on the local economy, lifestyle, and infrastructure. It has been well established that waste generation of an area is proportional to average income of the people of that area. It is also observed that generation of organic, plastic, and paper waste is high in high income areas.

An assessment states that the per capita waste generation is increasing by about 1.3% per year. With an urban growth rate of 3.0%–3.5% per year, the annual increase in waste quantities may be considered at 5% per year. Impacts of increasing ULB jurisdiction should also be considered while assessing future waste generation rates. Several studies were conducted by Central Pollution Control Board (CPCB) over the last 2 decades to arrive at waste generation details and composition of MSW generated in the country.

Summaries of the several findings are listed below:

1996 - The characterisation studies carried out by National Environmental Engineering Research Institute (NEERI) in 1996 indicate that MSW contains large organic fraction (30%–40%); ash and fine earth (30%–40%); paper (3%–6%); along with plastic, glass, and metal (each less than 1%). The calorific value of refuse ranges between 800 and 1,000 kilocalorie per kilogram (kcal/kg) and carbon-to-nitrogen (C/N) ratio ranges between 20 and 30. Study revealed that quantum of waste generation varies between 0.2 and 0.4 kg/capita/day in the urban centres and goes up to 0.5 kg/capita/day in metropolitan cities. The study was carried out in 43 cities of varying sizes. The results were presented in a report published by NEERI "Strategy Paper on Solid Waste Management in India" (1996).

1999-2000 - The study conducted by CPCB through Environment Protection Training and Research Institute (EPTRI) in 1999–2000 in 210 Class I cities and 113 Class II towns indicated that Class I cities generated 48,134 tons per day (TPD) of MSW while Class II towns generated 3,401 TPD of MSW. The study revealed that waste generation rate in Class I cities was approximately 0.34 kg/capita/day while the waste generation rate in Class II towns was found to be 0.14 kg/capita/day.

2004-2005 - NEERI's study "Assessment of Status of Municipal Solid Wastes Management in Metro Cities and State Capitals" in 2004–2005 assessed 59 cities (35 metro cities and 24 state capitals). Studies have revealed that waste generation rate varies from 0.12 to 0.60 kg/capita/day. Analysis of physical composition indicates that total compostable matter in the waste is 40%–60%, while recyclable fraction is 10%–25%. The moisture content in the MSW is 30%–60%, while the C/N ratio is 20–40.

2010-2011 - The survey conducted by the Central Institute of Plastics Engineering and Technology (CIPET) at the instance of CPCB has reported generation of 50,592 TPD of MSW in 2010–2011 in the same 59 cities.

2014-2015 - As per CPCB, 1,43,449 TPD of MSW was generated for 34 states and union territories during 2013–2014. The average rate of waste generation in India, based on this data, is 0.11 kg/capita/day. Out of the total waste generated, approximately 1,17,644 TPD (82%) of MSW was collected and 32,871 TPD (22.9%) was processed or treated.

Other studies and observations indicate that waste generation rate is between 200 and 300 gm/capita/day in small towns and cities with a population below 2,00,000. It is usually 300–350 gm/capita/day in cities with a population between 2,00,000 and 5,00,000; 350–400 gm/capita/day in cities with a population between 5,00,000 and 10,00,000.

The quantities of solid waste generated and collected are of importance in determining compliance with federal and state waste diversion programmes, selecting specific equipment and designing of waste collection routes, materials recovery facilities and disposal facilities. Compliance with Federal and State Diversion Programme Information on the total quantity of MSW as well as the quantity of waste that is now recycled or otherwise does not become part of the waste stream will be required to establish and assess the performance of mandated recycling programmes. For example, if 25% level of recycling is mandated, the following question must be answered Is the 25% based on the actual quantity generated or is it based on the amount currently collected. Design of Solid Waste Management Facilities -As the diversion and recycling of waste materials increase, the quantities of waste generated, separated for recycling, collected, and ultimately requiring disposal in landfills become determinants in planning and designing solid waste management facilities. The design of special vehicles for the curb side collection of source – separated wastes depends on the quantities of the individual waste components to be collected. The sizing of MRFs depends on the amount of waste to be collected as well as the variations in the quantities delivered hourly, daily, weekly and monthly. The sizing of landfills depends on the amount of residual waste that must be disposed of after all the recyclable materials have been removed.

Fig 3.1 Quantities of solid waste (source www.downtoearth.org.in)

3.2 Measurements and Methods to Measure Solid Waste Quantities

The principal reason for measuring the quantities of solid waste generated, separated for recycling, and collected for further processing or disposal is to obtain data that can be used to develop and implement effective solid waste management programme. In any solid waste management study, extreme care must be exercised in deciding what actually needs to be known and in allocating funds for data collection. Both volume and weight are used for the measurement of solid waste quantities. The use of volume as a measure of quantity can be misleading. For example, a cubic yard of loose wastes is a different quantity from a cubic yard of wastes that has been compacted in a collection vehicle, and each of these is different from a cubic yard of wastes that has been compacted further in a landfill. Accordingly, if the volume measurements are to be used, the measured volumes must be related to either the degree of compaction of wastes or the specific weight of the waste under the conditions of storage.

Current practice: Waste generation rates are quantified by measuring the load of waste in collection vehicles either at a municipal or private weighbridge in the city. Alternately, the volumes of different vehicle used for transportation of waste are considered and a rule of thumb of 400–500 kilogram per cubic meter (kg/m3) is applied for determining the quantity of waste transported per trip per type of vehicle. A summation of the quantities of waste transported by each vehicle type multiplied by the total number of trips to the landfill by similar vehicles determines the total quantity of waste transported in the ULB. The practice of an eye estimate of waste quantity transported is not reliable as many times trucks carrying waste are half full or carry light material.

The quantity of waste measured at transfer stations or processing or disposal sites also does not accurately reflect waste generation rates, since these measurements do not include waste disposed at unauthorised places, vacant lots, alleys, ditches etc, waste recovered by kabadi system, waste recovered by informal waste collectors or waste pickers from the streets, bins and intermediate transfer points etc.

To avoid confusion, solid waste quantities should be expressed in terms of weight. Weight is the only accurate basis for records because tonnages can be measured directly, regardless of the degree of compaction. Weight records are also necessary in the transport of the solid wastes because the quantity that can be hauled usually is restricted by highway weight limit rather than by volume. The volume and weight are equally important with respect to the capacity of the landfills.

Waste quantities are usually estimated on the basis of data gathered by conducting a waste characterization study, using previous waste generation data or some combination of the two approaches. It will be helpful to remember that most measurements of waste quantities do not accurately represent what they are reported or assumed to represent. For example, in predicting residential waste generation rates, the measured rate seldom reflects the true rates because there are confounding factors (e.g., onsite storage and the use of alternative disposal locations) that make the true rate difficult to assess. For U.S, most solid waste generation rates reported in the literature before 1990 are usually based on measurement of the amount of waste collected, not the actual amount generated.

Methods Commonly used to Estimate Waste Quantities

Load-count analysis

Weight – volume analysis

Materials- balance analysis

Load-Count Analysis: The number of individual loads and the corresponding waste characteristics (type of waste, estimated volume) are noted over a specified time period. If scales are available, weight data are also recorded & unit generation rates are determined by using the field data and where necessary published data.

Weight - Volume Analysis: Weight –Volume data obtained by weighing and measuring each load provides better information on the specific weight of the various forms of solid wastes at a given location. However, the question remains what information is needed in terms of study objectives.

Materials- Balance Analysis: The only way to determine the generation and movement of solid wastes with any degree of reliability is to perform a detailed mass balance analysis for each generation source, such as an individual home or a commercial or industrial activity. The approach to be followed in the preparation of a Materials Mass Balance Analysis is as follows:

- First, draw a system boundary around the unit to be studied to simplify the mass balance computations.
- Second, identify all the activities that cross or occur within the boundary and affect the generation of wastes.
- Third; identify the rate of waste generation associated with each of these activities.
- Fourth, determine the quantity of waste generated, collected and stored. Statistical Analysis of Measured Waste Quantities: In developing solid waste management systems, it is often necessary to determine the statistical characteristics of the observed solid waste generation rates. For many large industrial activities it would be impractical to provide container capacity to handle the largest conceivable quantity of solid waste to be generated in a given day. The container capacity to be provided must be based on a statistical analysis of the generation rates and the characteristics of the collection system.

The density of waste (mass per unit volume, kg/m3) determines the storage and transportation volume requirements. MSW density in India is typically around 450–500 kg/m3.

- Method for Bulk Density Measurement
- Materials and Apparatus
- Wooden box of l m3 capacity
- Wooden box of 1 ft3 capacity
- Spring balance weighing upto 50 kg.

Procedure: A composite sample of MSW collected from different parts of the heap should be taken in the smaller 1 ft3 box and weighed with the help of a spring balance. After weighing, contents of this smaller box (1 ft3) should be emptied into the bigger 1 m3 box. This is repeated until the larger box is filled to the top. Once the larger box is filled, the weight of the waste is noted. The waste should not be compacted by pressure. Repeat the entire procedure thrice and take the average weight to arrive at the weight per cubic meter.

3.3 Solid Waste Generation and Collection

The term "solid waste collection" is taken to include the initial storage of waste at the household, shop or business premises, the loading, unloading and transfer of waste, and all stages of transporting the waste until it reaches its final destination – a treatment plant or disposal site. The sweeping of streets and public places, the cleaning of open storm drains and the removal of these wastes are also included. The collection system must be designed and operated in an integrated way. This means that all of the links in the management chain should be considered when any part of the system is being designed, so that all system components are compatible. For example, the method of loading a collection truck must suit the containers that are used to store the waste. As another example if waste is to be recycled, the collection stage should be designed so that there is the minimum degree of contamination of the material destined for recycling. Again, if waste is to be deposited at a landfill, the trucks that take it there must be suitable for driving on the landfill.

Collection of segregated municipal waste is an essential step in MSWM. Inefficient waste collection services have an impact on public health and aesthetics of towns and cities. Collection of wet, dry and domestic hazardous waste separately ensures maximum recovery of recyclables. It also enhances the potential of cost-effective treatment of such wastes which can then easily meet the minimum quality criteria defined for different products, eg. production of compost from pure organic waste.

Waste collection services are divided into primary and secondary collection. Primary collection refers to the process of collecting, lifting and removal of segregated solid waste from source of its generation including households, shops, offices, markets, hotels, institutions and other residential or non-residential premises and taking the waste to a storage depot or transfer station or directly to the disposal site, depending on the size of the city and the waste management system prevalent in the city. Primary collection must ensure separate collection of certain waste streams or fractions depending on the separation and reuse system applied by the respective town or city. Primary collection refers to the collection of waste from source of generation.

Secondary collection includes picking up waste from community bins, waste storage depots, or transfer stations and transporting it to waste processing sites or to the final disposal site. At the secondary collectionpoints, segregated waste must be stored on-site in separate covered bins or containers for further collection and should be kept separate during all steps of waste collection, transportation, and processing. Further, ULBs should ensure that at the secondary storage points the waste is should be attended daily or before container starts overflowing. A well synchronized primary and secondary collection and transportation system, with regular and well communicated intervals of operation (with respect to primary collection), is essential to avoid containers overflow and waste littering. Further, the transport vehicles should be compatible with the equipment design at the waste storage depot and should be able to transport segregated waste. They should also be easy to maintain. It should be ensured that waste collected from the doorstep in motorized vehicles should be either directly transported to the processing facility or through material recovery facility or transfer station, or waste storage depots for facilitating, sorting, and bulk transfer of waste. The vehicles used for transportation should be covered and not visible to public. It should have a facility to prevent spillage of waste and leachate en-route to the processing or disposal facility.

In India, rapid urbanization and uncontrolled growth rate of population are main reasons for MSW to become an acute problem. According to population size per capita waste generation rate and its growth during a decade, It is anticipated that population of India would be about 1,823 million by 2051 and about 300 million tons per annum of MSW will be generated that will require around 1,450 km of land to dispose it in a systematic manner, if ULBs in India continue to rely on landfill route for MSW management (Position paper on the solid waste management sector in India, 2009). However, these projections are on conservative side, keeping 1.33% annual growth in per capita generation of MSW (Bhide&Shekdar, 1998; CPCB, 2000; Pappu, Saxena, &Asolekar, 2007; Shekdar, 1999). Therefore, with 5% annual growth in per capita generation landfill area required for disposal of waste could be many folds (CPCB, 2013).

Planning Commission Report (2014) reveals that 377 million people residing in urban area generate 62 million tons of MSW per annum currently and it is projected that by 2031 these urban centers will generate 165 million tons of waste annually and by 2050 it could reach 436 million tons. To accommodate this amount of waste generated by 2031, about 23.5 × 107 cubic meter of landfill space is required and in terms of area it would be 1,175 hectare of land per year. The area required from 2031 to 2050 would be 43,000 hectares for landfills piled in 20 meter height. These projections are based on 0.45 kg/capita/day waste generation. In India, due to lack of availability of primary data on per capita waste generation, inadequate data on waste characteristics, and influence of informal sectors, different reports give different values and projections. Therefore, it is difficult to assess the land requirement and select appropriate treatment/disposal techniques. The study carried out in 59 cities (35 Metro cities and 24 State Capitals) by the National Environmental Engineering Research Institute (NEERI) reveals that 39,031 TPD of MSW was generated from these cities/towns during the year 2004–2005. For the same 59 cities, a study was again carried out by CIPET during 2009–2010 for CPCB wherein it was seen that these cities are generating 50,592 TPD of waste (CPCB, 2013).During the year 2011, about 1,27,486 TPD MSW was generated from across the country, out of which only 89,334 TPD (i.e. 70%) was collected and 15,881 TPD (i.e. 12.45%) processed or treated (CPCB,2013). During the last decade, solid waste generation has increased 2.44 times (CPCB, 2013).

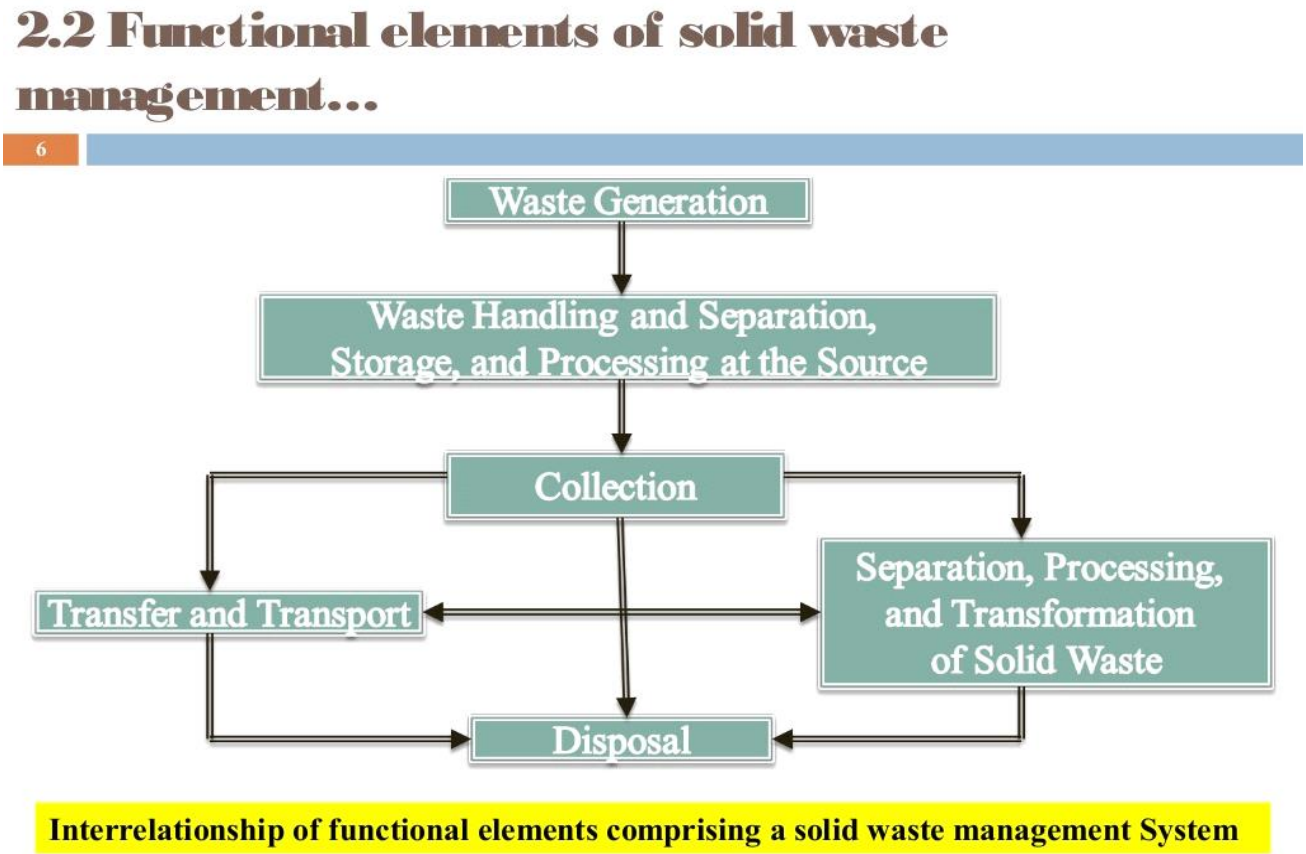
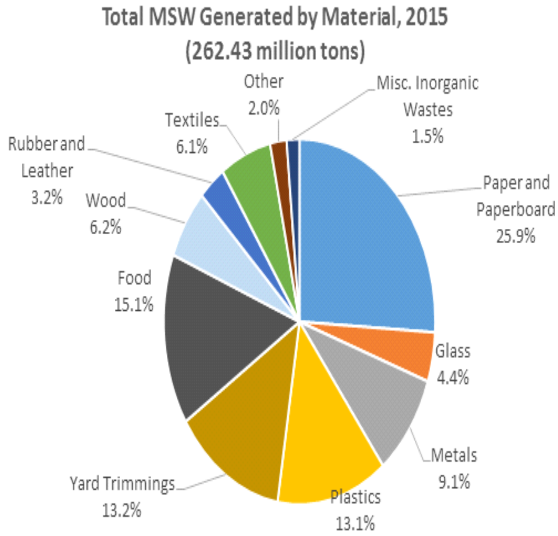


Fig 3.2 Solid waste management system (Source: www.slideshare.net/arvindbjo/solid-waste-management-40052229)

The main focus is on municipal solid waste, which is taken to include waste from households, businesses and institutions, construction and demolition waste in small quantities, general solid wastes from hospitals (excluding hazardous wastes), waste from smaller industries that is not classified as hazardous, and wastes from streets, public areas and open drains. It is not concerned with wastes from agriculture, larger industries or the mining industries which normally handle their own wastes. Such wastes are generated in huge quantities in many countries, but the systems for collecting, treating and disposing of them are separate from the systems used for municipal solid waste.

The total generation of municipal solid waste in 2015 was 262.4 million tons (U.S. short tons, unless specified) of MSW in 2015, approximately 3.5 million tons more than the amount generated in 2014. MSW generated in 2015 increased to 4.48 pounds per person per day. This is an increase from the 259 million tons generated in 2014 and the 208.3 million tons in 1990.



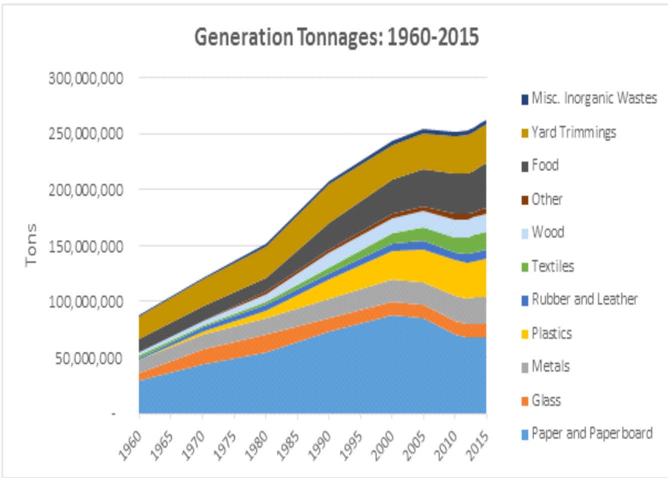


Fig 3.3 Total MSW generation (Source: www.epa.gov/facts-and-figures-about-materials-waste-and-recycling)

Per capita MSW generation increased from 4.45 pounds per person per day in 2014 to 4.48 pounds per person per day in 2015, which is one of the lowest estimates since 1990. MSW generation per person per day peaked in 2000.Paper and paperboard products made up the largest percentage of all the materials in MSW, at 25.9 percent of total generation. Generation of paper and paperboard products declined from 84.8 million tons in 2005 to 68.1 million tons in 2015. Generation of newspapers has been declining since 2000, and this trend is expected to continue, partly due to decreased page size, but mainly due to the increased digitization of news. The generation of office-type (high grade) papers also has been in decline, due at least partially to the increased use of the electronic transmission of reports, etc. Paper and paperboard products have ranged between 33 and 27 percent of generation since 2005.

Yard trimmings comprised the third largest material category, estimated at 34.7 million tons, or 13.3 percent of total generation, in 2015. This compares to 35 million tons (16.8 percent of total generation) in 1990. The decline in yard trimmings generation since 1990 is largely due to state legislation discouraging yard trimmings disposal in landfills, including source reduction measures such as backyard composting and leaving grass trimmings on the yard. In 2015, plastic products generation was 34.5 million tons, or 13.1 percent of generation. This was an increase of 3.1 million tons from 2010 to 2015, and it came from durable goods and the containers and packaging categories. Plastics generation has grown from 8.2 percent of generation in 1990 to 13.1 percent in 2015. Plastics generation as a percent of total generation has grown slightly over the past five years.

In 2015, 3.1 million tons of selected consumer electronics were generated, representing less than 2 percent of MSW generation. Selected consumer electronics include products such as TVs, VCRs, DVD players, video cameras, stereo systems, telephones, and computer equipment. Examples of Regional or Inter-Municipal Arrangements currently under Development.

Gujarat: Regional landfill sites have been identified in Gujarat 45 sites have been proposed for 161 municipalities; with a maximum transport distance of 25 km. Proposals envisage private sector involvement and the Gujarat State Waste Management Company will be the sole contracting agent. Memorandum of understanding will be signed between the cooperating municipalities and the state nodal agency. Nine sites are at an advanced stage of construction of sanitary landfill facilities.

Kerala: A study conducted by Suchitwa Mission recommended that the 14 districts in the state be divided into 6 zones, each with its own landfill site for receiving waste from all towns in that particular zone. The feasibility study for construction of one regional landfill has commenced.

West Bengal: In the Kolkata Metropolitan Development Authority area, six municipalities propose to use one common landfill site. Regional landfills are also being planned in other parts of the state such as the Asansol Municipal Corporation and Durgapur Municipal Corporation. The municipalities of Ranigunj, Jamuria, and Kulti, under the nodal Asansol Durgapur Development Authority, have developed a regional engineered landfill facility. A public private partnership was formed for project implementation.

Maharashtra: The Mumbai Metropolitan Regional Development Authority has decided to develop a regional landfill facility to cater to 2,500 tons of waste with a design period of 25 years. Urban local bodies (ULBs) in the metropolitan region from six municipal corporations or councils are envisaged to use this facility such as Kalyan–Dombivali, Bhiwandi–Nizampur, Ulhasnagar, Ambarnath, and Kulgaon–Badlapur.

Orissa: The cities of Bhubaneswar and Cuttack have associated to commission a common municipal solid waste management facility for treating approximately 600 tonnes of waste from both ULBs. The Orissa Industrial Infrastructure Development Corporation is acting as transaction advisory to facilitate this project. The selected concessionaire will be responsible for designing and constructing the requisite transfer station; transporting waste from the transfer station to the waste management facility; and identifying, designing, constructing, and operating waste management facilities based on appropriate technologies selected by the concessionaire.

Andhra Pradesh: The state government has developed a strategy and issued comprehensive guidelines for setting up regional facilities. 124 ULBs have been clubbed into 19 clusters. Five facilities were established and operated through private sector concession agreements.

Current Scenario in India

India, as a developing country, itself is also not an exception from the group of the developing countries. The situation in different states and different cities is different in respect to the management of solid waste. The quantity of municipal solid waste generated depends upon a number of factors such as food habits, standard of living and degree of commercial and industrial activity. The quantity of urban solid wastes varies seasonally and also from place to place. Data on quantity variation and generation are useful in planning collection and disposal systems. There are no authentic reports available on the generation of solid waste in Indian cities except for a few metro cities. In the absence of house to house collection data, the quantity of waste generation is assessed by direct ways like typical area study, truck load or using density and correction factor methods. A study conducted by WHO on Rapid Assessment of source of Air, Water and Land Pollution, the per capita of municipal solid waste generated in lower income areas in South East Asia was 0.4 kg/day. While Central Pollution Control Board (CPCB) through its surveys has reported that in metro cities like Mumbai, Delhi, Kolkata and Chennai, the generation of solid waste varies from 0.45 kg/capita/day to 0.62 kg/capita/day. In other cities the per capita contribution ranges from 0.17 kg/capita/day in Kohima to 0.76 kg/capita/day in Port Blair. According to the survey conducted by CPCB in 59 Indian cities, the total per day waste generation is 39031 tonnes per day and the average waste generation is 661.55 tonnes per day. The average per capita per day generated waste in above mentioned 59 cities is 0.40 kg. The result shows that the coastal cities are generating more waste than the cities located in the interior part of the country. In Indian waste there is a small percentage of recyclable material and more of compostable and inert materials like ash and road dust. There is very large informal sector of rag pickers which collects recyclable waste from the streets, bins and disposal sites. They take away paper, plastic, metal, glass, rubber etc. for their livelihood, but a small quantity of recyclable material is still left behind.

The developed countries have collection efficiency of the waste is more than 85% overall. On the other hand, India has collection efficiency is less than 60% as comparing to the developed countries it is very poor. And Delhi, capital city, has the efficiency of solid waste collection is below than the country's average. Thus the efficiency of the solid waste collection is calculated for the different cities of India. The results show that the biggest city of India, Mumbai, has the maximum solid waste collection efficiency. Delhi, the capital city, generates maximum waste and has lowest solid waste collection efficiency according to the data. Chennai, Ahmedabad, Lucknow and Faridabad have good collection efficiency of the waste collection.

3.4 Factors Affecting Solid Waste Generation Rate

The generation rate is the amount of waste generated by one person, one household (or one appropriate unit 14 for other types of generator) in one day. Usually it is expressed in terms of weight. The per capita generation rate, when multiplied by the population served, gives an indication of the total amount of waste to be collected and disposed. Generation rates measured at households may therefore overestimate the quantities that require collection and disposal, as suggested in example. It is common to quote estimates of the collection efficiency – the percentage of generated waste that is collected – as an indication of the success of the waste collection service.

If the total amount of waste to be collected is overestimated, the estimate of the collection efficiency that is based on this estimate will be too low.

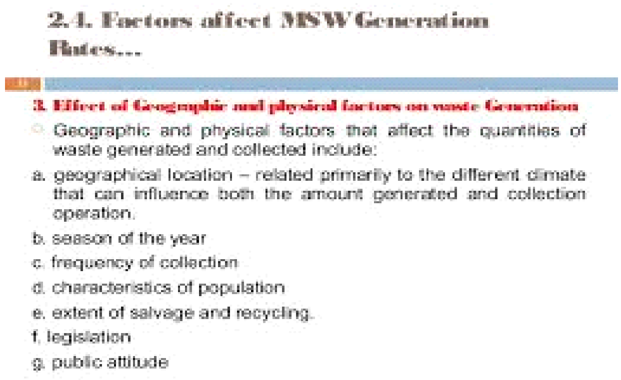


Fig 3.4 Factors affecting waste generation rate (source www.slideshare.net/mihretdananto)

Example

Uncertainty about total waste quantity

In one particular African city, when the city council's solid waste management system had almost completely broken down, it was estimated by a consultancy study that the city was generating 1,400 tons of wastes per day. However, as the collection system was being improved, it was found that when the collection capacity had reached 400 tons per day there was very little waste left in the city – apart from some peripheral areas where waste was buried on-site. This suggests that studies based on household surveys may greatly overestimate the amount of waste that needs be collected. Such differences may be due to on-site disposal, recycling, feeding waste to animals, or inaccuracies in the household survey methodology

- Source reduction and recycling activities
- Public attitudes and legislation
- Geographic and physical factors

Source reduction and recycling activities- Waste reduction may occur through the design, manufacture and packaging of products with minimum toxic content, minimum volume of materials and/or a longer useful life. Source reduction will likely become an important factor in reducing the quantity of waste generated in the future. Because source reduction is not a major element in waste reduction at the present time, it is difficult to estimate the actual impact that the source reduction programme have had or will have on the total quantity of waste generated. Ways in which source reduction can be achieved follow:

- Decrease unnecessary or excessive packaging,

- Develop and use products with greater durability and repairability (e.g., more durable appliances and tyres)
- Substitute reusable products for disposal in place of single-use products (e.g., reusable plates and cutlery, refillable beverage containers, cloth diapers and towels)
- Use fewer resources (e.g., two – sided copying)
- Increase the recycled materials content of products
- Develop rate structure that encourages generators to produce less waste. The existence of recycling programs within a community definitely affects the quantities of wastes collected for further processing or disposal.

Effect of Public Attitudes and Legislation on Waste Generation- Significant reduction in the quantities of solid waste generated occur when and if people are willing to change their habits and lifestyle to conserve natural resources and reduce the economic burdens associated with the management of solid wastes. A program of continuing education is essential in bringing about a change in public attitude. Perhaps the most important factor affecting the generation of certain types of wastes is the existence of regulations concerning the use of specific materials (e.g., regulations dealing with packaging and beverage container materials and the beverage container with deposit laws)

Geographic and Physical Factors-The climate influences both the amount of certain types of solid waste generated and the time period over which the wastes are generated (e.g., yard and garden wastes). The quantities of certain type of solid wastes are also affected by the season of the year (e.g., the quantities of food wastes related to the growing season for vegetables and fruits).Use of kitchen food waste grinder definitely reduces the quantity of kitchen wastes collected whether they affect quantities of waste generated is not clear because the use of home grinders varies widely throughout the country.

Frequency of collection when unlimited collection services is provided, more wastes are generated. For example, if a homeowner is limited to one or two containers per week, he may store newspaper or other materials with unlimited services, the homeowner would tend to throw them away. In this situation the quantity of wastes generated may actually be the same, but the quantity collected is considerably different the fundamental question of the effect of collection frequency on the waste generation remains unanswered.

Characteristics of Service Area peculiarities of the service area can influence the quantity of solid waste generated. For example, the quantities of yard wastes generated on a per capita basis are considerably greater in many wealthier neighbourhoods than in other parts of the town. Other factors include the size of lot, the degree of landscaping and the frequency of yard maintenance.

3.5 Quantities of materials recovered from MSW

The degree of recycling depends on the type of recycling programme that is in effect and on local regulations. Data on the quantities of hazardous waste found in MSW are quite variable, depending on the method used to classify the hazardous waste materials. Thus, it is difficult to draw any firm conclusions concerning the actual quantities involved. The goal of a waste characterization study is to identify the sources, characteristics, and quantities of the waste generated. Waste characterization study is difficult to perform because of the large number of sources and the limited number of waste samples that can be analyzed. The typical steps involved in a waste characterization study are as follows

- Gather Existing Information,
- Identify Waste Generation Sources and Waste Characteristics,
- Develop Sampling Methodology,
- Conduct Field Studies,
- Conduct Market Surveys for Special Wastes and Assess Factors Affecting Waste Generation Rates.

To assess the quantity of waste that is currently diverted, it will be necessary to first develop data on the total quantity of waste generated. The total waste generated will be made up of the amount of waste now placed in a landfill and the amount of waste now diverted. In determining the amount of waste diverted, a number of ambiguities will arise in the interpretation of what exactly is a waste material. Some states have ruled that federal and state mandated diversion percentages must be based on waste materials that are now discharged to landfills. Thus, if a material is considered a waste by a discharger, but is now totally recycled, it could be considered in determining the percentages diversion.

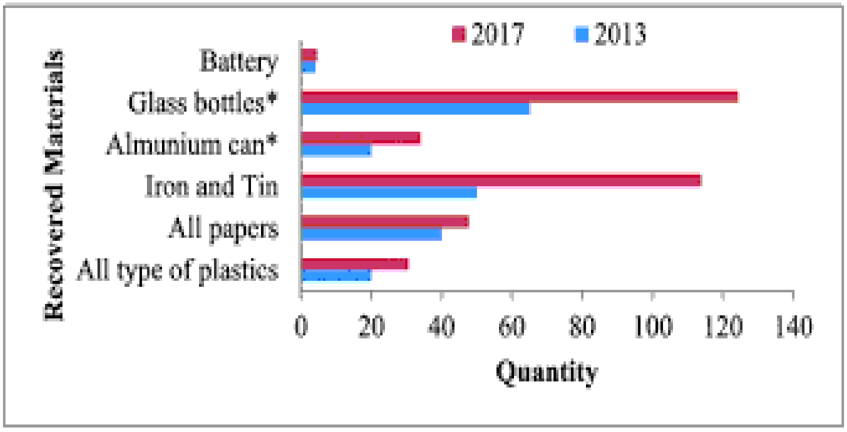


Fig 3.5 Quantities of materials recovered from MSW (source link.springer.com/chapter/10.1007)

The SWM(Solid Waste Management) Rules, 2016 defines "Materials Recovery Facility" (MRF) means a facility where non-compostable solid waste can be temporarily stored by the local body or any person or agency authorised by any of them to facilitate segregation, sorting and recovery of recyclables from various components of waste by authorised informal sector of waste pickers, informal recyclers or any other work force engaged by the local body for the purpose before the waste is delivered or taken up for its processing or disposal; Material recovery starts at the primary level, by households who segregate recyclables like newspapers, cardboard, plastics, bottles, etc. from waste to sell such material to local recyclers, scrap dealers or haulers. The item that cannot be sold to the kabadi system is discarded and becomes part of the MSW. Waste pickers pick up parts of this waste to earn their living. Well-segregated recyclables can directly be transferred to a processing site or to the recyclable market depending on local conditions.

The dry fraction of the segregated waste may be further segregated locally, at the transfer station or at the processing plant. The dry waste fraction can be segregated at the ward level, where waste from one or more wards is collected and segregated. Different recyclables are either sent directly to locally available recycling facilities or sold to wholesale dealers. The residual waste, depending on the composition, is sent for processing or disposal—compost, refuse derived fuel (RDF), landfilling. Where decentralised compost facilities are available, the wet waste fraction is processed locally. The dry waste fraction may also be transported to the waste transfer station where it is further segregated. Municipal corporations can also appoint informal waste pickers for manual sorting of waste at the transfer station. Segregation at the transfer station is through manual or mechanised segregation. Technical Aspects of Processing and Treatment of municipal solid waste 215– Where the dry waste fraction reaches the processing site (compost or RDF) directly, manual or mechanical pre-sorting should be carried out to recover recyclable material. This also ensures good quality process output. In case regional processing or disposal facilities exist, transfer of recyclables to the regional facility should be avoided. The dry waste fraction should be sorted out either at the ward level or transfer station level. If this is not possible, appropriate sorting facilities should be available at the regional facility.

Special waste including domestic hazardous waste that is collected either along with the dry waste fraction or separately is also to be segregated at the material recovery facility (MRF) and disposed according to the nature of the waste. Recyclable waste should be sent to the recycling industry, and hazardous waste should be disposed at the nearest treatment, storage, and disposal facility (TSDF) or as specified by the SPCB or PCC.

MRF units employ varying combinations of manual and mechanical processes, based on the type of facility, availability of equipment, labour availability, and associated cost implications. MRF units employing manual labour for sorting operations have relatively lower costs, but may also operate at lower efficiencies compared with mechanical sorting facilities. An MRF unit, depending on the level of complexity, will consist of a combination of units in varying degrees of mechanisation.

Pre-sorting Bulky and contaminated wastes hamper further sorting or processing in the facility; mechanical or manual pre-sorting is essential to separate out these wastes. Manual sorting results in higher labour costs and lower processing rates. Manual sorters remove bulky waste as the waste passes along a conveyor belt, which carries the pre-sorted waste to the mechanised sorting unit of the facility.

Mechanical sorting Mechanical processes based on principles of electromagnetic, fluid mechanics, pneumatics, etc. are used to segregate the different waste streams in the pre-sorted waste. Mechanical processes require specialised equipment for segregation of municipal waste. Mechanical sorting typically employs the following processes:

Screening: Screening achieves an efficient separation of particles into two or more size distributions. Two types of screens are used in MRF centres disc screens and trommels.

Ferrous Metal Separation: In the second stage, electromagnets are used for separating heavy ferrous metals from mixed waste.

Air Classification: The residual waste stream is passed through an air stream with sufficient velocity to separate light materials from heavy material, specifically for separating out lightweight plastics and paper from the mixed stream. Three types of air classifiers may be employed

- horizontal air classifier,
- vibrating incline air classifier, and

incline air classifier. Heavy or bulky plastics are sorted out either in the pre-processing line (manually) or in the "detect and routing" systems, employed at later stages of material recovery.

Non-ferrous Metal Separation: The non-ferrous metal separator segregates zinc, aluminium, copper, lead, nickel, and other precious metal from commingled waste. An eddy current separator removes non-ferrous items from the commingled waste based on their electrical conductivity.

Detect and Route System This system separates various grades of paper, plastics, and glass, which are not sorted out in the air classifier. This system works in two stages. The first stage employs programmed optical sensors to determine the nature of different materials. In the second stage, based on information received from the sensor, sorted material is routed to appropriate bins by directional air jets.

Size reduction Sorted materials after segregation are usually too large for further use or processing; they should be reduced to smaller sizes.

Baling Sorted and sized material is baled for further processing or use.

To do Activity

Overview

In this lesson, students will practice critical thinking skills while examining their own values related to reducing waste and the consumption of resources. Students will have the opportunity to express their own values and opinions about different waste reduction statements. Then they will share their opinions about the waste reduction statements with other students in small groups and explore how their values may differ from others.

Objectives

Students will

1. Express their values about reducing waste.

2. Describe whether their values about reducing waste changed because of discussions with other students.

3. Understand and apply the term "evidence."

Teacher Background

People express a wide variety of opinions, values and behaviours related to the environment. Values represent how a person rates the usefulness or importance of a principle or ideal. Values provide the foundation for beliefs that drive decision making and behaviour. People can also value material objects for their worth. Producing these objects requires the use of natural resources, which can be classified as renewable or non-renewable. Consumption of some of these resources may eventually lead to either the loss or the near loss of these resources within the current century. Students can develop the ability to think critically and carefully about their values, can develop their own opinions, and can learn to convey and justify their thoughts in order to make decisions based on their values. During the decision-making process, students may attempt to locate additional evidence that may support their opinions on topics such as reducing waste. Through this process students can discuss their values with others and be exposed to values and opinions that differ from their own. By looking at both sides of an issue, students can learn the importance of respecting the values and opinions of others.

Materials

Students

- "Value Statements" & "Fast Facts" (one per student)
- "Student Reflection" worksheet(one per student)

Teacher

- "Value Statements" &"Fast Facts" overhead
- Rubic overhead
- Rubics (one per student)

Preparation

Be prepared to assign the students into five groups. Each group will be assigned to one of five different value statements.

Discussion

- Ask students to think about different ways that people dispose of waste materials; some may help reduce waste and others may not. For example, some people are very careful—before they throw something away, they consider whether it can be reused, recycled, or composted. They use recycling and compost bins and produce very little waste. Other people do not recycle much and sometimes even contribute to litter by throwing waste on the ground or out of a car window.
- Ask students to share some examples of things that people might throw away that could be of value to someone else.

- Define the word ”value” “the quality of an object that makes it desired or wanted.” If we value something like a material object, we will sometimes pay or do much to getit. A value may also be defined as “the beliefs of an individual or social group that guide how decisions are made.” For example, a school may have a recycling club made up of students who believe that recycling is important.The students participating have the common goal of reducing waste at school through recycling.

- Ask students to name something that they value. Explain that this can be an object, belief or principle. Share some examples as needed to start the discussion.

- You may want to specifically discuss examples of principles or beliefs that people value so that students understand the difference between valuing material things and beliefs or principles. For example, Cesar Chavez fought for the rights of migrant farm workers who experienced unsafe working conditions and low wages, and Dr. Martin LutherKing Jr. sought equal protection for citizens of all races during the Civil Rights Movement.

- Explain that people may base their values on factual information or evidence; e.g., some people choose tobring a cloth bag to the store when shopping instead ofusing a paper bag. The practice of usinga cloth bag shows that they value the resources needed to make a paper bag by reducing the amount of paper they use.

- It is important for students to be able to justify their values and to answer questions about their values based onfactual evidence.

Procedure

- Organize the students into five groups.

- Pass out a “Value Statements” card to each student in the group. There are five versions of the value statement cards so each group will have different statements. Forexample, all students in group one will have a card titled“Group One.”

- Post up the overhead for one of the group value statements and model for the students how to fill it out. For each statement have them circle a number. A “10” signifies that you strongly agree with the statement. A “1”signifies that you strongly disagree with the statement.

- Next, ask the students to answer the questions below each statement that ask them to cite factual evidence to support their opinions. Factual information is located on the back of their value statement cards.

- When the students are done filling out the card, ask them to take turns sharing their opinions about the value statements, citing evidence to support their opinions.

- Ask each group to share one or two value statements they discussed with the entire class, citing examples of how their opinions were similar or different.

- Have the students return to their seats.

- Pass out the "Student Reflection" worksheet to each student and have them answer the questions.

Wrap-Up

- Ask students to raise their hands if any of their values changed after talking with a partner who had a different value. Ask for students to share what evidence persuaded or influenced them to change their values.
- Ask students whether there were any value statements they had difficulty agreeing or disagreeing with. What additional evidence or factual information would have helped them better understand the waste reduction value statement?

Final Assessment Idea

Have students write their own value statements about reducing waste. Ask them to cite evidence supporting their beliefs, where they located the information, and whether they have additional questions they would like to research.

Summary

- Solid waste collection means the act of removing solid waste from the premises of a primary generating source.
- Both volume and weight are used for the measurement of solid waste quantities.
- In 2015, plastic products generation was 34.5 million tons & 3.1 million tons of selected consumer electronics were generated.
- Source reduction, recycling activities, public attitudes and geographic factors affect the solid waste generation rate.
- Material recovery starts at the primary level, by households who segregate recyclables like newspapers, cardboard, plastics, bottles, etc. from waste to sell such material to local recyclers, scrap dealers or haulers.

Model Questions

1. What is the quantity of solid waste collected & recycled in India?
2. Find the methods used to measure solid waste quantities?
3. What are the factors affecting solid waste generation rate?

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Chapter 4 Handling, Separation, Storage & Disposal of solid waste

Introduction

The handling, separation, storage and processing of solid wastes at the source before they are collected is the second of the six functional elements in the solid waste management system because this element can have a significant effect on the characteristics on the waste, on subsequent functional elements, on public health and on public attitudes concerning the operation of the waste management system. It is important to understand what this elements involves.

Objectives

- To define fundamentals of waste handling, separation, storage and disposal of solid waste.
- To evaluate storage of solid wastes at the sources and its effects.
- To assess the disposal of Municipal solid waste

4.1 Handling, Separation & Storage of Solid Waste

Handling

In general, Handling refers to the activities associated with managing solid wastes until they are placed in the containers used for their storage before collection or return to drop-off and recycling centers. The specific activities associated with handling waste materials at the source of generation will vary depending on

- Types of waste materials that is separated for reuse and recycling.
- The extent to which these materials are separated from the waste stream.
- Type of collection service where handling may also be required to move the loaded containers to the collection point and to return the empty containers to the point where they are stored between collections.

Onsite handling refers to the activities associated with handling of solid waste until they are placed in the containers used for their storage before collection. Depending on the type of collection service, handling may also be required to move the loaded containers to the collection point and to return the empty containers to the point where they are stored between collections. Chutes for use in apartment buildings are available in diameters from 12 to 36 in (3- 9.15) cm. The most common size is 24 inch in diameter. All the available chutes can be furnished with suitable intake doors.

In some of the more recent apartment building developments underground pneumatic transport systems have been used in conjunction with the individual apartment chutes. The underground pneumatics systems are used to transport the wastes from the chute discharge points in each building to a central location for storage in large containers or onsite processing.

Waste Handling and Separation at commercial Buildings

- Collected in large containers mounted with rollers.
- Once filled, these containers removed by service elevators and emptied into

  1. Large storage containers

  2. Compactors used with storage containers

  3. Stationary compactors with designed container

  4. Other processing equipments.

- In many office and commercial buildings, the papers collected for recycling.
- The waste to be recycled stored in separate containers
- In large commercial facilities baling equipment used for paper and can crushers used for aluminium cans.

Figure 4.1 Functional elements of SWM system (Source www.slideplayer.com (ECH 4102 Environmental health engineering ppt)

(a)

(b)

Figure 4.2 On-site handling (https//www.drdarrinlew.us/environmental-engineering-2/onsite-handling-and-storage.html)

Separation

The separation of waste paper, cardboard, aluminium cans, glass and plastic containers at the source. It is the most effective ways to achieve recovery and reuse of material stored in a separate container until they are collected.

Compaction

Two principal types of compactors used for processing of wastes in residential dwellings Small (individual) home and apartment compaction units and large compactors used to compact wastes from a large number of apartments.

1. Home and Apartment Compaction Units

- Small compactors manufactured based on the ratio of loose paper and corrugated paper.
- It reduces the volume of waste upto 70%.

They can be used for only small proportion of the solid waste generated.

The drawback of compaction, if the wastes to be separated into components at MRF, the compacted waste have to be broken up before sorting.

Also by compacting, the waste may become so saturated with the liquids present in the food waste that the recovery of paper or other components may not be feasible.

2. Compactors for large Apartment Buildings

Compactor is installed at the bottom of the solid waste chute.

Wastes falling through chute active the compactor by means of photoelectric cells or limit switches.

The compressed waste may be formed into bales and loaded automatically into metal container or paper bags. When a bale formed or container or bag filled, the compactor shutdown automatically and warning light turns on. The operator tie and remove the bale from compactor, or remove the full bag and replace it with empty one. The compactors reduce the volume, the weight remains same. The compacted volume 20 to 60% less of the original volume.

Storage

The first phase to manage solid waste is at home level. It requires facilities for temporarily storing of refuse on the premises.

Individual house holders (or) tenants have responsibility for onsite storage of solid waste.

Four factors that should be considered in the on-site storage of solid waste are

1. The effects of storage on the waste components.

2. Type of container to be used

3. The location of containers

4. Public health and aesthetics

Effects of Storage on Waste Components

The effects based on the characteristics of waste being stored

These effects of storing wastes include

1. Microbiological decomposition

2. The absorption of fluids

3. The contamination of waste components

1. Microbiological decomposition

- Food and other waste placed in containers immediately start microbiological decomposition (putrefaction) as a result growth of bacteria and fungi.
- For extended period of time, flies start breed and odours.

2. The absorption of fluids

- Waste components have initial moisture contents are stored together, paper will absorb moisture from food waste and garden trimmings.
- Degree of absorption depends on time the waste stored until collection
- If stored more than a week in enclosed container, the moisture distributed throughout the waste .

3. The contamination of waste components

Most serious effect of on site storage

Major waste components contaminated by small amount of waste like motor oils, cleaners and paints.

It reduces the value of individual components for recycling.

Storage Container

The types and capacities of containers depend on

- Characteristics and types of solid waste to be collected
- The type of collection system in use
- The collection frequency

The space available for placement of containers.

Container storage locations depends on

- Type of dwelling or commercial facilities
- The available space
- Access to collection services

Residential Dwellings

- Between collections, containers used in low-rise detached dwellings placed

  1. at the sides or rear of the house

  2. in alleys, where alley collection is used

3.In or next to garage/carport or some common location specifically designed for that purpose.

- Two or more dwellings located close, a concrete pad open or surrounded by wooden enclosure.
- For low- and medium-rise apartment buildings include basement storage and outdoor storage.
- In large high-rise apartments, waste storage and processing equipment is located in the basement of the building.

Storage containers as per Indian Conditions

- The segregation of garbage at source is primarily meant to keep solid waste generated separately in different containers (i.e.) bio degradable waste in one container (GREEN) and non-biodegradable waste in another container (RED).
- The storage of garbage used by pedestrians (or) the floating populations, bins should be located at regular intervals. The bins should be placed on "TWO BINS BASIS"
- Some types of receptacles presently used for storage are

(a) Buckets

(b) Plastics / HDPE / MDPE bins

(c) Plastic bags

(d) Metal bins with (or) without lids.

The MSW Rules, 2000 describes, "The littering of municipal solid waste shall be prohibited in cities, towns and in urban areas notified by the State Government"

Plastic liners for cans and wrapping for garbage reduce the need for cleaning of cans and containers. It avoids bad odours, rat and fly breeding.

Galvanized metal is preferable for garbage storage because it is resistant to corrosion.

Bulk containers are recommended where large volumes of refuse are generated such as hotels, restaurants, apartment houses, shopping centres.

They should have tightly fitting covers.

They must be of such size that, when full, can be lifted easily by one man.

They should be located in a cool place over platforms, at least 30 cm above ground level.

The bins must be emptied at least daily and maintained in clean conditions.

An adequate number of suitable containers should be provided with proper platforms with stand. Suitable containers shall be water tight, rust resistant, tight fitting covers, fire resistant, enough size, light in weight, side handle & washable.

4.2 **Combustion and energy recovery from Municipal solid waste**

Combustion is actually a scientific term for burning. We are all aware of burning, but did you know that burning is actually a chemical reaction? Combustion is a chemical process where any fuel has a reaction with air (oxidant) to produce heat energy. And when this heat energy releases it will also produce light in the form of a flame. This is the visible part of the reaction, the flames. The general exothermic reaction of combustion can be expressed as Hydrocarbon + Oxygen → Carbon Dioxide + Water + Heat Energy

Examples of Combustion

- Burning of Wood or Coal to heat your home
- Burning of Petrol or Diesel to run your Car
- Combustion of Natural Gas or LPG to cook for on your stovetop
- For the production of energy in thermal power plants

Fireworks

Combustion is a chemical process or a reaction between Fuel (Hydrocarbon) and Oxygen. When fuel and oxygen react it releases the heat and light energy. Heat and light energy then result in the flame. So, the formula for Combustion reaction is Hydrocarbon + Oxygen = Heat energy. Combustion is used in car motors and rocket engines and many other machineries. There are 5 different types of combustion. Let us learn about types of combustion.

Types of Combustion

1] Complete Combustion

One of the types of combustion is Complete Combustion. Complete combustion occurs in an unlimited supply of air, oxygen in particular. Also, complete combustion is also known as clean combustion. Here the hydrocarbon will burn out completely with the oxygen and leave only two byproducts, water, and carbon dioxide.

An example of this is when a candle burns. The heat from the wick will vaporize the wax which reacts with the oxygen in the air. The two products of the reaction are water and carbon dioxide. In an ideal situation all the wax burns up and complete combustion takes place.

2] Incomplete Combustion

Incomplete combustion takes place when the air is in limited supply. And as opposed to complete combustion it is otherwise known as dirty combustion. Due to lack of oxygen, the fuel will not react completely. This, in turn, produces carbon monoxide and soot instead of carbon dioxide.

An example is burning of paper. It leaves behind ash (a form of soot) as a by product. In a complete combustion, the only products are water and carbon dioxide. Also, incomplete combustion produces less energy than complete combustion.

3] Rapid Combustion

Another type of combustion is Rapid Combustion. Rapid energy needs external heat energy for the reaction to occur. The combustion produces a large amount of heat and light energy and does so rapidly. The combustion will carry on as long as the fuel is available.

An example is when you light a candle. The heat energy is provided when we light the candle with a matchstick. And it will carry on till the wax burns out. Hence it is a rapid combustion

4] Spontaneous Combustion

As the name suggests the combustion occurs spontaneously. This means that it requires no external energy for the combustion to start. It happens due to self-heating. A substance with low-ignition temperatures gets heated and this heat is unable to escape.

The temperature rises above ignition point and in the presence of sufficient oxygen combustion will happen. The reaction of alkali metals with water is an example.

5] Explosive Combustion

Energy Recovery from Waste

Combustion of MSW grew in the 1980s, with more than 15 percent of all U.S. MSW being combusted by the early 1990s. The majority of the non-hazardous waste incinerators were recovering energy by this time and had installed pollution control equipment. With the newly recognized threats posed by mercury and dioxin emissions, the EPA enacted the Maximum Achievable Control Technology (MACT) regulations in the 1990s. As a result, most existing facilities had to be retrofitted with air pollution control systems or be shut down.

Economics

The upfront capital needed to build an MSW combustion plant can be a significant hurdle when building a new facility. A new plant typically requires at least $100 million upfront to finance the construction; larger plants may require double to triple that amount. The economic benefits of MSW combustion may take several years to be fully realized. Long-term contracts (generally 30 years) are often developed between the facility and municipality to secure a guaranteed waste stream. MSW Combustion facilities typically collect a tipping fee from the independent contractors that drop the waste off on a daily basis. The facilities also receive income from utilities after the electricity generated from the waste is sold to the grid. A possible third stream of revenue for the facilities comes from the sale of both ferrous (iron) and non-ferrous scrap metal collected from the post-combusted ash stream.

Combustion with Energy Recovery

Types of MSW Combustion Technologies

There are three types of technologies for the combustion of MSW.

Mass Burn Facilities – Mass burn facilities are by far the most common types of combustion facilities in the United States. The waste used to fuel the mass burn facility may or may not be sorted before it enters the combustion chamber. Many advanced municipalities separate the waste on the front end to pull off as many recyclable products as possible. Mass burn units are designed to burn MSW in a single combustion chamber under conditions of excess air. In combustion systems, excess air must be used to promote mixing and turbulence to ensure that air can reach all parts of the waste. This is necessary because of the inconsistent nature of solid waste. Most mass-burn facilities burn MSW on a sloping, moving grate that is vibrated or otherwise moved to agitate the waste and mix it with air.

Modular Systems – Modular Systems are designed to burn unprocessed, mixed MSW. They differ from mass burn facilities in that they are much smaller and are portable. They can be moved from site to site.

Refuse Derived Fuel Systems – These facilities use mechanical methods to shred incoming MSW, separate out non-combustible materials, and produce a combustible mixture suitable as a fuel in a dedicated furnace or as a supplemental fuel in a conventional boiler system.

Mass Burn Process

Waste to Energy Plant Diagram depicting the process from dumping the trash to its incineration, through the pollution control system that removes nitrogen oxide, mercury, dioxin, acid gas, and particulates before emitting water vapour and cleaned flue gases and the removal of ash on a conveyor belt and its transport to a landfill. At an MSW combustion facility, MSW is unloaded from collection trucks and placed in a trash storage bunker. An overhead crane is used to sort the waste and then lift it into a combustion chamber to be burned. The heat released from burning is used to convert water to steam. The steam is then sent to a turbine generator to produce electricity. The remaining ash is collected and taken to a landfill. Particulates are captured by a high-efficiency bag house (a filtering system). As the gas stream travels through these filters, more than 99 percent of particulate matter is removed. Captured fly ash particles fall into hoppers (funnel-shaped receptacles) and are transported by an enclosed conveyor system to the ash discharger where they are wetted to prevent dust and mixed with the bottom ash from the grate. The ash residue is then conveyed to an enclosed building where it is loaded into covered, leak-proof trucks and taken to a landfill designed to protect against groundwater contamination. Ash residue from the furnace can be processed for removal of recyclable scrap metals.

Ash Generated from the MSW Combustion Process

The amount of ash generated ranges from 15-25 percent by weight of the MSW processed and from 5-15 percent of the volume of the MSW processed. Generally, MSW combustion residues consist of two types of material fly ash and bottom ash. Fly ash refers to the fine particles that are removed from the flue gas and includes residues from other air pollution control devices, such as scrubbers.

Fly ash typically amounts to 10-20 percent by weight of the total ash. The rest of the MSW combustion ash is called bottom ash (80-90 percent by weight). The main chemical components of bottom ash are silica (sand and quartz), calcium, iron oxide, and aluminium oxide. Bottom ash usually has a moisture content of 22-62 percent by dry weight. The chemical composition of the ash varies depending on the original MSW feedstock and the combustion process. The ash that remains from the MSW combustion process is sent to landfills**.**

Explosive Combustion happens when the reaction occurs very rapidly. The reaction occurs when something ignites to produce heat, light and sound energy, the simple way to describe is it to call it an explosion. Some classic examples are firecrackers or blowing up of dynamite. Energy recovery from waste is the conversion of non-recyclable waste materials into usable heat, electricity, or fuel through a variety of processes including combustion, gasification, pyrolization, anaerobic digestion and landfill gas recovery. This process is often called waste to energy. Energy recovery from the combustion of municipal solid waste is a key part of the non-hazardous waste management hierarchy, which ranks various management strategies from most to least environmentally preferred. Energy recovery ranks below source reduction and recycling/reuse but above treatment and disposal. Confined and controlled burning, known as combustion, can not only decrease the volume of solid waste destined for landfills, but can also recover energy from the waste burning process. This generates a renewable energy source and reduces carbon emissions by offsetting the need for energy from fossil sources and reduces methane generation from landfills.

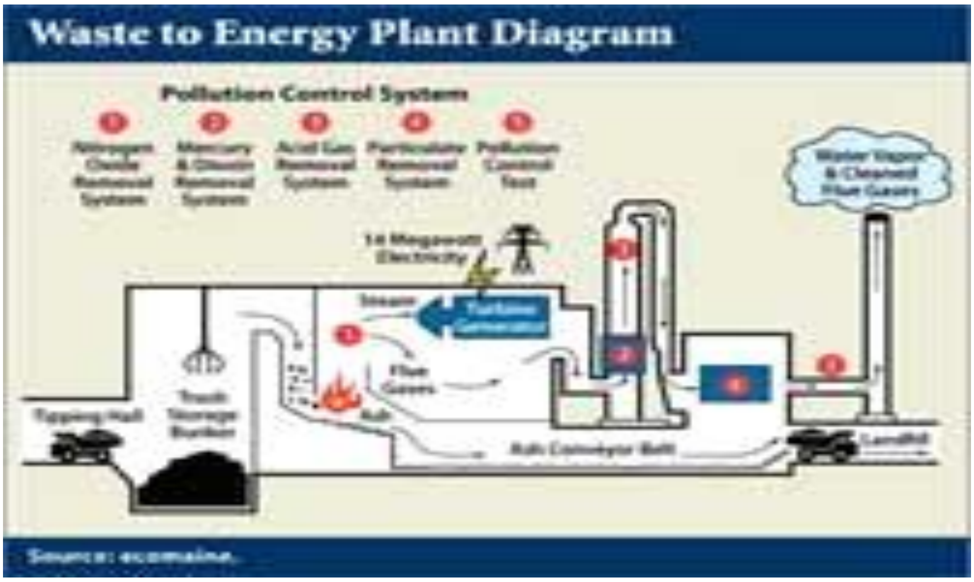

Figure 4.3 Waste to energy plant diagram (Source www.ecomaine.org)

Basic Techniques of Energy Recovery from Waste

Energy can be recovered from the organic fraction of waste (biodegradable as well as non-biodegradable) through thermal, thermo-chemical and biochemical methods.

A brief description of the commonly applied technologies for energy generation from waste is as follows:

Anaerobic Digestion/Biomethanation

In this process, the organic fraction of the waste is segregated and fed into a closed container (biogas digester). In the digester, the segregated waste undergoes biodegradation in presence of methanogenic bacteria and under anaerobic conditions, producing methane-rich biogas and effluent. The biogas can be used either for cooking/heating applications, or for generating motive power or electricity through dual-fuel or gas engines, low-pressure gas turbines, or steam turbines. The sludge from anaerobic digestion, after stabilization, can be used as a soil conditioner. It can even be sold as manure depending upon its composition, which is determined mainly by the composition of the input waste.

Combustion/Incineration

In this process, wastes are directly burned in presence of excess air (oxygen) at high temperatures (about 800°C), liberating heat energy, inert gases, and ash. Combustion results in transfer of 65%–80% of heat content of the organic matter to hot air, steam, and hot water. The steam generated, in turn, can be used in steam turbines to generate power.

Pyrolysis/Gasification

Pyrolysis is a process of chemical decomposition of organic matter brought about by heat. In this process, the organic material is heated in absence of air until the molecules thermally break down to become a gas comprising smaller molecules (known collectively as syngas)Gasification can also take place as a result of partial combustion of organic matter in presence of a restricted quantity of oxygen or air. The gas so produced is known as producer gas. The gases produced by pyrolysis mainly comprise carbon monoxide (25%), hydrogen and hydrocarbons (15%), and carbon dioxide and nitrogen (60%). The next step is to 'clean' the syngas or producer gas. Thereafter, the gas is burned in internal combustion (IC) engine generator sets or turbines to produce electricity.

Landfill Gas recovery

The waste dumped in a landfill becomes subjected, over a period of time, to anaerobic conditions. As a result, its organic fraction slowly volatilizes and decomposes, leading to production of 'landfill gas', which contains a high percentage of methane (about 50%). It can be used as a source of energy either for direct heating/cooking applications or to generate power through IC engines or turbines.

Case study (Source MNRE (http//mnre.gov.in/nmp/technology-we.pdf), with additional research from EAI)

Evaluating the indian market for distributed energy generation from sewage and municipal solid waste

The Background

The Bill & Melinda Gates Foundation is dedicated to bringing innovations in health, development, and learning to the global community. The Water, Sanitation and Hygiene division of the Foundation was keen on exploring possibilities to implement solutions in India that could convert waste, especially non sewer faecal sledges or faecal sludge and municipal waste (a problem) into energy (an opportunity). The foundation (client) was looking to fund innovative solutions in the domain of non-sewer faecal sludge to high value energy products. In this context, they approached EAI to undertake a study.

The Solution

Identification of Prospective Companies

EAI team along with the Gates Foundation visited a wide range of companies, research organizations, academia and industry experts to understand the potential and challenges in deriving energy from sewage waste, municipal solid waste and mixed waste.

EAI then provided a detailed analysis of the companies visited and provided recommendations for the possible grant or investment opportunities and strong partners to the client.

Technology Landscape Analysis

EAI also assisted the foundation by preparing a technical and process document which detailed

The diverse pathways for waste to energy in India and the characteristics of each pathway.

The optimum size of the waste-based power plants and the economically feasible feedstock costs for both kW size plants and MW size plants.

Potential for carbon credit financing.

Helping a Medium Size Indian Corporate Understand the Critical Aspects of the Indian Waste to Energy Landscape

4.3 Landfill - Classification, planning, sitting, permitting & landfill processes

A landfill is a large outdoor site specifically designed for the disposal of waste. Not all landfills are the same. Different kinds of landfills accept different kinds of waste including

Industrial waste

Hazardous waste

Construction and demolition debris

Municipal Solid Waste (MSW), commonly defined as household trash or garbage.

When you think of a landfill, you probably are thinking of the landfill that accepts your household trash or garbage.

A landfill site (also known as a tip, dump, rubbish dump, garbage dump or dumping ground and historically as a madden) is a site for the disposal of waste materials by burial. It is the oldest form of waste treatment (although the burial part is modern; historically, refuse was just left in piles or thrown into pits). Historically, landfills have been the most common method of organized waste disposal and remain so in many places around the world. Some landfills are also used for waste management purposes, such as the temporary storage, consolidation and transfer, or processing of waste material (sorting, treatment, or recycling). Unless they are stabilized, these areas may experience severe shaking or soil liquefaction of the ground during a large earthquake.

Land filling is the ultimate disposal process for Municipal Solid Waste (MSW) management. The quantity of MSW for land disposal can be substantially reduced by setting up of waste processing facilities and recycling the waste materials as much as possible. A few Urban Local Bodies (ULBs) have attempted to demonstrate “Zerogarbage” on Municipal Solid Wastes Management (MSWM) by adopting method of recycling/reusing and processing of wastes. Still, some inert wastes are left out for disposal. It is estimated that the inert wastes for landfilling occupies 40-55% of the total wastes depending upon type of city.

The landfill is an unavoidable component in MSW Management and its planning and design, construction, operation & maintenance involves technical skills and safety measures in terms of health and environmental protection. The Municipal Solid wastes (Management & Handling) Rules, 2000 specify relevant points with regard to site selection for proposed landfill site, facilities requires at landfill site, specification for landfilling, pollution prevention, water quality monitoring, ambient air quality monitoring, plantation at landfill site, closure of landfill site/ post closure, etc. These specific provisions are to be implemented as per rules and need to be ensured during the planning and design stage. The adequacy and performance of these provisions are to be monitored by the regulating authorities (SPCBs/PCCs) during issue of consent/authorization. Central Pollution Control Board (CPCB) has made an effort to bring out the present document incorporating the check-list for quick review during monitoring of the landfill facilities all stages right from planning to commission of landfill facilities. Information on a few existing/operating landfill facilities set up by the local bodies is also presented in this document for reference purpose.

Regulatory aspects/provision of MSW Landfills

Under section 6 (3) of the MSW (M&H) Rules, 2000 State Pollution Control Board (SPCBs) or Pollution Control Committee (PCCs), shall issue authorization in Form-III to the municipal authority or an operator of a facility within forty-five days stipulating compliance criteria and standards as specified in Schedule II, III and IV including such other conditions, as may be necessary. SPCBs/PCCs, after the receipt of application from the municipal authority or the operator of a facility including landfills, shall examine the proposal taking into consideration the views of other agencies like the State Urban Development department, the Town and Country Planning department, Air port or Air Base authority, the ground Water Board or any such other Agency prior to issuing the authorization.

Landfills as per MSW rules

Requisites of Landfills

The Sl. No.6.under Schedule-II of MSW Rules, 2000 prescribes that landfilling shall be permitted to non-biodegradable, inert waste and other wastes that are not suitable either for recycling or for biological process. Landfilling shall also be carried out for residues of waste processing facilities as well as pre-processing rejects from waste processing facilities. Landfilling of mixed waste shall be avoided unless the same is found unsuitable for waste processing. Under unavoidable circumstances or till installation of alternate facilities, landfilling shall be done following proper norms.

Specifications for landfill Sites

(a) **Site selection**

Landfill identification shall be done by 'Development Authorities' for the area falling under 'Development Authority', otherwise it shall be done by the concerned Municipal authority. The site selection shall be done based on examination of environmental issues. The landfill site shall be planned and designed with proper documentation of a phased construction plan as well as a closure plan. The landfill facility shall be nearby waste processing plant or an integral part of it. The landfill site shall be designed for 20-25 years. The proposed landfill site should be away from habitation clusters, forest areas, water bodies, monuments, national Parks, Wetlands and places of important cultural, historical or religious interest. Also, approval shall be taken from the concerned authorities in case the landfill site is located within 20 km from the airport/airbase.

(b) **Facilities at Site**

The landfill shall be fenced with proper gate at entrance for monitoring incoming wastes/vehicles, to prevent entry of cattle, to keep record movement of vehicles and wastes, etc. Also, provision of weigh-bridge may be made for assessing quantum of wastes. Drinking water and other sanitary facilities and other safety measures including health check up shall be provided to workers.

(c) **Specification for land filling**

Waste subjected to land filling shall be compacted in thin layers to achieve maximum capacity of landfill. The disposed wastes shall be covered immediately/at the end of working day with 10 cm of soil. Prior to commencing monsoon period, an immediate soil cover of 40-65 cm thickness shall be placed on the landfill with compaction to prevent rainwater infiltration. Proper drainage to be provided to divert run-off water from the active landfill cell.

After completion of landfill, a final capping shall be provided with

(i) A barrier of soil covers of 60 cm of clay or amended soil with permeability of 1X10-7 cm/sec

(ii) On top of the barrier soil layer, there shall be a drainage layer of 15 cm and

(iii) On top of the drainage layer, there shall be vegetation layer of 45 cm to support natural plant growth to minimize soil erosion.

(d) **Pollution Prevention**

In order to prevent pollution problems from landfill operation the necessary steps should be taken viz.

(i) Diversion of storm water to minimize leachate generation and to avoid flooding/water logging.

(ii) Construction of non-permeable linings system at the base and walls of waste disposal area against contamination from domestic hazardous wastes. The liner shall be a composite barrier having 1.5 mm HDPE.

(f) **Ambient air quality monitoring**

Installation of landfill gas control system including gas collection system shall be made at landfill site to minimize odour generation, prevent off-site migration of gases and to protect vegetation planted permeability least than 1X10-7 cm/sec. The water table should be at least 2 m below the base clay or amended soil barrier layer.

(e) **Water quality monitoring**

Ground water quality to be monitored within 50 m periphery of landfill site. Also, ground water quality data to be generated before construction of landfill site for future reference.The concentration of methane gas at the landfill site shall not exceed 25 LEL. The landfill gas collected from the facility shall be utilized either direct thermal application or power generation, otherwise, landfill gas shall be flared to prevent direct escape. Passive venting will be allowed if flaring is not possible.

(g) **Plantation at Landfill site**

A vegetative cover shall be provided over completed site as follows;

(i) Selected species of locally adopted non-edible perennial plants that resistance to drought and extreme temperature shall be allowed to grow.

(ii) The roots of the plants grown should not penetrate more than 30 cm.

(iii) The plant species shall have ability to thrive on low nutrient soil and

(iv) the density of plantation shall be sufficient to minimize soil erosion.

(h) **Closure of landfill site and post- care**

The post-closure care of landfill site shall be conducted after fifteen years and long term monitoring to assess;

(i) Maintaining integrity and effectiveness of final cover and repair required.

(ii) Efficiency of leachate collection system.

(iii) Ground water quality and action required to improve.

(iv) Maintenance and operation of gas collection system to meet the standards. The closed landfill may be used for human settlement after 15 years of post closure care by ensuring gaseous emission and leachate compliance.

(i) **Special provisions for hilly areas**

Cities/ towns located in hilly areas shall adopt location specific methods of disposal with permission of concerned SPCB/PCCs.

Landfill processes

One of several landfills used by Dryden, Ontario, Canada. Typically, operators of well-run landfills for non-hazardous waste meet predefined specifications by applying techniques to

- confine waste to as small an area as possible
- compact waste to reduce volume
- they can also cover waste (usually daily) with layers of soil or other types of material such as woodchips and fine particles.

During landfill processes, a scale or weighbridge may weigh waste collection vehicles on arrival and personnel may inspect loads for wastes that do not accord with the landfill's waste-acceptance criteria. Afterward, the waste collection vehicles use the existing road network on their way to the tipping face or working front, where they unload their contents. After loads are deposited, compactors or bulldozers can spread and compact the waste on the working face. Before leaving the landfill boundaries, the waste collection vehicles may pass through a wheel-cleaning facility. If necessary, they return to the weighbridge for re-weighing without their load. The weighing process can assemble statistics on the daily incoming waste tonnage, which databases can retain for record keeping. In addition to trucks, some landfills may have equipment to handle railroad containers. The use of "rail-haul" permits landfills to be located at more remote sites, without the problems associated with many truck trips. Typically, in the working face, the compacted waste is covered with soil or alternative materials daily. Alternative waste-cover materials include chipped wood or other "green waste”, several sprayed-on foam products, chemically "fixed" bio-solids, and temporary blankets. Blankets can be lifted into place at night and then removed the following day prior to waste placement. The space that is occupied daily by the compacted waste and the cover material is called a daily cell. Waste compaction is critical to extending the life of the landfill. Factors such as waste compressibility, waste-layer thickness and the number of passes of the compactor over the waste affect the waste densities.

Advantages

Landfills are often the most cost-efficient way to dispose of waste, especially in countries with large open spaces. While resource recovery and incineration both require extensive investments in infrastructure, and material recovery also requires extensive manpower to maintain, landfills have fewer fixed—or ongoing—costs, allowing them to compete favourably. In addition, landfill gas can be upgraded to natural gas—landfill gas utilization—which is a potential revenue stream. Another advantage is having a specific location for disposal that can be monitored, where waste can be processed to remove all recyclable materials before tipping.

Social and environmental impact

Landfill operation in Hawaii. Note that the area being filled is a single, well-defined "cell" and that a protective landfill liner is in place (exposed on the left) to prevent contamination by leachates migrating downward through the underlying geological formation. Landfills have the potential to cause a number of issues. Infrastructure disruption, such as damage to access roads by heavy vehicles, may occur. Pollution of local roads and water courses from wheels on vehicles when they leave the landfill can be significant and can be mitigated by wheel washing systems. Pollution of the local environment, such as contamination of groundwater or aquifers or soil contamination may occur as **Leachate**

In some places, efforts are made to capture and treat leachate from landfills before it reaches groundwater aquifers. However, liners always have a lifespan, though it may be 100 years or more. Eventually, every landfill liner will leak, allowing pollutants to contaminate groundwater.

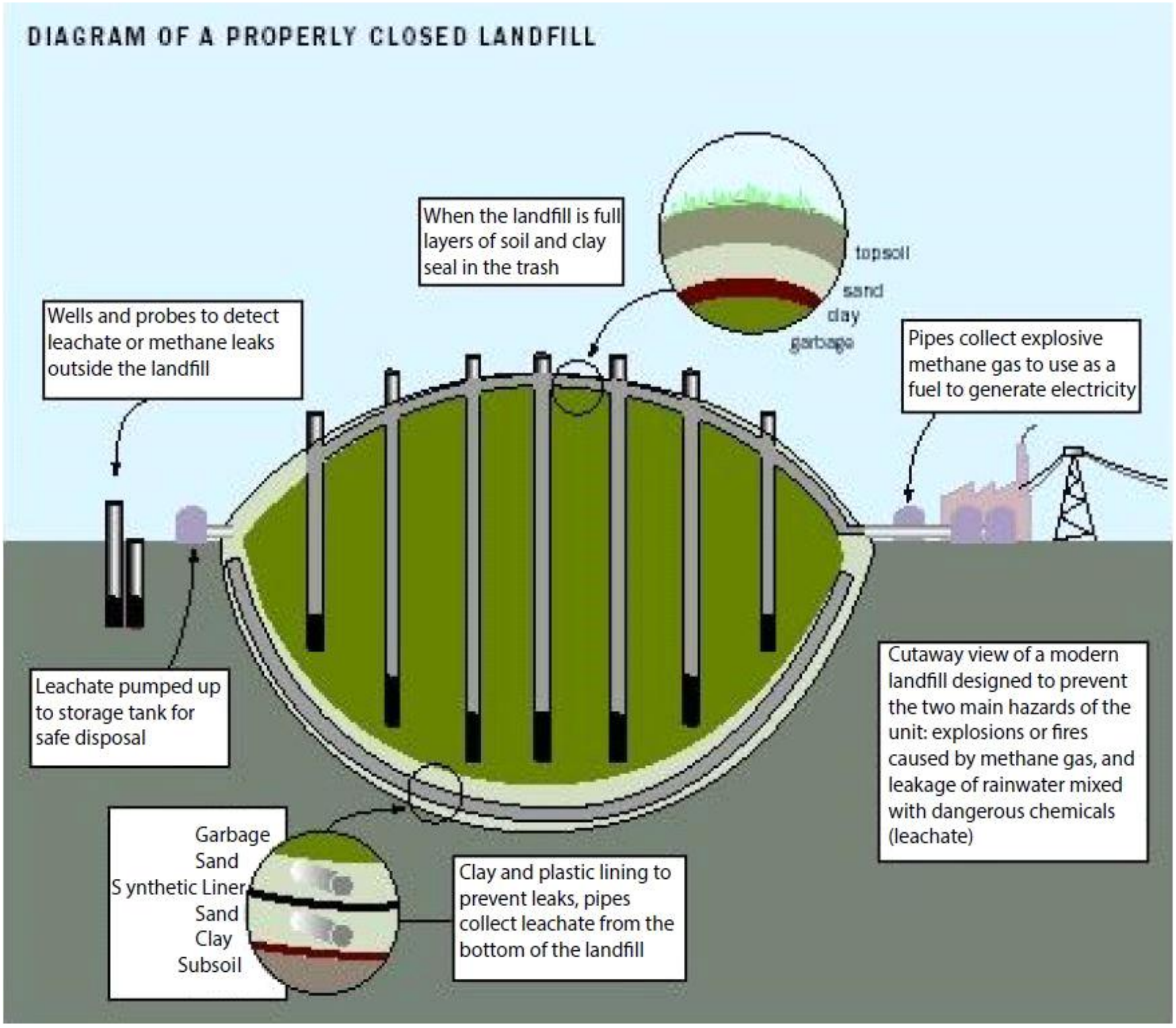

Figure 4.4 Landfill (Source https//www.epa.gov/landfills/municipal-solid-waste-landfills)

Why do we need any landfills?

Waste reduction, reuse and recycling divert large parts of our waste from landfills, but not all of it. That waste must be managed safely to protect human health and the environment.

Landfill Site of Ahmedabad

Ahmedabad Urban Development Authority (AUDA) has constructed a common landfill site at Fatehwadi (Ahmedabad) for sharing this facility by 12 Nagar Palikas of West AUDA area. The landfill area of 1178 sq. km. will take care of 200 TPD MSW generated by 12 Nagar Palikasviz.Chandkheda, Kali, Ranip, Ghatlodia, Chandlodia, Memnagar, Thaltej,Bodakdev, Vastrapur, Vejalpur, Jodhpur and Sarkhej Nagar Palika. Total population is estimated to be 10 lacs and waste generation of 200TPD. The average annual rainfall is 300mm, the depth of groundwater table is 6 meters and the soil is sandy. AUDA has constructed a common landfill site at Fatehwadi village with a disposal capacity of 1,45,534 cum and designed for 50TPD (8 years). The size of the landfill is 151m X 122m X 7.9m.

Leachate collection and treatment facility

150 mm diameter HDPE perforated pipe having holes of 10mm@ centre to centre at 150 mm distance are laid in drainage layer. Leachate will be collected in leachate collection tank having size of 2m X 2m X 3m height. The collected leachate will be pumped out in tanker and discharges in to nearby trunk sewer line.

Gas collection

Gas collection vent pipe having 230mm diameter size HDPE pipe having holes of 10mm @ c/c 150mm distance has been provided.

Stormwater drainage

Stormwater drainage system has been provided on outer side of top service road and at the bottom of edge of the cell to drain out storm water.

Other information

The waste processing (aerobic compost) plant of capacity 150 TPD is under execution. It is planned to fix up operation and maintenance agency for landfill cell and compost plant.

4.4 Differentiate sanitary landfill and incineration as final disposal system for solid waste

A landfill is a solid waste disposal method in which discarded materials are buried between layers of earth in an attempt to reduce public health hazards caused by decaying refuse. According to the Environmental Protection Agency (EPA), there are more than 10,000 old municipal landfills and more than 1,754 active landfills in the United States as of 2007. Though modern landfills are required to be impermeable waste containers, most of the older landfills were simply holes dug in the ground where everything from cans of paint to old washing machines was buried. However, even the newest landfill containers have been found to leak over time. The use of landfills has contributed to both air and water pollution.

Specifications for Sanitary Landfills

(i) The department in the business allocation of land assignment shall provide suitable site for setting up of the solid waste processing and treatment facilities and notify such sites.

(ii) The sanitary landfill site shall be planned, designed and developed with proper documentation of construction plan as well as a closure planin a phased manner. In case a new landfill facility is being established adjoining an existing landfill site, the closure plan of existing landfill should form a part of the proposal of such new landfill.

(iii) The landfill sites shall be selected to make use of nearby wastes processing facilities. Otherwise, wastes processing facility shall be planned as an integral part of the landfill site.

(iv)Landfill sites shall be set up as per the guidelines of the Ministry of Urban Development, Government of India and Central Pollution Control Board.

(v)The existing landfill sites which are in use for more than five years shall be improved in accordance with the specifications given in this Schedule.

(vi)The landfill site shall be large enough to last for at least 20-25 years and shall develop 'landfill cells' in a phased manner to avoid water logging and misuse.

(vii) The landfill site shall be 100 meter away from river, 200 meter from a pond, 200 meter from Highways, Habitations, Public Parks and water supply wells and 20 km away from Airports or Airbase. However in a special case, landfill site may be set up within a distance of 10 and 20 km away from the Airport/Airbase after obtaining no objection certificate from the civil aviation authority/Air force as the case may be. The Landfill site shall not be permitted within the flood plains as recorded for the last 100 years, zone of coastal regulation, wetland, Critical habitat areas, sensitive ecofragileareas..

(viii) The sites for landfill and processing and disposal of solid waste shall be incorporated in the Town Planning Department's land-use plans.

(ix) A buffer zone of no development shall be maintained around solid waste processing and disposal facility, exceeding five Tonnes per day of installed capacity. This will be maintained within the total area of the solid waste processing and disposal facility. The buffer zone shall be prescribed on case to case basis by the local body in consultation with concerned State Pollution Control Board.

(x) The biomedical waste shall be disposed of in accordance with the Bio-medical Waste Management Rules, 2016, as amended from time to time. The hazardous waste shall be managed in accordance with the Hazardous and Other Wastes (Management and Trans boundary Movement) Rules, 2016, as amended from time to time. The E-waste shall be managed in accordance with the e-waste (Management) Rules, 2016 as amended from time to time.

(xi) Temporary storage facility for solid waste shall be established in each landfill site to accommodate the waste in case of non- operation of waste processing and during emergency or natural calamities.

Land disposal is the most common management strategy for municipal solid waste. Refuse can be safely deposited in a sanitary landfill, a disposal site that is carefully selected, designed, constructed, and operated to protect the environment and public health. One of the most important factors relating to landfilling is that the buried waste never comes in contact with surface water or groundwater. Engineering design requirements include a minimum distance between the bottom of the landfill and the seasonally high groundwater table. Most new landfills are required to have an impermeable liner or barrier at the bottom, as well as a system of groundwater-monitoring wells. Completed landfill sections must be capped with an impermeable cover to keep precipitation or surface runoff away from the buried waste. Bottom and cap liners may be made of flexible plastic membranes, layers of clay soil, or a combination of both.

Figure 4.5 Sanitary landfill vs incinerator

(Source: https//sciencing.com/landfills-vs-incinerators-5523826.html)

Constructing the landfill

The basic element of a sanitary landfill is the refuse cell. This is a confined portion of the site in which refuse is spread and compacted in thin layers. Several layers may be compacted on top of one another to a maximum depth of about 3 metres (10 feet). The compacted refuse occupies about one-quarter of its original loose volume. At the end of each day's operation, the refuse is covered with a layer of soil to eliminate windblown litter, odours, and insect or rodent problems. One refuse cell thus contains the daily volume of compacted refuse and soil cover. Several adjacent refuse cells make up a lift, and eventually a landfill may comprise two or more lifts stacked one on top of the other. The final cap for a completed landfill may also be covered with a layer of topsoil that can support vegetative growth.

Daily cover soil may be available on-site, or it may be hauled in and stockpiled from off-site sources. Various types of heavy machinery, such as crawler tractors or rubber-tired dozers, are used to spread and compact the refuse and soil. Heavy steel-wheeled compactors may also be employed to achieve high-density compaction of the refuse.

The area and depth of a new landfill are carefully staked out, and the base is prepared for construction of any required liner and leachate-collection system. Where a plastic liner is used, at least 30 cm (12 inches) of sand is carefully spread over it to provide protection from landfill vehicles. At sites where excavations can be made below grade, the trench method of construction may be followed. Where this is not feasible because of topography or groundwater conditions, the area method may be practiced, resulting in a mound or hill rising above the original ground. Since no ground is excavated in the area method, soil usually must be hauled to the site from some other location. Variations of the area method may be employed where a landfill site is located on sloping ground, in a valley, or in a ravine. The completed landfill eventually blends in with the landscape.

Controlling by-products

Organic material buried in a landfill decomposes by anaerobic microbial action. Complete decomposition usually takes more than 20 years. One of the by-products of this decomposition is methane gas. Methane is poisonous and explosive when diluted in the air, and it can flow long distances through porous layers of soil. If it is allowed to collect in basements or other confined areas, dangerous conditions may arise. In modern landfills, methane movement is controlled by impermeable barriers and by gas-venting systems. In some landfills the methane gas is collected and recovered for use as a fuel. A highly contaminated liquid called leachate is another by-product of decomposition in sanitary landfills. Most leachate is the result of runoff that infiltrates the refuse cells and comes in contact with decomposing garbage. If leachate reaches the groundwater or seeps out onto the ground surface, serious environmental pollution problems can occur, including the possible contamination of drinking-water supplies. Methods of controlling leachate include the interception of surface water in order to prevent it from entering the landfill and the use of impermeable liners or barriers between the waste and the groundwater. New landfill sites should also be provided with groundwater-monitoring wells and leachate-collection and treatment systems.

Landfill Problems

Many landfills, especially older landfills in rural areas, are prone to producing leachate. Leachate is an often toxic liquid that results from rain passing through a landfill and seeping into the ground water. As rainwater passes through the landfill, it picks up organic and inorganic materials that contain elements harmful to humans. For example, heavy metals, pesticides and solvents combine with the water that eventually makes its way into 40 percent of municipal drinking water and 90 percent of rural drinking water. Dangerous gases emitted from the decaying contents of landfills increase air pollution. Studies on how close you live to a landfill show a marked likelihood of developing certain illnesses, including diabetes.

Incinerators

Incineration is a disposal method in which solid organic wastes are subjected to combustion so as to convert them into residue and gaseous products. This method is useful for disposal of both municipal solid waste and solid residue from waste water treatment. This process reduces the volumes of solid waste by 80 to 95 percent. Incineration and other high temperature waste treatment systems are sometimes described as "thermal treatment". Incinerators convert waste materials into heat, gas, steam, and ash. Incineration is carried out both on a small scale by individuals and on a large scale by industry. It is used to dispose of solid, liquid and gaseous waste. It is recognized as a practical method of disposing of certain hazardous waste materials (such as biological medical waste). Incineration is a controversial method of waste disposal, due to issues such as emission of gaseous pollutants. Incineration is common in countries such as Japan where land is more scarce, as the facilities generally do not require as much area as landfills. Waste-to-energy (WtE) and energy-from-waste (EfW) are broad terms for facilities that burn waste in a furnace or boiler to generate heat, steam or electricity. Combustion in an incinerator is not always perfect and there have been concerns about pollutants in gaseous emissions from incinerator stacks. Particular concern has focused on some very persistent organic compounds such as dioxins, furans, and PAHs, which may be created and which may have serious environmental consequences.

Some solid waste, especially health-care waste, is destroyed using incinerators, which burn discarded materials into ash. According to the EPA, Pennsylvania, Maine and Minnesota are the top three states that use combustion to destroy solid waste, with Alaska, Oregon, Virginia, New York and Florida following closely behind. But even if there is little or no waste incinerated in your state, this does not mean that potentially toxic incinerated material is not present in your area. Incinerator ash is exported to other states to be used as landfill cover, contributing to the landfill leachate that seeps into the water supply.

Burning is a very effective method of reducing the volume and weight of solid waste. In modern incinerators the waste is burned inside a properly designed furnace under very carefully controlled conditions. The combustible portion of the waste combines with oxygen, releasing mostly carbon dioxide, water vapour, and heat. Incineration can reduce the volume of uncompacted waste by more than 90 percent, leaving an inert residue of ash, glass, metal, and other solid materials called bottom ash. The gaseous by-products of incomplete combustion, along with finely divided particulate material called fly ash, are carried along in the incinerator airstream. Fly ash includes cinders, dust, and soot. In order to remove fly ash and gaseous by-products before they are exhausted into the atmosphere, modern incinerators must be equipped with extensive emission control devices. Such devices include fabric baghouse filters, acid gas scrubbers, and electrostatic precipitators. Bottom ash and fly ash are usually combined and disposed of in a landfill. If the ash is found to contain toxic metals, it must be managed as a hazardous waste.

Municipal solid-waste incinerators are designed to receive and burn a continuous supply of refuse. A deep refuse storage pit, or tipping area, provides enough space for about one day of waste storage. The refuse is lifted from the pit by a crane equipped with a bucket or grapple device. It is then deposited into a hopper and chute above the furnace and released onto a charging grate or stoker. The grate shakes and moves waste through the furnace, allowing air to circulate around the burning material. Modern incinerators are usually built with a rectangular furnace, although rotary kiln furnaces and vertical circular furnaces are available. Furnaces are constructed of refractory bricks that can withstand the high combustion temperatures.

Combustion in a furnace occurs in two stages primary and secondary. In primary combustion, moisture is driven off, and the waste is ignited and volatilized. In secondary combustion, the remaining unburned gases and particulates are oxidized, eliminating odours and reducing the amount of fly ash in the exhaust. When the refuse is very moist, auxiliary gas or fuel oil is sometimes burned to start the primary combustion.

In order to provide enough oxygen for both primary and secondary combustion, air must be thoroughly mixed with the burning refuse. Air is supplied from openings beneath the grates or is admitted to the area above. The relative amounts of this underfire air and overfire air must be determined by the plant operator to achieve good combustion efficiency. A continuous flow of air can be maintained by a natural draft in a tall chimney or by mechanical forced-draft fans.

Incinerator Problems

Burning waste emits toxic gases and particulates (which can settle in your lungs) into the air. It is not confined to the area where it is incinerated, as air currents can distribute the toxins this burning produces around the world. Both air emissions and incinerator ash include heavy metals and chemicals, such as cadmium, mercury, sulphuric acid and hydrogen chloride, as well as the deadly poison dioxin.

Solutions

Every man, woman and child in the United States throws away 4.5 pounds of trash every day. By practicing the principles of “reduce, reuse and recycle,” you can be instrumental in helping to solve our waste management problems. The EPA projects that our landfills and incinerators can only handle the solid waste our growing population produces for another 20 years. If you choose products with minimal or biodegradable packaging, purchase products with long lives, reuse an existing item in a different way and recycle your discards properly, the waste management system will be less impacted. Contact your legislator to promote recycling in your area and to make him aware of the increasing dangers of discarded electronics. Computers, printers and televisions contain toxic materials and need to be disposed of carefully.

Case study (Source MNRE (http//mnre.gov.in/nmp/technology-we.pdf), with additional research from EAI)

Helping a medium size Indian corporate understand the critical aspects of the Indian waste to energy landscape

EAI was retained to assist a second generation Indian entrepreneur keen on entering the Indian waste to energy sector.

The EAI team provided clarity to the client on both the technology and processes involved in the conversion of the diverse waste feedstock into energy. These involved all the prominent processes – anaerobic digestion, pyrolysis, incineration and gasification.

The EAI team provided the client comprehensive technical and feasibility analyses for the two shortlisted routed – anaerobic digestion and gasification. Special emphasis was laid on providing clarity to the client on the pros and cons of each technology. Our team also provided clear breakdowns of both capital and operational costs to the client for the two shortlisted routes so that the client appreciated the total project cost comprehensively.

EAI’s service also included assisting in vendor in evaluating cutting edge technical solutions for gasification, such as plasma arc gasification.

4.5 Biochemical processes

Biomethanation-

Biomethanation is the anaerobic (in the absence of free oxygen) fermentation of biodegradable matter in an enclosed space under controlled conditions of temperature, moisture, pH, etc. The waste mass undergoes decomposition due to microbial activity, thereby generating biogas comprising mainly of methane and carbon dioxide (CO2), and also digested sludge, which is almost stabilised but may contain some pathogen. Due to the anaerobic environment, hydrogen sulfide (H2S) is generated with varying percentage depending on the sulphur content in the system (in the form of protein, sulphate, etc.). Like composting, biomethanation is one of the most technically viable options for Indian municipal solid waste (MSW) due to the presence of high organic and moisture content.

Simple small to medium scale systems have been developed in India, especially for cattle manure; these plants are called Gobar Gas Plants. According to the Ministry of New and Renewable Energy (MNRE), 4.3 million family type biogas plants have been installed in India. Toilet linked biogas plants have been installed at family, community and institutional levels. Application of biomethanation for MSW can be seen broadly in three categories

(i) small biogas plants for canteen waste;

(ii) medium-sized digesters for market waste (flower, fruit, vegetable, slaughterhouse, etc.);

(iii) and large-scale plants.

There are some well-known examples of installation of MSW based biogas plants

(i) 16 tonnes MSW plus 4 tonnes per day (TPD) slaughterhouse waste based facility in Vijayawada;

(ii) 30 TPD flower fruit market waste based biogas plant in Koyambedu, Chennai; and

(iii)500 TPD MSW based facility at Lucknow. So far, large biogas plants fed with MSW have not been successful in India although such plants have been successful in some other countries. The failure of MSW based biogas plants is not related to the basic technology; this is more due to lack of understanding of the process and planning capability and due to mismatch between the expectations of the concessionaire and the consignee with respect to quality and quantity of MSW supply. However, there are ongoing attempts by different urban local bodies (ULBs) to set up MSW based biogas plants. Medium to large digesters are appropriately designed and engineered for smooth operation.

Merits of Biomethanation Process

- Energy generation, the produced biogas can be used for cooking or for the production of electricity and heat.
- Biogas may also be cleaned by removing CO2 and H2S. The resulting methane enriched biogas containing more than 90% methane (CH4) is somewhat like compressed natural gas (CNG). However, for this gas to be used as automotive fuel, the percentage of CO2 has to be less than 5%, which corresponds to methane percentage of 95% or more. H2S has to be less than 10 parts per million (ppm) for use in automobiles. Use of this fuel is more benign for the environment than using petroleum-based automotive fuels. Like composting, biomethanation also leads to reduced landfill requirement, thus extending the life of existing landfills.
- Biomethanation of biodegradable organic material would result in stabilised sludge which can be used as a soil conditioner and fertiliser. However, pathogen kill or inactivation may not be complete during anaerobic digestion with the relatively short hydraulic retention time (HRT) designed for optimisation of biogas production. Therefore, aerobic composting of

the sludge is recommended to pass the material through temperature cycle of above 60°C–70°C for at least 2 days.

- Although the total system of biomethanation is more cost intensive than the total system of open aerobic composting, biomethanation has certain advantages with respect to much less odour and bird menace. The time frame (cycle time) is also less, so that less land is required for the same capacity. These two can be a big advantage where the only available sites are close to habitation. This way, biomethanation can be compared to in-vessel composting, which is again more expensive than open aerobic composting.

Applicability of Biomethanation

Biomethanation is ideal for wet organic wastes, e.g., cooked food. Biomethanation plants require a consistent source of degradable organic matter, free from inert and toxic material. Slaughter house waste is eminently suitable for biomethanation.

Odour problems are also considerably reduced by adopting biomethanation. If the proposed waste processing site is in close proximity to residential areas, biomethanation is a preferred treatment option, especially considering odour issues.

Anaerobic digestion technology can be adopted in both

— decentralised systems—up to 5 TPD (much smaller quantities can be processed where O&M is not outsourced); and

— centralised systems—in modules of up to 50 TPD digesters (for higher capacity in one digester, the size may become unwieldy and difficult to maintain).

The design of the plant has to be done according to the substrate (feed material) for smooth functioning. The next most important challenge is to make the digester leak-proof. Proper O&M is a critical factor for ensuring the success of the biogas plant which can be achieved through a well-defined standard operating procedure (SOP). Economic viability of the plants is ensured when there is a sustainable and viable market for the generated biogas in the vicinity of the plant and the sludge manure produced during the process.

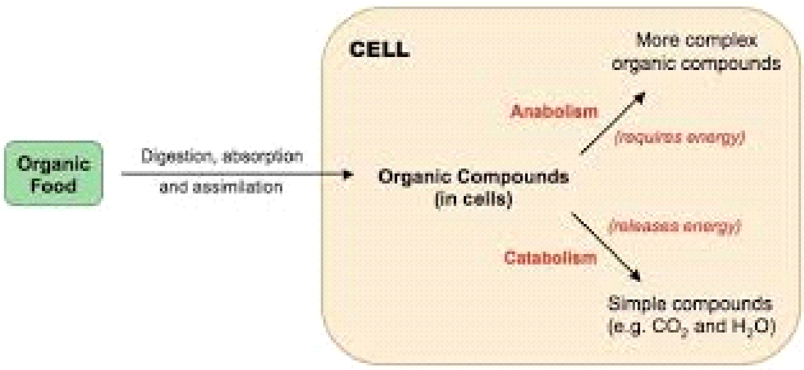

Figure 4.6 Biochemical processes

(Source: https//www.google.com/search?biw=820&bih=456&tbm=isch&sa=1&ei=6SdgXNKoJ9mv9QOCwIrYCg&q)

Composting

Municipal solid waste (MSW) primarily consists of organic, inorganic and inert fractions. Under natural conditions, the organic fraction of waste continually decomposes, accompanied by a strong foul odour and production of gases, which are predominantly methane or CO2 depending on the aerobic condition of the decomposing mass. Vector infestation during the natural decomposition is a common phenomenon. Composting is a process of controlled decomposition of the organic waste, typically in aerobic conditions, resulting in the production of stable humus-like product, i.e., compost. Considering the typical composition of wastes and the climatic conditions, composting is highly relevant in India and should be considered in all municipal solid waste management (MSWM) concepts. Composting of the segregated wet fraction of waste is preferred. Mixed waste composting, with effective and appropriate pre-treatment of feedstock, may be considered as an interim solution; in such cases, stringent monitoring of the compost quality is essential.

Benefits of Composting

- The real economic benefits of compost use include improved soil quality, enhanced water retention capacity of soil, increased biological activity, micronutrient content, and improved pest resistance of crops.
- Composting minimises or avoids GHG emissions from anaerobic decomposition of organic waste (such as in a large unturned heap).
- Composting increases the design life of other waste management facilities.
- Stringent design requirements and associated costs for catering to management of leachate from organic waste decomposition may be reduced in those landfills that do not receive organic waste.
- Compost is particularly useful as organic manure; it contains macronutrients (nitrogen, phosphorous, and potassium) as well as micronutrients. When used in conjunction with chemical fertilisers, optimum results are obtained.
- The use of compost reduces the dependency on chemical fertilisers for agricultural operations. When used as a soil amendment, compost reduces the need for water, fertilisers, and pesticides. Compost acts as a soil conditioner, therefore supporting the long-term fertility of soil.
- Compost may be used to revitalise vegetation habitats and add life to marginal, impoverished soils and waste lands.
- Compost may also be used as a bio matrix in remediation of chemical contaminants and as a remediated soil in contaminated sites; compost helps in binding heavy metals and other contaminants, reducing leachate and bio-absorption.

To do Activity

What Is Biodegradable?

Overview

Students will watch a video that introduces the process of decomposition in a compost bin or pile. They will classify found objects collected on school grounds as biodegradable or nonbiodegradable.

OBJECTIVES

Students will

1. define the differences between things that are biodegradable and nonbiodegradable.
2. identify five materials that are biodegradable and five that are nonbiodegradable.

Teacher Background

Items that we use every day are made from materials that can be classified as biodegradable or nonbiodegradable. Some of these materials such as plastics and metals are considered nonbiodegradable. These materials will not decompose or biodegrade over a short period of time and will often remain intact in the environment for many years. In contrast, biodegradable materials such as food, plant trimmings and paper will decompose under ideal conditions over a relatively short period of time. Composting is a great way to turn biodegradable materials into compost, a rich soil amendment for plants. Air, moisture, and microbial activity in a composting are essential to the process of decomposition. When materials end up in a landfill, they will remain there for many years because of a lack of air, moisture and microbial activity. One easy way to reduce waste is to compost biodegradable materials at home or school. Some cities are even collecting food scraps and other organic materials in curb side bins usually with plant debris or wood. These materials will get composted on a much larger municipal scale.

Materials

Students

Plastic or paper bags(one per group)

"Biodegradable nonbiodegradable" worksheet

Teacher

❑Do the Rot Thing video

❑Examples of biodegradable and nonbiodegradable materials

❑Rubric overhead

❑Rubrics (one per student)

Preparation

Collect plastic or paper bags from home or grocery stores. Organize students into groups of three to four (you will need an even number of groups).

Discussion

1. Ask students to name items that get thrown away at school and at home. Record their suggestions on the board. Explain that some of the items listed on the board are biodegradable (circle these items) such as notebook paper, leaves and food scraps, which means they can easily decay.

2. Pass around some examples of biodegradable items. Ask students whether they can share some examples of items that may not decompose or decay over time. Have students point out nonbiodegradable items on the board and underline them. Pass around some examples of nonbiodegradable items.

3 Ask students whether they use more biodegradable or more nonbiodegradable materials.

4. Have students share their ideas on how to recycle biodegradable materials. Explain that these materials can be recycled through composting.

5. Tell the students that they will learn about biodegradable materials by watching a video of things decomposing overtime in a compost bin and collecting examples of biodegradable and nonbiodegradable materials outside.

6. Show an overhead of the lesson rubric, and review the expectations for this lesson.

Procedure

1. Show the video Do the Rot Thing. Prepare the students to watch the video by assigning them to look for the differences between biodegradable and nonbiodegradable materials.

2. Lead students in a discussion about the video that will provide examples of the differences between biodegradable and nonbiodegradable. Review and define the concepts presented in the video.

3. Organize students into small groups. Assign half of the groups to take bags outdoors and collect items that they think are biodegradable, e.g., leaves, twigs, food scraps, etc. The other half will collect items that they think are nonbiodegradable, e.g., metals, plastics, rocks.

4. Pair up small groups (one biodegradable and one nonbiodegradable), and ask the groups to switch bags and examine the examples collected by the other group. For example, students in a group that collected nonbiodegradable items will examine biodegradable items collected by another group.

5. In groups, students will classify the items as biodegradable (organic materials from once living organisms) and nonbiodegradable (usually from non-living origins, such as metal, rock, etc.). Some items may be moved from one collection into another if there is a group consensus.

6. As a class, discuss examples in each group that were difficult to classify.

7. Ask students how they could test objects to find out whether they are biodegradable. What evidence would they expect to observe that would indicate that the object is biodegradable? For example, what conditions are necessary for things to decompose (air, water, heat, etc.)?

8. Assign students to write a list of at least five items that are biodegradable and five items that are nonbiodegradable.

Wrap-Up

1. Have students compare and contrast the materials shown in the video to the materials collected outside. Discuss similarities and differences.

2. Ask the students whether they think they can find materials that are biodegradable at home. Discuss ways to recycle these materials such as starting a compost bin.

Final Assessment Idea

Have students write a description of the differences between items that are biodegradable versus those that are nonbiodegradable in their own words.

Summary

1. Onsite handling refers to the activities associated with handling of solid waste until they are placed in the containers used for their storage before collection.

2. Combustion is a chemical process or a reaction between Fuel (Hydrocarbon) and Oxygen.

3. A landfill is a large outdoor site specifically designed for the disposal of waste.

4. The basic element of a sanitary landfill is the refuse cell whereas Incineration is a disposal method in which solid organic wastes are subjected to combustion so as to convert them into residue and gaseous products.

5. Bio methanation is the anaerobic (in the absence of free oxygen) fermentation of biodegradable matter in an enclosed space under controlled conditions of temperature, moisture, pH, etc.

Model questions

Q1. What are the rules and regulations guiding waste management in India?

Q2. What are the common methods of waste disposal?

Q3. Discuss the easy and effective ways for individuals to handle waste.

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Chapter 5 Processing and Conversion Technologies of Solid Waste

Introduction

Presently, the society is facing a serious challenge for the effective management of the increasing amount of produced municipal solid wastes. These problems led to serious public concerns, which in turn resulted in political actions aiming to reduce the amount of wastes reaching the environment. These actions aim to promote sustainable waste management solutions. The main objective of these policies is to promote the recycling of municipal solid waste and the conversion of waste to energy and valuable chemicals.

Objectives are:

- To discuss processing of solid waste at residential, commercial and industrial site.
- To explain conversion technologies.
- To highlight the method of recycling of materials found in solid waste.
- To find out organic waste treatment and new technologies.
- To tell the government schemes for power generation from waste in India.

5.1 Processing of solid waste at residential, commercial and industrial site

On site processing is one of the most effective and sustainable ways to achieve resource recovery.

• It reduces hazards and diverts different fractions of material present in the waste stream to locations for appropriate treatment in the solid waste management.

• It reduces the quantity of general waste and minimizes the toxicity of the general waste stream (if hazardous materials are diverted).

• It minimizes the cost of the operation and reduces maintenance problems of biological - treatment and recycling technologies. The

economic viability of most biological treatment options largely depends on separation of waste materials at source.

• Without sorting at source, expensive pre-sorting and final refining

Grinding, sorting, compaction, shredding, composting, and hydropulpery are all onsite processing methods used to

(1) reduce the volume, (2) alter the physical form, or (3) recover usable materials from solid wastes.

Grinding: Home grinders are used primarily for waste from the preparation, cooking, and serving foods, and they cannot be used for large bones or other bulky items. Functionally, grinders render the material that passes through them suitable for transport through the sewer system. However, because the organic material added to sewage has resulted in overloading many treatment facilities, it has been necessary, in some communities, to forbid the installation of grinders in new developments until additional treatment capacity becomes available. In terms of the collection operation, the use of home grinders does not have significant impact on the volume of solid wastes collected. In some cases where grinders are used, it has been possible to increase the time period between collections pickups because wastes that might readily decay are not stored.

Sorting: The sorting or separation of waste materials into newspapers, aluminium cans, and glass and others by hand at the household is one of the most positive ways to achieve the recovery and reuse materials.

Compaction: Within the past few years, a number of small compactors designed for home use have appeared on the market for compaction of loose paper and cardboard. Although it is possible to reduce the original volume of wastes placed in them by up to 70 percent, they can be used only for a small proportion of the wastes actually generated.

Composting: It is an effective way of reducing the volume and altering the physical composition of solid waste while at the same time producing a useful by-product.

Home incineration: Until recently, home incineration, burning combustible materials in fireplaces and burning rubbish in crude backyard incinerators was a common practice. Backyard incineration is now banned in many countries. The design of small outdoor and indoor incinerators has improved. The simplest outdoor incinerator consists of a metal drum with holes punched near the bottom.

The more elaborated units are lined with refractory brick and are equipped with cast-iron grates and small chimneys.

Shredding and Pulping are alternative processing operations that have been used, both in conjunction with the previous methods and by themselves, for reducing the volume of wastes that must be handled. Where shredding is used alone without the addition of water, the volume of wastes has often been observed to increase. Although the system works well and the volume of solid wastes is reduced, it is expensive. Special equipment may be required to remove and empty the full pulp containers. An alternative is to discharge the pulped material to the local sewer. This is often done in small operations where a pulper is used to destroy outdated confidential documents. Because the discharge of pulped material increases the organic loading on local treatment facilities, the use of pulverizes may be restricted if the treatment capacity is limited.

Commercial wastes are those produced from businesses such as food and drink establishments, shops, banks and by public administration offices. These wastes contain similar materials to residential waste, although the proportions may vary. For example, a restaurant will produce more food waste than a normal household and an insurance office will produce more paper and less food waste.

There are also many industrial facilities in Ethiopia that process agricultural products such as cotton, flour, hides and skins. Other important industries include plastic and resin manufacturing, textiles, cement, metallurgical, foods, general chemicals and pharmaceuticals. All these industries manufacture useful products and contribute to the country's economy but, at the same time, they can also be a major contributor to the country's solid waste and pollution problems.

The composition of the waste produced by industry depends very much on the nature of the industry concerned. For example, animal hide processing produces large amounts of biodegradable waste (animal parts), while the construction industry produces a lot of excavated soil, rock and demolition waste (bricks, stones, wood, glass, etc.). For this reason, industrial waste is usually processed and disposed of by the industry itself, often using specialised technologies. These wastes can be classed as either hazardous or nonhazardous depending on the inherent dangers associated with their physical and chemical properties.

Figure 5.1 Processing of solid waste (Source https//en.wikipedia.org/wiki/Waste)

Disposal Methods

Depending upon the characteristics of the wastes, different types of disposal methods can be used for hazardous and non-hazardous industrial wastes. The most predominant and widely practised methods for wastes disposal are

(a) Landfill, (b) Incineration and (c) Composting.

For thousands of years, man has disposed the waste products in a variety of ways, the disposal method might reflect convenience, expedience, expense, or best available technology. There were no major ecological or health hazards associated with these practices until the last century. Explosive increase in the amount of chemical waste produced and the indiscriminate dumping of hazardous industrial waste in the last few decades has created health and ecological crisis in many areas of the world. In many instances, leachate from the wastes dumped by one generation haunts the later generation in the form of ground water and subsoil water contamination. The recent discovery of volatile organic chemicals from landfills and industrial disposal ponds is disturbing because many of these chemicals are known or suspected carcinogens and are not removed easily by natural geochemical processes. The risk of the contamination of groundwater supplies due to leachates from landfills depends on several factors; toxicity and volume of the contaminant generated at each site, the nature of the geologic medium underlying the site, and the hydrologic conditions dominant in the area.

In the past, the least expensive and most widely used waste management option for both municipal and industrial waste has been the sanitary landfill, where wastes are compacted and covered with earth. In any geographic area other than arid zones, the fill is subjected to percolating rainwater or snowmelt which eventually flows out from the bottom of the landfill site and moves into the local groundwater system. Leachate is a liquid that is formed as infiltrating water migrates through the waste material extracting water-soluble compounds and particulate matter. The mass of leachate is directly related to precipitation, assuming the waste lies above the water table. Much of the annual precipitation, including snowmelt is removed by surface run off and evaporation; it is only the remainder that is available to form leachate. Since the landfill covers to a large extent and controls leachate generation, it is exceedingly important that the cover be properly designed, maintained and monitored in order to minimise leachate production. Fortunately, many substances are removed from the leachate as it filters through the unsaturated zones, but leachate may pollute groundwater and even streams. These leachates, can contain large amount of inorganic and organic contaminants. At some sites, the leachate is collected and treated. But even in the best engineered sites, some leachate escapes into the groundwater system because no permanent engineering solution has been found to isolate the leachate completely from the groundwater.

It is now recognised that the interaction between leachate and soil are actually very complex and depend both on the nature of soil and on the leachate. When leachate percolates through solid wastes that are undergoing decomposition, both biological materials and chemical constituents are picked up. Recent research in the United Kingdom (U.K) has, however, shown that chemical and biological phenomena in landfill such as microbiological process; neutralisation; precipitation and complexion; oxidation and reduction; volatilisation; adsorption reduce the quantity and quality of polluting leachate from landfill site and achieve some degree of onsite treatment or immobilisation. In spite of all these, the leachate often pose severe disposal problem at a landfill site. Two of the most economic but efficacious purification methods are spraying over grassland or percolation through an aerobic bed of sand or gravel. In general, it has been found that the quantity of leachate is a direct function of the amount of external water entering the landfill. In fact, if a landfill is constructed properly, the production of measurable quantities of leachate can be eliminated. When sewage sludge is to be added to the solid wastes to increase the amount of methane produced, leachate control facilities must be provided. In some cases leachate treatment facilities may also be required. The pollution of static water ditches, rivers or the sea can occur when a sanitary landfill adjoins a body of water. The normal source of the leachate causing this pollution is rain falling on the surface of the fill, percolating through it, and passing over an impermeable base to water at a lower level. The quantity of leachate can be substantially increased when upland water drains across the site of the landfill, but the worst case is when a stream crosses the site. The solutions to these problems lie in appropriate site engineering such as

(i) Diversion or culverting of all water courses which flow across the site,

(ii) Diversion of upland water by means of drainage ditches along appropriate contours,

(iii)Containment of leachate arising from precipitation by the construction of an impermeable barrier where necessary, such as a clay embankment adjoining a river,

(iv) Grading the final level of the site so that part of precipitation is drained across surface, thereby reducing percolation below the level needed to produce a leachate.

Works of this nature will obviously add to the cost of a sanitary landfill project. However, when capital expenditure is spread over the life of the project, the cost/ton of waste disposed might be less than for any alternative method of disposal.

Furthermore, some of these forms of expenditure, such as culverts or river walls, represent capital assets of continuing value when the reclaimed land is handed over for its final use, perhaps for agriculture or recreation. Incineration of hazardous industrial waste has been advocated in developed countries. Guidelines for safe incineration of hazardous chemical waste have been drawn up by United States Environmental Protection Agency. Incineration of hazardous waste is a process requiring sophisticated expensive incinerators and a high degree of technological expertise for satisfactory operation. The capital cost of incinerator is high, especially if it is intended for hazardous wastes and gas scrubbing equipment is required. Some wastes such as oils and organic solvents can be readily treated by incineration. If financial constraints come in the way of purchasing sophisticated incinerators then the utilisation of open pit incinerator under careful technical supervision can be considered as an option.

5.2 **Biological and chemical conversion technologies**

Conversion technologies are an array of emerging technologies capable of converting post-recycling residual solid waste into useful products and chemicals, green fuels like ethanol and biodiesal and clean renewable energy.

Sample Conversion Technologies

Thermal

Pyrolysis is the thermal processing of waste in the absence of oxygen.

Gasification is the thermal processing of waste with a limited amount of oxygen using some combination of heat, pressure and steam to convert materials directly into a gas.

Chemical

Acid Hydrolysis is the chemical decomposition of waste using acid and water to split chemical bonds.

Biological

- Anaerobic digestion is the bacterial breakdown of organic materials in the absence of oxygen.
- Aerobic digestion is essentially composting.
- Bioenergy conversion technologies-
- Direct combustion processes.
- Thermochemical processes.

- Biochemical processes.

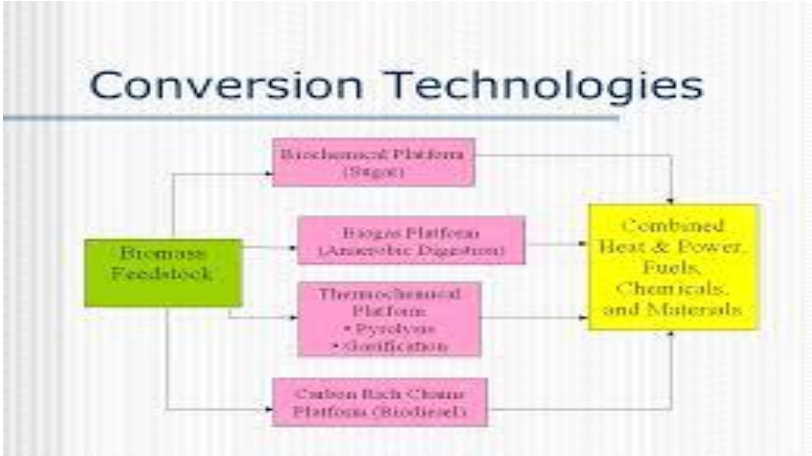

Figure 5.2- Conversion technologies (Source https//slideplayer.com/slide/5755243)

There are five fundamental forms of biomass energy use.

(1) The "traditional domestic" use in developing countries (fuelwood, charcoal and agricultural residues) for household cooking (e.g. the "three stone fire"), lighting and space-heating. In this role- the efficiency of conversion of the biomass to useful energy generally lies between 5% and 15%.

(2) the "traditional industrial" use of biomass for the processing of tobacco, tea, pig iron, bricks & tiles, etc, where the biomass feedstock is often regarded as a "free" energy source. There is generally little incentive to use the biomass efficiently so conversion of the feedstock to useful energy commonly occurs at an efficiency of 15% or less.

(3) "Modern industrial." Industries are experimenting with technologically advanced thermal conversion technologies which are itemised below. Expected conversion efficiencies are between 30 and 55%.

(4) Newer "chemical conversion" technologies ("fuel cell") which are capable of by-passing the entropy-dictated Carnot limit which describes the maximum theoretical conversion efficiencies of thermal units.

(5) "Biological conversion" techniques, including anaerobic digestion for biogas production and fermentation for alcohol.

In general, biomass-to-energy conversion technologies have to deal with a feedstock which can be highly variable in mass and energy density, size, moisture content, and intermittent supply. Therefore, modern industrial technologies are often hybrid fossil-fuel/biomass technologies which use the fossil fuel for drying, preheating and maintaining fuel supply when the biomass supply is interrupted.

Direct combustion processes

Co-firing-

Feedstocks used are often residues such as woodchips, sawdust, bark, hogfuel, black liquor, bagasse, straw, municipal solid waste (MSW), and wastes from the food industry.

Direct combustion furnaces can be divided into two broad categories and are used for producing either direct heat or steam. Dutch ovens, spreader-stoker and fuel cell furnaces employ two-stages. The first stage is for drying and possible partial gasification, and the second for complete combustion. More advanced versions of these systems use rotating or vibrating grates to facilitate ash removal, with some requiring water cooling.

The second group, include suspension and fluidised bed furnaces which are generally used with fine particle biomass feedstocks and liquids. In suspension furnaces the particles are burnt whilst being kept in suspension by the injection of turbulent preheated air which may already have the biomass particles mixed in it. In fluidised bed combustors, a boiling bed of pre-heated sand (at temperatures of 500 to 900°C) provides the combustion medium, into which the biomass fuel is either dropped (if it is dense enough to sink into the boiling sand) or injected if particulate or fluid. These systems obviate the need for grates, but require methods of preheating the air or sand, and may require water cooled injection systems for less bulky biomass feedstocks and liquids.

A modern practice which has allowed biomass feed stocks an early and cheap entry point into the energy market is the practice of co-firing a fossil-fuel (usually coal) with a biomass feedstock. Co-firing has a number of advantages, especially where electricity production is an output.

Firstly, where the conversion facility is situated near an agro-industrial or forestry product processing plant, large quantities of low cost biomass residues are available. These residues can represent a low cost fuel feedstock although there may be other opportunity costs.

Secondly, it is now widely accepted that fossil-fuel power plants are usually highly polluting in terms of sulphur, CO2 and other GHGs. Using the existing equipment, perhaps with some modifications, and co-firing with biomass may represent a cost-effective means for meeting more stringent emissions targets. Biomass fuel's low sulphur and nitrogen (relative to coal) content and nearly zero net CO2 emission levels allows biomass to offset the higher sulphur and carbon contents of the fossil fuel.

Thirdly, if an agro-industrial or forestry processing plant wishes to make more efficient use of the residues generated by co-producing electricity, but has a highly seasonal component to its operating schedule, co-firing with a fossil fuel may allow the economic generation of electricity all year round. Agro-industrial processors such as the sugarcane sugar industry can produce large amounts of electricity during the harvesting and processing season, however, during the off-season the plant will remain idle. This has two drawbacks, firstly, it is an inefficient use of equipment which has a limited life-time, and secondly, electrical distribution utilities will not pay the full premium for electrical supplies which can't be relied on for year round production. In other words the distribution utility needs to guarantee year round supply and may therefore, have to invest in its own production capacity to cover the off-season gap in supply with associated costs in equipment and fuel. If however, the agro-processor can guarantee electrical supply year-round through the burning of alternative fuel supplies then it will make efficient use of its equipment and will receive premium payments for its electricity by the distribution facility.{GEF, 1992}

Thermo chemical processes-

- Pyrolysis
- Carbonisation
- Gasification
- Catalytic Liquefaction

These processes do not necessarily produce useful energy directly, but under controlled temperature and oxygen conditions are used to convert the original biomass feedstock into more convenient forms of energy carriers, such as producer gas, oils or methanol. These carriers are either more energy dense and therefore reduce transport costs, or have more predictable and convenient combustion characteristics allowing them to be used in internal combustion engines and gas turbines.

Pyrolysis

The biomass feedstock is subjected to high temperatures at low oxygen levels, thus inhibiting complete combustion, and may be carried out under pressure. Biomass is degraded to single carbon molecules (CH_4 and CO) and H_2 producing a gaseous mixture called "producer gas." Carbon dioxide may be produced as well, but under the pyrolytic conditions of the reactor it is reduced back to CO and H_2O; this water further aids the reaction. Liquid phase products result from temperatures which are too low to crack all the long chain carbon molecules so resulting in the production of tars, oils, methanol, acetone, etc. Once all the volatiles have been driven off, the residual biomass is in the form of char which is virtually pure carbon.

Pyrolysis has received attention recently for the production of liquid fuels from cellulosic feedstocks by "fast" and "flash" pyrolysis in which the biomass has a short residence time in the reactor. A more detailed understanding of the physical and chemical properties governing the pyrolytic reactions has allowed the optimisation of reactor conditions necessary for these types of pyrolysis. Further work is now concentrating on the use of high pressure reactor conditions to produce hydrogen and on low pressure catalytic techniques (requiring zeolites) for alcohol production from the pyrolytic oil.

Carbonisation

This is an age-old pyrolytic process optimised for the production of charcoal. Traditional methods of charcoal production have centred on the use of earth mounds or covered pits into which the wood is piled. Control of the reaction conditions is often crude and relies heavily on experience. The conversion efficiency using these traditional techniques is believed to be very low; on a weight basis Openshaw estimates that the wood to charcoal conversion rate for such techniques ranges from 6 to 12 tonnes of wood per tonne of charcoal. {Openshaw, 1980}.

During carbonisation most of the volatile components of the wood are eliminated; this process is also called "dry wood distillation." Carbon accumulates mainly due to a reduction in the levels of hydrogen and oxygen in the wood.

The wood undergoes a number of physico-chemical changes as the temperature rises. Between 100 and 170°C most of the water is evaporated; between 170°C and 270°C gases develop containing condensible vapours, CO and CO2. These condensible vapours (long chain carbon molecules) form pyrolysis oil, which can then be used for the production of chemicals or as a fuel after cooling and scrubbing. Between 270°C and 280°C an exothermic reaction develops which can be detected by the spontaneous generation of heat.

The modernisation of charcoal production has lead to large increases in production efficiencies with large-scale industrial production in Brazil now achieving efficiencies of over 30% (by weight).

There are three basic types of charcoal-making

a) Internally heated (by controlled combustion of the raw material),

b) externally heated (using fuelwood or fossil fuels), and

c) hot circulating gas (retort or converter gas, used for the production of chemicals).

Internally heated charcoal kilns are the most common form of charcoal kiln. It is estimated that 10 to 20% of the wood (by weight) is sacrificed, a further 60% (by weight) is lost through the conversion to, and release of, gases to the atmosphere from these kilns. Externally heated reactors allow oxygen to be completely excluded, and thus provide better quality charcoal on a larger scale. They do, however, require the use of an external fuel source, which may be provided from the "producer gas" once pyrolysis is initiated.

Recirculating heated gas systems offer the potential to generate large quantities of charcoal and associated by-products, but are presently limited by high investment costs for large scale plant.

Gasification.

High temperatures and a controlled environment lead to virtually all the raw material being converted to gas. This takes place in two stages. In the first stage, the biomass is partially combusted to form producer gas and charcoal. In the second stage, the C02 and H2O produced in the first stage is chemically reduced by the charcoal, forming CO and H2. The composition of the gas is 18 to 20% H2, an equal portion of CO, 2 to 3% CH4, 8 to 10% CO2, and the rest nitrogen. These stages are spatially separated in the gasifier, with gasifier design very much dependant on the feedstock characteristics.

Gasification requires temperatures of about 800°C and is carried out in closed top or open top gasifiers. These gasifiers can be operated at atmospheric pressure or higher. The energy density of the gas is generally less than 5.6 MJ/m3, which is low in comparison to natural gas at 38 MJ/m3, providing only 60% the power rating of diesel when used in a modified diesel engine.

Gasification technology has existed since the turn of the century when coal was extensively gasified in the UK and elsewhere for use in power generation and in houses for cooking and lighting.

Gasifiers were used extensively for transport in Europe during World War II due to shortages of oil, with a closed top design predominating.

A major future role is envisaged for electricity production from biomass plantations and agricultural residues using large scale gasifiers with direct coupling to gas turbines. The potential gains in efficiency using such hybrid gasifier/gas turbine systems make them extremely attractive for electricity generation once commercial viability has been demonstrated. Such systems take advantage of low grade and cheap feedstocks (residues and wood produced using short rotation techniques) and the high efficiencies of modern gas turbines to produce electricity at comparable or less cost than fossil-fuel derived electricity. Net atmospheric CO2 emissions are avoided if growth of the biomass is managed to match consumption. The use of BIG/STIG (Biomass Integrated Gasifier Steam Injected Gas turbine) initially and BIG/GTCC (Biomass integrated Gasifier Gas Turbine Combined Cycle) as the technology matures, is predicted to allow energy conversion efficiencies of 40% to 55%. Modern coal electrical plants have efficiencies of about 35% or less. Combined Heat and Power systems could eventually provide energy at efficiencies of between 50% to 80%. The use of low-grade feedstocks combined with high conversion efficiencies makes these systems economically competitive with cheap coal-based plants and energetically competitive with natural gas-based plants.

Studies are continuing in the use of such technologies for the cost effective treatment of MSW e.g. in the Netherlands a study by Faaij et al. {1992} considers that "gasification can become a strong competitor to anaerobic digestion, composting and incineration for biomass waste treatment." This is based on the use of BIG/STIG technology with the system gasification using Atmospheric Circulating Fluidized Bed (ACFB) technology. They expect the potential to be "realised within 4 to 7 years". {Faaij et al., 1992}

Catalytic Liquefaction

This technology has the potential to produce higher quality products of greater energy density. These products should also require less processing to produce marketable products.

Catalytic liquefaction is a low temperature, high pressure thermochemical conversion process carried out in the liquid phase. It requires either a catalyst or a high hydrogen partial pressure. Technical problems have so far limited the opportunities of this technology.

Biochemical processes-

- Anaerobic Fermentation
- Methane Production in Landfills
- Ethanol Fermentation

Biodiesel

The use of micro-organisms for the production of ethanol is an ancient art. However, in more recent times such organisms have become regarded as biochemical "factories" for the treatment and conversion of most forms of human generated organic waste. Microbial engineering has encouraged the use of fermentation technologies (aerobic and anaerobic) for use in the production of energy (biogas) and fertiliser, and for the use in the removal of unwanted products from water and waste streams.

Anaerobic Fermentation

Anaerobic reactors are generally used for the production of methane rich biogas from manure (human and animal) and crop residues. They utilise mixed methanogenic bacterial cultures which are characterised by defined optimal temperature ranges for growth. These mixed cultures allow digesters to be operated over a wide temperature range i.e. above 0°C up to 60°C.

When functioning well, the bacteria convert about 90% of the feedstock energy content into biogas (containing about 55% methane), which is a readily useable energy source for cooking and lighting. The sludge produced after the manure has passed through the digester is non-toxic and odourless. Also, it has lost relatively little of its nitrogen or other nutrients during the digestion process thus, making a good fertiliser. In fact, compared to cattle manure left to dry in the field the digester sludge has a higher nitrogen content; many of the nitrogen compounds in fresh manure become volatised whilst drying in the sun. On the other hand, in the digested sludge little of the nitrogen is volatised, and some of the nitrogen is converted into urea. Urea is more readily accessible by plants than many of the nitrogen compounds found in dung, and thus the fertiliser value of the sludge may actually be higher than that of fresh dung.

Anaerobic digesters of various types were widely distributed throughout India and China. Extension programmes promote biogas plants as ideal candidates for rural village use due to their energy and fertiliser production potential along with their improved health benefits. Health benefits primarily arise from the cleaner combustion products of biogas as opposed to other biomass or fossil fuels which may be used in the domestic environment, these two countries now have an estimated 5 to 6 million units in use.

Reliability problems have arisen from a number of problems i.e. construction defects, the mixed nature of the bacterial population, the digesters requirements for water and the maintenance of the optimum nitrogen ratio of the medium. Another problem is the digester's demand for dung, which may have alternative uses.

Modern designs have answered many of these problems and digesters are again becoming useful, especially with regard to the potential of digesters to remove toxic nutrients such as nitrates from water supplies; levels of which are now much more stringently controlled in many industrialised countries. The combination of energy production with the ability to enhance crop yields makes biogas technology a good candidate for more widespread use now that reliable operation can be demonstrated. Recent Danish commercial experience with large scale digesters provides a useful example.

Methane Production in Landfills

Anaerobic digestion in landfills is brought about by the microbial decomposition of the organic matter in refuse. The levels of organic matter produced per capita vary considerably from developed to developing countries e.g. the percentage of Municipal Solid Waste (MSW) which is putrescible in Sierra Leone is about 90% {Steele, 1992}, compared to about 60% for US MSW. The reduced levels of putrescibles in US MSW are a result of the increased proportions of plastics, metals and glass, mostly from packaging {Slivka et al., 1992}. Landfill-generated gas is on average half methane and half carbon dioxide with an energy content of 18 to 19 MJ/m3. Its production does not occur under pressure, and thus recovery processes must be active.

Commercial production of land-gas can also aid with the leaching problems now increasingly associated with landfill sites. Local communities neighbouring land fill sites are becoming more aware of the potential for heavy metals and nutrients to leach into aquifers. Landfill processing reduces the volume of sludge to be disposed of, and the nutrient content, thus facilitating proper disposal.

Methane is a powerful greenhouse gas, with substantial amounts being derived from unutilized methane production from landfill sites. Its recovery therefore, not only results in the stabilisation of the landfill site, allowing faster reuse of the land, but also serves to lessen the impact of biospheric methane emissions on global warming.

Ethanol Fermentation

Ethanol is mainly used as a substitute for imported oil in order to reduce their dependence on imported energy supplies. The substantial gains made in fermentation technologies now make the production of ethanol for use as a petroleum substitute and fuel enhancer, both economically competitive (given certain assumptions) and environmentally beneficial. For example, subsidies for alcohol production in Brazil are now becoming regarded as detrimental to the stability of the ethanol market, and thus obsolete. In Zimbabwe, foreign exchange savings are seen as a major bonus, which along with the employment and environmental benefits have made the long term future and expansion of the this programme a priority for the Zimbabwean government.

The most commonly used feedstock in developing countries is sugarcane, due to its high productivity when supplied with sufficient water. Where water availability is limited, sweet sorghum or cassava may become the preferred feedstocks. Other advantages of sugarcane feedstock include the high residue energy potential and modern management practices which make sustainable and environmentally benign production possible whilst at the same time allowing continued production of sugar. Other feedstocks include saccharide-rich sugarbeet, and carbohydrate rich potatoes, wheat and maize.

One of the most promising fermentation technologies to be identified recently is the "Biostil" process which uses centrifugal yeast reclamation, and continuous evaporative removal of the ethanol. This allows the fermentation medium to be continuously sterilised and minimises water use. The Biostil process markedly lowers the production of stillage, whilst the non-stop nature of the fermentation process allows substrate concentrations to be constantly kept at optimal levels and therefore fermentation efficiency is maximised. Improved varieties of yeast, produced through clonal selection techniques have also raised the tolerance levels of the yeast to alcohol concentrations, again improving efficiency.

Recent advances in the use of cellulosic feedstock, may allow the competitive production of alcohol from woody agricultural residues and trees to become economically competitive in the medium term. Since 1982, prices have fallen from about US$ 45 per GJ (95 c/l) to about US$ 13 per GJ (28 c/l) for ethanol, and for methanol, projected prices have been reduced from US$ 16 per GJ (27 c/l) to

$15 per GJ (25 c/l) and could fall to prices competitive with gasoline produced from oil priced at US$ 25 per barrel.

Biodiesel

The use of vegetable oils for combustion in diesel engines has occurred for over 100 years. In fact, Rudolf Diesel tested his first prototype on vegetable oils, which can be used, "raw", in an emergency. Whilst it is feasible to run diesel engines on raw vegetable oils, in general the oils must first be chemically transformed to resemble petroleum-based diesel more closely.

The raw oil can be obtained from a variety of annual and perennial plant species. Perennials include, oil palms, coconut palms, physica nut and Chinese Tallow Tree. Annuals include, sunflower, groundnut, soybean and rapeseed. Many of these plants can produce high yields of oil, with positive energy and carbon balances.

Transformation of the raw oil is necessary to avoid problems associated with variations in feedstock. The oil can undergo thermal or catalytic cracking, Kolbe electrolysis, or transesterification processes in order to obtain better characteristics. Untreated oil causes problems through incomplete combustion, resulting in the build up of sooty residues, waxes, gums etc. Also, incorrect viscosities can result in poor atomization of the oil also resulting in poor combustion. Oil polymerisation can lead to deposition on the cylinder walls.

Generally, the chemical processing required to avoid these problems is simple, and in the case of soyabean oil may be carried out in existing petroleum refineries. The use of diesel powered vehicles is widespread throughout agriculture, and biodiesel provides an environmentally friendly, CO2-neutral alternative. It is now being widely promoted in the EC and elsewhere, as its use does not require major modification to existing diesel engines.

A bio-chemical conversion system for lignocellulosic biomass will generally consist of a pretreatment step to release the C6 and C5 sugars followed by conversion of the polysaccharides into products like fuels or chemicals. Second-generation cellulosic ethanol production is the best known example.

Fundamental biomass characteristics that influence the potential success of biochemical conversion of lignocellulose biomass into fuels and chemicals are:

Lignin content: Lignin can hardly be degraded by enzymes and microorganisms. Secondly, it acts as a shield that prohibits the bioconversion of cellulose and hemicellulose. The higher the lignin content, the more difficult it is to use lignocellulose as feedstock in biochemical conversion processes. Lignin is also associated with formation of antiquality compounds or inhibitors, such as polyphenols. These may hinder downstream fermentation processes.

High carbohydrate content: The main components of interest in biochemical conversion of (lignocellulosic) biomass are cellulose and hemicellulose, which are carbohydrate polymers consisting of sugar polymers. High cellulose and hemicellulose content will make biomass more suitable for biochemical conversion.

Low ash content: As with the other two conversion methods, ash or inorganic material cannot be converted within biochemical processes and generally adds to the costs of conversion.

Protein: This may also be relevant from another point of view. Protein could be extracted and valorized so a higher content could be desirable if the protein can be removed.

In biochemical conversion, biomass molecules are broken down into smaller molecules by bacteria or enzymes. This process is much slower than thermochemical conversion, but does not require much external energy. The three principal routes for biochemical conversion are

•Digestion (anaerobic and aerobic)
•Fermentation
•Enzymatic or acid hydrolysis

The main products of anaerobic digestion are methane and carbon dioxide in addition to a solid residue. Bacteria access oxygen from the biomass itself instead of from ambient air. Aerobic digestion, or composting, is also a biochemical breakdown of biomass, except that it takes place in the presence of oxygen. It uses different types of microorganisms that access oxygen from the air, producing carbon dioxide, heat and a solid digestate.

In fermentation, part of the biomass is converted into sugars using acid or enzymes. The sugar is then converted into ethanol or other chemicals with the help of yeasts. The lignin is not converted and is left either for combustion or for thermochemical conversion into chemicals. Unlike in anaerobic digestion, the product of fermentation is liquid.

Fermentation of starch and sugar-based feedstock (i.e., corn and sugarcane) into ethanol is fully commercial, but this is not the case with cellulosic biomass because of the expense and difficulty in breaking down (hydrolyzing) the materials into fermentable sugars. Ligno-cellulosic feedstock, like wood, requires hydrolysis pre-treatment (acid, enzymatic, or hydrothermal) to break down the cellulose and hemicellulose into simple sugars needed by the yeast and bacteria for the fermentation process. Acid hydrolysis technology is more mature than enzymatic hydrolysis technology, though the latter could have a significant cost advantage.

Biomass biochemical conversion technologies refer to the conversion of biomass into corresponding products through certain physical, chemical, and biological pre-treatments. Pre-treatments in the biochemical conversion technologies of biomass aim to help reach ideal conversion effects, not to produce final products, which is the essential difference between the aforementioned physical and chemical conversion of biomass. In addition, biochemical conversion technologies of biomass are more moderate than the other two.

Biomass can be turned into different products, such as hydrogen, biogas, ethanol, acetone, butanol, organic acids (pyruvate, lactate, oxalic acid, levulinic acid, citric acid), 2,3-butanediol, 1,4-butanediol, isobutanol, xylitol, mannitol, and xanthan gum by selecting different microorganisms in the process of biochemical conversion (Chen, 2010). On the one hand, such products can synthetize replacements of petroleum-based products. On the other hand, the products can replace products derived from grains, such as ethanol.

Compared with other conversion technologies, biomass biochemical conversion technologies are moderate, pure, clean, and efficient. Moreover, biomass can be turned into various intermediates by screening different enzymes or microorganisms through biochemical conversion technologies, thus providing many platform substances for the conversion of renewable materials, fuels, and chemicals. As a result, people pay much attention to biochemical conversion technologies of biomass.

Advantages and limitations of techniques

Biochemical conversion pathways and the enzyme catalysts that enable their success have significant advantages. Biotechnology is a relatively new toolkit, and innovations are being rapidly developed. Exemplary areas include synthetic biology, as well as the genomics realm. Genetic manipulation of organisms for industrial purposes has a long history, but engineers have recently pushed the ease of manipulating microbial genomes with the aim of synthesizing entirely new biological organisms. Biofuel and bioproduct synthesis has been a popular ‘test bed’ for emerging tools of synthetic biology. In the area of genomics and bioinformatics, available microbial sequence information that drives discovery of novel biocatalysts has exploded, driven by dramatic reduction in DNA sequencing costs. With the ability to sequence DNA from uncultured organisms, a vast unexplored territory of microbe diversity is accessed. While techno-economic modelling by NREL currently predicts that the MESP for ethanol produced by biochemical conversion and by thermo chemical conversion are quite similar (Foust et al., 2009), thermo chemical approaches utilize relatively more mature technologies, and arguably may demonstrate with slower rates of progress relative to the ‘younger’ field of biotechnology.

A limitation associated with use of biochemical catalysts for biomass conversion is their intrinsic stability. While the use of biological agents as catalysts for converting recalcitrant lignocellulose to sugars is attractive from a capital cost viewpoint due to their compatibility with mild reaction conditions, this also means that care must be taken to maintain appropriate conditions such as temperature and pH during hydrolysis. Since processes cannot be undertaken under sterile conditions, industrial-scale reactions must utilize enzymes and organisms that are robust enough to withstand contamination by naturally occurring organisms.

Environmental Benefits

Conversion technologies have a number of environmental benefits.

Conversion technologies often incorporate pre-processing subsystems to produce a more homogeneous feedstock. This provides the opportunity to recover chlorine-containing plastic (as a recyclable), which could otherwise contribute to the formation of organic compounds or trace contaminants.

Syngas produced by thermal conversion technologies is a much more homogeneous and cleaner burning fuel than MSW.

Conversion technology processes occur in a reducing environment, so that formation of unwanted organic compounds or trace contaminants is precluded or minimized.

Conversion technologies are closed pressurized systems such that there are no direct air emission points. Contaminants are removed from the syngas and/or from the flue gases before being exhausted from a stack.

The volume of syngas produced in the conversion of the feedstock is considerably lower than the volume of flue gases formed by WTE facilities. Smaller gas volumes are easier and less costly to treat.

Pre-cleaning of syngas is possible, thus reducing the potential for corrosion in power generation equipment and reducing overall air emissions. Sulphur compounds can be removed by commercially available equipment and recovered as marketable sulphur or gypsum.

Syngas produced by thermal conversion technologies is a much more homogeneous and cleaner-burning fuel than MSW.

Methane emissions from landfills are significant even with energy recovery.

Using a conversion technology to convert the carbon content of the MSW to combustible syngas, instead of allowing it to degrade in a landfill to methane, eliminates this environmental impact.

The inert, glassy slag recovered from high-temperature gasification is similar to that produced from steel mills and coal-fired power plants. It can be used for making roofing tiles and as sandblasting grit or asphalt filler.

Renewable energy and fuels

In creating electricity and useful by-products, conversion technologies typically reduce the amount of MSW by more than 95%.

The use of MSW for power generation results in significant savings in the use of fossil fuels and their associated life-cycle impacts from the mining and transportation of the fuels.

Conversion technologies typically reduce the amount of MSW by more than 95%. Another advantage of conversion technologies is the production of renewable energy. MSW is often classified as a renewable fuel under state Renewable Portfolio Standards (RPS) programmes in the US. "Green power" from MSW and other renewable sources commands a premium price in some states.

Another option with syngas produced using a conversion technology is its further processing to produce methanol (a feedstock for many chemical processes) or ethanol (a valuable transportation fuel).

Barriers to the implementation of conversion technologies

Despite the success of conversion technologies in Europe and Japan, no MSW facilities have yet been constructed at a commercial scale in North America none of these lengthy procurement processes have ended with a "buy decision.

Examples of barriers that appear to restrain further development of conversion technologies include

Lack of regulations needed for permits

- Financial risk
- Technical risk
- Economics

Reluctance of cities and counties to take on environmental groups or to commit to the public education required for successful sitting and permitting.

Some of these barriers have precluded demonstration scale projects from going forward when economics was not even a primary consideration. This makes it more difficult to move these promising technologies from small scale to commercial scale, where costs will be much more competitive. With the exception of the decision by the City of Edmonton in Canada to continue with its MSW gasification demonstration scale project, there is still a lot of looking but no buying going on. This has been very frustrating and costly for conversion technology suppliers.

As cities and counties progress their evaluations and continue to face both increasing costs from landfills and increasing pressure to make wiser MSW management choices, removal of the regulatory and economic barriers is expected, allowing implementation of conversion technologies to proceed.

5.3 Recycling of materials found in solid waste

Recycling is processing used materials (waste) into new, useful products. This is done to reduce the use of raw materials that would have been used. Recycling also uses less energy and great way of controlling air, water and land pollution.

Recycling includes the collection, sorting, marketing, and processing, of materials removed from the solid waste stream, and the transformation or remanufacture of those materials for use as feedstock for new products and/or other productive uses. Successful recycling includes an examination of the solid waste stream to determine what is recyclable and marketable. Recycling efforts can be implemented in the residential, commercial and industrial sectors.

Municipal solid waste (MSW) is comprised of a number of solid waste streams. The three principal solid waste streams that compose MSW are

• Residential solid waste: Solid waste generated from single-family residences, and multifamily residences. Recyclables prevalent in the residential waste stream include paper, plastics, metals, food scraps, yard trimmings, textiles and personal electronics.

• Commercial solid waste: Solid waste generated from businesses, offices, stores, markets, institutions, government, and other commercial establishments. Recyclables common in the commercial waste stream include paper, plastic, metals, food, yard trimmings, lumber, textiles, and electronic devices.

• Industrial solid waste: Solid waste generated from non-process lines, shipping, plant offices; solid wastes not regulated under the Clean Water Act, Clean Air Act, and Subtitle C of the Resource Conservation and Recovery Act; Other solid waste streams that may also be a part of MSW include

• Bio-medical wastes treated waste, where allowed, generated from hospitals and other acute care facilities, health research institutions and homes that result from the use and administration of medications, surgery or other medical procedures, or medical or health research and development.

• Bio solids typically waste generated from the de-watering of municipally generated wastewater.

• Construction and demolition debris materials resulting from the construction and demolition (C&D) of buildings and other structures, including materials such as metals, wood, gypsum, asphalt shingles, roofing, concrete, rocks, rubble, soil, paper, plastics and glass, but excluding putrescible wastes. C&D components can be a significant portion of the MSW stream with a high potential for recycling. Non-recyclable C&D wastes may be disposed in municipal solid waste landfills or specially designated landfills, or if cleaned of unacceptable debris, used for land reclamation.

- Other : there are a host of other separately managed solid wastes that may be a part of MSW such as tires, street sweepings, storm catchment wastes, automotive shredding fluff, carpet, white goods, furniture and mattresses. Recycling material from the waste stream can be encouraged through several approaches, including
- Ordinances/legislation/mandatory programs
- Voluntary programs at businesses or institutions
- Reward or incentive based programs
- Recyclables can be collected through a variety of approaches, including
- Curb side collection of commingled recyclables (single-stream collection)
- Curb side collection of source separated recyclables
- Curb side collection of mixed MSW
- Drop-off and buy-back programs
- Deposit ordinances and legislation
- Commercial and industrial collections specific to the participating generator.

It is not sufficient to just encourage recycling and collect recyclable materials. The efficacy of these programs is dependent on a number of factors, including location, demographics, and availability of processing capacity and markets.

Figure 5.3 Recycling of solid waste (Source http//www.oswegocounty.com/dsw/recycle.html)

Discussion of recycling opportunities

Municipal solid waste is a complex mixture of many materials discarded by every individual, business, government, and industry in North America. This section reviews these material segments from the standpoint of the potential for local government to effectively implement recycling programs.

A. **Paper**

Paper, which is found in everything from packaging to mail to office supplies, makes up the largest percentage of the municipal solid waste stream. It is also one of the most recovered materials, as recycling opportunities are often readily available. Opportunities to recycle may be reduced if the paper products are contaminated by such constituents as wax and adhesives, but recyclers are increasingly finding ways to overcome these obstacles.

1. Packaging : Paper packaging (paperboard), such as cereal and pasta boxes, is often itself made from recycled paper stock

2. Cardboard : Corrugated cardboard boxes make up the largest percentage of shipping boxes. When disposed of, this material is called Old Corrugated Cardboard (OCC) and has a long-established niche in the recycled paper market. OCC has a strong recycling market domestically and abroad, and is often compacted in bailers to reduce the volume of shipping.

3. Newsprint and Magazines : Newsprint and magazines can be effectively taken out of the municipal solid waste stream through curbside collection or drop-off centers. Old newsprint is recycled by de-inking mills. Markets for recycled magazines and other coated papers can be limited.

4. Office Paper: High-grade de-inking grades such as office papers are utilized to produce tissue products such as paper towels, toilet paper, and facial tissue.

5. Mixed Paper : Mixed paper is a large portion of the municipal solid waste stream. The potential for recycling this material can be hampered by contaminants such as coated paper stock, pressure sensitive labels, metal foils, and organic materials. Limiting or eliminating the presence of such contaminants could improve the recyclability of these papers. Utilization of this material as a feedstock for composting or as a fuel in a waste-to energy facility should be considered.

B. **Containers**

1. Ferrous Metal : Food cans are a major source of ferrous metal in the municipal solid waste stream. The market for scrap ferrous is stable, and recovery of ferrous from collected recyclables is relatively simple because of its magnetic characteristics. Scrap metal processors play an integral role in the processing and aggregation of scrap metal.

2. Aluminium : Aluminium beverage containers constitute the major portion of aluminium in the municipal solid waste stream. The recovery market is strong. Public education and cooperative efforts, including some state-wide bottle/can deposit programs, during the past 20 to 30 years have proven effective at recovering aluminium.

3. Glass : Glass containers come in two versions – refillable and non-refillable – and many colours (clear, green, brown, blue), which affects the marketability of recovered product.

The dominant share of the market is non-refillable food and beverage containers. Markets for glass containers are well-established but, recovered glass must meet strict industry specifications for quality, including sorting by colour. Material recovery facilities (MRFs) can separate and process recovered glass containers, turning it into a glass cullet. Source separating glass by colour before it reaches the MRF can also improve the quality and marketability of the cullet. Markets for glass are more limited in rural areas, where transportation costs can render recycling cost prohibitive

4. Plastic : Plastic containers continue to gain an increasing share of the consumer packaging market. Most plastic products carry a code indicating what type of plastic resin(s) are used in the product, thus facilitating separation and recycling of single-resin plastic products. However, some plastic containers, (such as squeezable bottles and flexible pouches), may be a mix of several plastic resins, which complicates their recyclability. The plastics industry is working to develop an infrastructure to make recycling of more complex plastic containers a viable option.

5. Composite Packaging : Composite packaging, a combination of different types of packing materials, is frequently utilized for beverages and select foodstuffs. This packaging group includes plastic coated paper milk containers and paper/plastic/foil "aseptic" packs for juice and sauces. Composite packaging is difficult to recycle, though processing approaches are under development.

C. **Food Scraps**

Commercial food scraps along with yard trimmings, represent the most easily separated organic wastes in the municipal solid waste stream. The major sources of commercial food scraps are food service establishments, grocery and super stores and the warehouse/distribution industry.

Many local governments are increasingly seeking ways to implement separate collection systems for these commercial, large-scale food scraps, while also evaluating the addition of household food scraps to curb side organics collection programs. This would allow the capture of these materials for composting or anaerobic digestion.

D. **Vegetative Wastes**

Vegetative wastes include, yard wastes, street sweeping waste, lawn service wastes, nursery wastes and other similar organics. Soiled paper waste may also be added to this category. There are several ways to recycle or reuse vegetative wastes including mulching; on-site composting by generators (e.g. residences, nurseries, or horticulture activities); through organized collection systems with centralized composting or anaerobic digestion operations.

Residential or "backyard" composting can complement large scale composting or anaerobic digestion.

E. **Non-food/beverage container glass**

Small quantities of glass, such as broken dishes or window panes, and ceramics are present in the solid waste stream, but the chemistry of this glass is not compatible with container glass. This type of mixed glass can be crushed and used in insulation or "glassphalt", (which is road asphalt that includes a percentage of recycled glass). State and federal regulations play a role in the marketability of recovered material for these uses.

F. **Household Hazardous Wastes (HHW) /Paints/Pesticides/Unregulated Hazardous Wastes**

These wastes are a very small portion (typically less than 1 percent) of the municipal solid waste stream. Removal of these products from the disposed waste stream does not result in measurable reductions in weight or volume, but does result in the reduction of some toxic materials from the residential solid waste stream. HHW is typically considered a universal waste exempt from federal disposal restrictions though the same products disposed by small businesses are banned from landfills. Thus, many communities and agencies nation-wide have developed permanent or recurring HHW and very small quantity generator hazardous waste collection programs. Collected materials require special handling and if they are hazardous wastes must be disposed of as such. Some producers (such as agricultural pesticide manufacturers) are developing extended producer responsibility programs to take back products and empty containers.

G. **Construction & Demolition Debris**

Construction and demolition debris is sometimes disposed of in separate inert or demolition debris landfills rather than MSW landfills because of the different nature of the material and the existence of regulations allowing and/or making alternate disposal facilities cost competitive. Depending on the building activity and age of the building stock in an area, C&D debris can represent a significant portion of the municipal solid waste stream. Much of this waste is recoverable, and can be reclaimed, reused, or recycled. If collected mixed, processing is required to separate the material components and render them suitable for marketing. Materials can also be source separated on site, which reduces the need for processing, and facilitates re-use and recycling.

H. **Batteries**

Consumers tend to consider all household batteries as hazardous waste. However, batteries contain varying degrees of toxic and corrosive materials that help define the appropriate management system. Some may be more suited for recycling, some for disposal within an MSW landfill, and some for handling as a hazardous waste.

A number of communities have started collection programs for batteries. Options include

• Deposit programs that encourage their return to dealers.

• Collection at household hazardous waste collection days.

• Separate collection at the source with recyclables or MSW.

• Producer responsibility requirements to collect and process the batteries.

The advantage of collecting batteries as part of household hazardous waste collections is that it sends a clear message to the public that these products are not benign and they require special handling. This may discourage their use except where necessary. Careful consideration of costs and processing capacity for these materials must be used when implementing a program to ensure its long term viability.

I. **Other Recyclable Materials**

There are many types of waste materials that do not fit neatly into categories. These include tyres, used oil and filters, discarded appliances ("white goods"), discarded electronic waste (“e-waste”) and similar hard to collect difficult-to-process materials. These materials need specialized collection and processing systems in order to successfully remove them from the waste stream. Recovered tyres, for example, can be burned in some facilities as a fuel to generate electricity, made into new durable products, processed to manufacture new rubber products, or even formed into reefs to provide marine habitats.

Here is how paper waste is recycled

Collection, transportation and storage

The biggest task for paper recycling companies is probably the collection, transporting and sorting of waste paper. This is because we always add paper to other waste items and get them contaminated with food, plastics and metals. Sometimes collected paper is sent back to the landfills because they are too contaminated for use. Try to keep waste paper in separate grades at home or in the office — example, do not mix newspapers and corrugated boxes up.

Recycle paper types

All paper recovered is sent to the recycling center, where it is packed, graded, put into bales and sent to the paper mill. At the mill, all the paper is stored in a warehouse until it is needed.

Repulping and Screening

From the storage shelves, they are moved into a big paper-grinding machine called a vat (pulper). Here the paper is chopped into tiny pieces, mixed with water and chemicals and heated up to break it down into organic plant material called fibre. After, it is screened to remove contaminants such as bits of plastic and globs of glue.

Deinking

This involves 'washing' the pulp with chemicals to remove printing ink and glue residue. Sometimes, a process called floatation is applied to further remove stubborn stains and stickies. Floatation involves the use of chemicals and air to create bubbles which absorb the stickies in the pulp.

Refining, Bleaching and Colour Stripping

Refining involves beating the recycled pulp to make them ideal for paper-making. After refining, additional chemicals are added to remove any dyes from the paper. It is then bleached to whiten and brighten it up.

Paper making

At this stage, the pulp is ready to be used for paper. Sometimes new pulp (virgin pulp) is added to give it extra strength and smoothness. Water is added to the pulp and sprayed onto a large metal screen in continuous mode. The water is drained on the screen and the fibres begin to bond with each other. As it moves through the paper-making machines, press rollers squeeze out more water, heat them dry and coat them up. They are then finished into rolls.

Importance and benefits of waste recycling

Recycling helps protect the environment

This is because the recyclable waste materials would have been burned or ended up in the landfill. Pollution of the air, land, water and soil is reduced.

Recycling conserves natural resources

Recycling more waste means that we do not depend too much on raw (natural) resources, which are already massively depleted.

Recycling saves energy

It takes more energy to produce items with raw materials than from recycling used materials. This means we are more energy efficient and the prices of products can come down.

Recycling creates jobs

People are employed to collect, sort and work in recycling companies. Others also get jobs with businesses that work with these recycling units. There can be a ripple of jobs in the municipality.

5.4 Organic waste treatment and new technologies

Waste Management offers a variety of organic treatment and remediation solutions for recycling industrial byproducts. Whether your treatment priorities are driven by economics, transportation haul distances, technological preferences, or the support of environmental stewardship. Waste Management can assess each of the available options and recommend the organic solutions most appropriate to your needs.

Waste Management's organic technologies include

Plastics Recovery - Using a pyrolysis process, it can convert difficult-to-recycle plastics into a high-value synthetic crude oil. This oil can, in turn, be converted into ultra-low sulfur diesel and other transportation fuels and petroleum products.

Thermo chemical Technologies - These are working with technology partners to process various waste streams through the use of gasification, plasma and pyrolysis processes to create additional waste-to-biofuels options.

Organics Recovery Unit (ORU) - ORU uses indirect heat to drive organic material, water and solids from soil or other media. This process is suitable for chlorinated solvents, organic dyes and dye intermediates, pesticides and herbicides, process wastes, refinery wastes, semi-volatile organics, and Volatile Organic Compounds (VOCs).

Composting is a managed process which utilizes microorganisms naturally present in organic matter and soil to decompose organic material. These microorganisms require basic nutrients, oxygen, and water in order for decomposition to occur at an accelerated pace. The end-product, compost, is a dark brown, humus-like material which can be easily and safely handled, stored, and used as a valuable soil conditioner. The composting process is dependent upon several factors, including the population of microorganisms, carbon to nitrogen ratio, oxygen level, temperature, moisture, surface area, pH, and time.

Figure 5.4 Organic waste treatment(Source https//www.researchgate.net/figure/Schematic-overview-of-organic-waste-management)

Aerobic Composting

The composting process involves microorganisms feeding on organic material and consuming oxygen. The process generates heat, drives off moisture, and reduces bulky organic waste into a beneficial soil-like material containing nutrients, humus and microorganisms in just a few months. Material in an unmanaged pile of organic debris will eventually break down but the process will take a long time and may result in odour or other nuisance problems due to poor aeration.

Composting is an excellent method of recycling grass clippings. However, do not compost grass clippings or any other plant residues that have been treated with herbicides. If carried out properly, it can reduce the potential weed seeds and diseases from being reintroduced into the fields. The finished compost is a stable organic material which is a useful soil conditioner or nutrient source. Due to the characteristics of fresh grass clippings (high-moisture, high-nitrogen content and small particle size), co-composting with a high-carbon bulking agent is essential.

Unacceptable materials for composting Chemically treated wood products, plastic (e.g. pots, bags and sheet film), unprocessed sod and chunks of soil, large bulky items (e.g. stumps, pallets, concrete and asphalt)

Acceptable Materials for composting Green and woody plant clippings and trimmings, soil, plant media, untreated wood and uncoated paper scraps

Site Selection for Compost Piles

Proper site selection is a prerequisite to the establishment of safe and effective composting operations. The location of a composting operation directly impacts the amount of site preparation required and the measures needed to satisfy environmental and regulatory requirements.

Protection of Water Resources

Sites need to be evaluated for their potential impact on water resources. Of primary concern are proximity to public water supplies, wetlands, floodplains, surface waters, and depth to groundwater. Below are guidelines from the “Guide to Agricultural Composting”

Composting Basics

There are five main areas that must be "controlled" during composting.

Feedstock and Nutrient Balance

Composting, or controlled decomposition, requires a proper balance of "green" organic materials and "brown" organic materials. "Green" organic material includes grass clippings, food scraps, and manure, which contain large amounts of nitrogen. "Brown" organic materials include dry leaves, wood chips, and branches, which contain large amounts of carbon but little nitrogen. Obtaining the right nutrient mix requires experimentation and patience. It is part of the art and science of composting.

Particle Size

Grinding, chipping, and shredding materials increases the surface area on which microorganisms can feed. Smaller particles also produce a more homogeneous compost mixture and improve pile insulation to help maintain optimum temperatures (see below). If the particles are too small, however, they might prevent air from flowing freely through the pile.

Moisture Content

Microorganisms living in a compost pile need enough moisture to survive. Water is the key element that helps transports substances within the compost pile and makes the nutrients in organic material accessible to the microbes. Organic material contains some moisture in varying amounts, but moisture also might come in the form of rainfall or intentional watering.

Oxygen Flow

Turning the pile, placing the pile on a series of pipes, or including bulking agents such as wood chips and shredded newspaper all help aerate the pile. Aerating the pile allows decomposition to occur at a faster rate than anaerobic conditions. Care must be taken, however, not to provide too much oxygen, which can dry out the pile and impede the composting process.

Temperature

Microorganisms require a certain temperature range for optimal activity. Certain temperatures promote rapid composting and destroy pathogens and weed seeds. Microbial activity can raise the temperature of the pile's core to at least 140° F. If the temperature does not increase, anaerobic conditions (i.e., rotting) occur. Controlling the previous four factors can bring about the proper temperature.

Onsite Composting

Organizations that are going to compost small amounts of wasted food can compost onsite. Composting can significantly reduce the amount of wasted food that is thrown away. Yard trimmings and small quantities of food scraps can be composted onsite. Animal products and large quantities of food scraps are not appropriate for onsite composting.

The climate and seasons changes will not have a big effect on onsite composting. Small adjustments can be made when changes happen such as when the rainy season approaches.

Food scraps need to be handled properly so they don't cause odours or attract unwanted insects or animals.

Onsite composting takes very little time or equipment. Education is the key. Local communities might hold composting demonstrations and seminars to encourage homeowners or businesses to compost on their own properties.

Creating compost can take up to two years, but manual turning can speed up the process to between three to six months.

Compost, however, should not be used as potting soil for houseplants because of the presence of weed and grass seeds.

You can leave grass clippings on the lawn-known as "grass cycling." These cuttings will decompose naturally and return some nutrients back to the soil, similar to composting.

You can put leaves aside and use them as mulch around trees and scrubs to retain moisture.

Vermicomposting

Red worms in bins feed on food scraps, yard trimmings, and other organic matter to create compost. The worms break down this material into high quality compost called castings. Worm bins are easy to construct and are also available for purchase. One pound of mature worms (approximately 800-1,000 worms) can eat up to half a pound of organic material per day. The bins can be sized to match the volume of food scraps that will be turned into castings.

It typically takes three to four months to produce usable castings. The castings can be used as potting soil. The other byproduct of vermicomposting known as "worm tea" is used as a high-quality liquid fertilizer for houseplants or gardens.

Things to Think About

- Ideal for apartment dwellers or small offices.
- Schools can use vermiculture to teach children conservation and recycling.
- It is important to keep the worms alive and healthy by providing the proper conditions and sufficient food.
- Prepare bedding, bury garbage, and separate worms from their castings.
- Worms are sensitive to changes in climate.
- Extreme temperatures and direct sunlight are not healthy for the worms.
- The best temperatures for vermicomposting range from 55° F to 77° F.
- In hot, arid areas, the bin should be placed under the shade.
- Vermicomposting indoors can avoid many of these problems.

Aerated (Turned) Windrow Composting

Aerated or turned windrow composting is suited for large volumes such as that generated by entire communities and collected by local governments, and high volume food-processing businesses (e.g., restaurants, cafeterias, packing plants). It will yield significant amounts of compost, which might require assistance to market the end-product. Local governments may want to make the compost available to residents for a low or no cost.

This type of composting involves forming organic waste into rows of long piles called “windrows” and aerating them periodically by either manually or mechanically turning the piles. The ideal pile height is between four and eight feet with a width of 14 to 16 feet. This size pile is large enough to generate enough heat and maintain temperatures. It is small enough to allow oxygen flow to the windrow's core.

Large volumes of diverse wastes such as yard trimmings, grease, liquids, and animal byproducts (such as fish and poultry wastes) can be composted through this method.

Things to Think About

- Windrow composting often requires large tracts of land, sturdy equipment, a continual supply of labour to maintain and operate the facility, and patience to experiment with various materials mixtures and turning frequencies.
- In a warm, arid climate, windrows are sometimes covered or placed under a shelter to prevent water from evaporating.
- In rainy seasons, the shapes of the pile can be adjusted so that water runs off the top of the pile rather than being absorbed into the pile.
- Windrow composting can work in cold climates. Often the outside of the pile might freeze, but in its core, a windrow can reach 140° F.
- Leachate is liquid released during the composting process. This can contaminate local ground water and surface-water supplies. It should be collected and treated.
- Windrow composting is a large-scale operation and might be subject to regulatory enforcement, zoning, and sitting requirements. Compost should be tested in a laboratory for bacterial and heavy metal content.
- Odours also need to be controlled. The public should be informed of the operation and have a method to address any complaints about animals or bad odours.

Aerated Static Pile Composting

Aerated static pile composting produces compost relatively quickly (within three to six months). It is suitable for a relatively homogenous mix of organic waste and work well for larger quantity generators of yard trimmings and compostable municipal solid waste (e.g., food scraps, paper products), such as local governments, landscapers, or farms. This method, however, does not work well for composting animal byproducts or grease from food processing industries.

In aerated static pile composting, organic waste mixed in a large pile. To aerate the pile, layers of loosely piled bulking agents (e.g., wood chips, shredded newspaper) are added so that air can pass from the bottom to the top of the pile. The piles also can be placed over a network of pipes that deliver air into or draw air out of the pile. Air blowers might be activated by a timer or temperature sensors.

Things to Think about

- In a warm, arid climate, it may be necessary to cover the pile or place it under a shelter to prevent water from evaporating.
- In the cold, the core of the pile will retain its warm temperature. Aeration might be more difficult because passive air flowing is used rather than active turning. Placing the aerated static piles indoors with proper ventilation is also sometimes an option.
- Since there is no physical turning, this method requires careful monitoring to ensure that the outside of the pile heats up as much as the core.
- Applying a thick layer of finished compost over the pile may help alleviate any odours. If the air blower draws air out of the pile, filtering the air through a bio filter made from finished compost will also reduce any of the odours.
- This method may require significant cost and technical assistance to purchase, install, and maintain equipment such as blowers, pipes, sensors, and fans.
- Having a controlled supply of air allows construction of large piles, which require less land than the windrow method.

In-Vessel Composting

In-vessel composting can process large amounts of waste without taking up as much space as the windrow method and it can accommodate virtually any type of organic waste (e.g., meat, animal manure, biosolids, food scraps). This method involves feeding organic materials into a drum, silo, concrete-lined trench, or similar equipment. This allows good control of the environmental conditions such as temperature, moisture, and airflow. The material is mechanically turned or mixed to make sure the material is aerated. The size of the vessel can vary in size and capacity.

This method produces compost in just a few weeks. It takes a few more weeks or months until it is ready to use because the microbial activity needs to balance and the pile needs to cool.

Things to Think About

- Some are small enough to fit in a school or restaurant kitchen.
- Some are very large, similar to the size of school bus. Large food processing plants often use these.
- Careful control, often electronically, of the climate allows year-round use of this method.
- Use in extremely cold weather is possible with insulation or indoor use.
- Very little odour or leachate is produced.
- This method is expensive and may require technical expertise to operate it properly.

- Uses much less land and manual labour than windrow composting.

Sites must not be located within 400 feet (Zone I) of a public drinking water supply well or within 250 feet of a private well. For sites located within a Zone II or interim wellhead protection area (½ mile radius), MassDEP may require that extra precautions be taken in the design or operations depending on the quantities and types of material to be composted. Sites within Zone II may not be allowed under certain circumstances.

Under the wetlands regulations, sitting of composting and storage areas is considered to be "normal improvement of land in agricultural use" when it occurs on land in agricultural use when it is directly related to the production or raising of certain agricultural commodities, and when it is undertaken in such a manner as to prevent erosion and siltation of adjacent water bodies and wetlands.

Sites should be located at such a distance to ensure that there will not be any potential adverse impacts from compost site runoff into surface waters.

Soils should be permeable enough to minimize runoff, yet capable of filtering drainage water. Excessively drained soils (e.g., sand) should be avoided if possible, as they may lack the physical properties necessary for effective filtering of potential contaminants. Highly impermeable soils (e.g., clay) should also be avoided if possible, as this may lead to poor site drainage and excessive runoff or erosion.

Sites should be avoided where groundwater rises closer than 4 feet or where bedrock is closer than 5 feet from the surface. Such conditions may lead to an operating surface that is too wet, and it increases the potential for nutrients to leach into groundwater.

Buffer to Sensitive Land Uses

Buffers, in the way of distance and/or visual screens, can go a long way toward reducing the real or perceived aggravations of noise, odour, litter, and aesthetic objections often associated with composting operations. Compost piles should always be distant and downwind from sensitive neighbours and not sited close to residential property. A distance of at least 250 feet from the nearest residence to the composting area is recommended, and the composting site should be at least 50 feet from the property line. More importantly, the buffer must be adequate to satisfy reasonable neighbour concerns. Keep the activities as far away from the property line as possible.

Available sites should be analyzed for conditions potentially detrimental to production and access. There needs to be enough space to store and process waste, operate and turn active windrows or piles, and store and cure finished compost. A facility that is short on space will eventually experience problems. Composting can have off-site impacts.

Composting can also create water quality problems. Piles should be protected from surface water and storm water runoff. Piles may need to be protected from rain. This is because a compost pile can get saturated, stop working and, become anaerobic. This will create odour problems. Saturated piles will need to be remixed and rebuilt. Runoff from an active compost pile or stored compost can also create water pollution problems. Standing water can cause odour problems. Compost piles should always be sited so that runoff is minimized. Any runoff should be collected and used rather than allowed to leave the property.

State and Local regulations regarding composting facilities should be thoroughly investigated.

The Basic Composting Process

The general steps in the biological process which creates compost are the same regardless of the raw materials being composted or the size and complexity of the production facility. A compost must pass through all of the steps outlined here in order for it to be considered of high enough quality for use in organic potting mixes.

The progress of organic matter decomposition during composting can be followed by monitoring the temperature of the compost pile. During the initial phase of composting the temperature of the pile increases rapidly as the population and activity of decay microorganisms increases in response to the readily decomposable carbon in the raw materials. The goals are to reach a temperature between 131°F or more and to maintain this temperature range until the microorganisms begin to exhaust the readily available carbon. During composting the pile is turned and remixed several times to ensure complete heating and decomposition.

To comply with the National Organic Program standards compost piles must maintain 131-170ºF for at least 3 days (static pile) or at least 15 days (windrow, turned at least 5 times). High temperatures are necessary to kill any human pathogens especially if farm manure is a component. Also, weed seeds and plant diseases are most successfully killed at high temperatures. Most weed seeds are destroyed at 145°F.

Following the high temperature phase there is an extended period of gradual temperature decline until the pile reaches ambient air temperature. Now, if the pile is turned, reheating will not occur. At this point the compost is said to be "near maturity", but to ensure that the compost is stable and ready to use, most producers allow some extra time for the compost to "cure". How long composting lasts varies with the method. It could take about 1-2 years in a static unturned pile, 6-9 months if the pile is turned occasionally, or only 1-4 months the pile is turned frequently. Many types of raw materials can be used for making compost.

Benefits of organic treatment services include

Low remediation expenses- These are environmentally friendly solutions, cost effective, energy efficient, and the residuals produced are compliant with federal and state treatment standards.

Reduced liability- These organic treatment services are in full compliance with all local, state and federation regulations, thus minimizing your legal exposure.

Support of environmental stewardship. Organic treatment can help your company better pursue its environmental stewardship goals.

Beneficial Reuse. Organic treatment allows many liquid wastes to be recycled as fuel.

5.5 Incentives, financial and technical assistance for power generation from waste in India

Government Support for Sewage to Energy Projects

Projects based on high rate biomethanation technology

Financial assistance of Rs. 2.0 crore / MW will be provided for projects based on power generation from MSW through high rate biomethanation technology.

Power generation at sewage treatment plants

Financial assistance @ 40% of the project cost subject to a maximum of Rs 2.0 crore/MW shall be provided for projects for generation of power from biogas being produced at Sewage Treatment Plants. Project cost will include the cost of engine-genset, H_2S removal plant and other related equipment.

Carbon Credit Benefits of Sewage to Energy

Projects based on generation of electric power from biogas, which is being produced as a result of digestion of sludge in STPs, are eligible for CDM (Clean Development Mechanism), as it will help in reducing and stabilizing the emissions due to methane which is a green house gas. Based on the potential of biogas/power generation from STPs, expenditure on O&M can be offset by earning 'carbon credits' on recurring basis. Some sewage treatment plants in India are on the verge of getting the carbon credits for its efforts for reducing the carbon-dioxide emission in their sewage treatment plants.

For demonstration projects comprising innovative projects for generation of power from municipal solid wastes and selected industrial wastes, financial assistance up to 50% of capital cost of the project limited to Rs. 3.00 crore per MW is provided to the project proponent.

For power generation through Sewage Treatment Plants (STPs), financial assistance up to 50% of the incremental capital cost for generation of power from biogas being generated at STPs is provided.

In addition to the above, financial incentive at the rate of Rs. 15.00 lakh per MW is given to Municipal Corporations/ Urban Local Bodies, for supplying the garbage free of cost at the project site and providing land on a long-term lease, viz. 30 years and above, at a nominal rent.

State Nodal Agencies are given an incentive @ Rs.5.00 lakh per MW of power for promotion, co-ordination and monitoring of projects.

For financial institutions, a service charge of 2% of the actual subsidy channelled through them to the promoter or other FIs is allowed, subject to a maximum of Rs.2.00 lakh per project.

There is also a provision for giving 50% of the cost of preparation of Detailed Project Reports (DPR) or Techno-economic Feasibility Reports, subject to a maximum of Rs.2.00 lakh per report to the project proponent.

If considered necessary by MNES, financial assistance may also be provided towards full cost of carrying out studies for assessment of resources for setting up waste-to-energy projects.

For promotional activities, assistance is available for organizing of training courses, workshops and seminars, awareness generation and publicity.

With growing public awareness about sanitation, and with increasing pressure on the government and urban local bodies to manage waste more efficiently, the Indian waste to energy sector is poised to grow at a rapid pace in the years to come. The dual pressing needs of waste management and reliable renewable energy source are creating attractive opportunities for investors and project developers in the waste to energy sector.

Figure 5.5 Incentives to Go Green (Source https//timesofindia.indiatimes.com/city/navi-mumbai)

Why Waste to Energy?

Most wastes that are generated find their way into land and water bodies without proper treatment, causing severe water and air pollution. The problems caused by solid and liquid wastes can be significantly mitigated through the adoption of environment-friendly waste to energy technologies that will allow treatment and processing of wastes before their disposal.

The environmental benefits of waste to energy, as an alternative to disposing of waste in landfills, are clear and compelling. Waste to energy generates clean, reliable energy from a renewable fuel source, thus reducing dependence on fossil fuels, the combustion of which is a major contributor to GHG emissions.

These measures would reduce the quantity of wastes, generate a substantial quantity of energy from them, and greatly reduce pollution of water and air, thereby offering a number of social and economic benefits that cannot easily be quantified.

In addition to energy generation, waste-to-energy can fetch significant monetary benefits. Some of the strategic and financial benefits from waste-to-energy business are

Profitability - If the right technology is employed with optimal processes and all components of waste are used to derive value, waste to energy could be a profitable business. When government incentives are factored in, the attractiveness of the business increases further.

Government Incentives - The government of India already provides significant incentives for waste to energy projects, in the form of capital subsidies and feed in tariffs. With concerns on climate change, waste management and sanitation on the increase (a result of this increasing concern is the newly formed ministry exclusively for Drinking Water and Sanitation), the government incentives for this sector is only set to increase in future.

Related Opportunities - Success in municipal solid waste management could lead to opportunities in other waste such as sewage waste, industrial waste and hazardous waste. Depending on the technology/route used for energy recovery, eco-friendly and “green” co-products such as charcoal, compost, nutrient rich digestate (a fertilizer) or bio-oil can be obtained. These co-product opportunities will enable the enterprise to expand into these related products, demand for which are increasing all the time.

Emerging Opportunities - With distributed waste management and waste to energy becoming important priorities, opportunities exist for companies to provide support services like turnkey solutions. In addition, waste to energy opportunities exist not just in India but all over the world. Thus, there could be significant international expansion possibilities for Indian companies, especially expansion into other Asian countries.

The Committee were informed by the Ministry that, at the Central level, various Ministries, i.e. Ministry of Urban Development, Ministry of Environment, Forest and Climate Change and Ministry of New and Renewable Energy, etc. are involved in handling Municipal Solid Waste, viz. its collection, transportation, treatment and safe disposal. On being asked by the Committee about the role of the respective Ministries/Agencies in Solid Waste Management and Generation of Power from Solid Waste, the Ministry furnished the following information

"Handling of the Subject at Central Level as per Government of India (Allocation of Business) Rules, 1961 At Central level, following three Ministries are involved in handling the subject of Municipal Solid Waste in respect of its collection, transportation, treatment and safe disposal -

a) Ministry of Urban Development (MoUD)

MoUD is the nodal Ministry for formulation of policies, strategies and guidelines and assists the States by providing financial assistance for development of water supply and sanitation including municipal solid waste management infrastructure in the cities and towns.

b) Ministry of Environment, Forest and Climate Change (MoEF& CC)

MoEF& CC is involved in framing the rules for management and handling of Municipal Solid Waste under the –

i) Environment (Protection) Act;

ii) Water(Prevention and Control of Pollution) Act;

iii) Air (Prevention and Control of Pollution) Act; and

iv) Central Pollution Control Board

c) Ministry of New and Renewable Energy (MNRE)

MSW being renewable in nature, MNRE Supports MSW based power generation projects."

The Committee have observed that there is a need for coordinated efforts to be made to solve this problem of garbage and to make Waste to Energy Projects successful and viable. A Monitoring Committee, consisting of representatives from all the Central Ministries concerned like the Ministry of New and Renewable Energy, Ministry Of Urban Development, Ministry of Environment, Forest and Climate Change, etc., along with the representatives of the State Governments and Urban Local Bodies, should be established to coordinate the efforts at each level and suggest suitable methods and technologies to be adopted, on case to case basis, to make Waste to Energy Plants a success. This Monitoring Committee may also have technical experts, financial analysts, representatives from private sector, etc.

The Committee were apprised about the following Waste to Wealth Interventions by the Government

"Waste to Energy Central Electricity Regulatory Commission (CERC) on 07.10.2015 has notified Generic tariff for Waste-to-Energy of Rs 7.90 per unit of power for RDF (Refuse Derived Fuel). States have initiated process for determining the tariff. Ministry of Power has revised the Tariff Policy 2006 vide resolution dated 28.01.2016, under the Indian Electricity Act, 2003, making it mandatory for State DISCOMS to purchase power from Waste-to-Energy plants.

Waste to Compose

M/o Chemicals & Fertilizers has notified on 10.02.2016, the policy on promotion of City Compost, thereby providing Market Development Assistance of Rs. 1,500 per Metric Tonne to scale up production and consumption of compost.

M/o Chemicals & Fertilizers has tagged compost manufacturing plants with fertilizer distribution companies in all States (purchase price of Rs. 2,500 per MT established)"

The Committee have observed that the Central Electricity Regulatory Commission (CERC) has notified Generic tariff for Waste-to-Energy of Rs 7.90 per unit of power for RDF (Refuse Derived Fuel). The Committee noted that fixing of tariff by the CERC is not the right solution and the tariff should be decided through competitive bidding as this act of tariff determination by the CERC may encourage inefficiency and non-transparency. Therefore, in view of the Committee, open competitive bids should be invited as is the case in Andhra Pradesh and Punjab.

The Committee also noted that it has been made mandatory for State DISCOMS to purchase power from Waste-to-Energy plants at this tariff of Rs 7.90 and this increased cost of electricity would ultimately be borne by the common consumers. The Committee is of the view that waste disposal is the responsibility of the State Governments and the ULBs; so the cost should be borne by them and not the common consumer. To make Waste to Energy Plants viable, the principle of "Polluters Pay, along with common but differentiated responsibility" should be adopted, i.e. the increased cost should not be borne by all customers equally instead of the one who produce more solid waste (such as Restaurants, Hotels, Marriage Halls, other commercial establishments, etc.) should be made to pay more through a tax/cess/fine.

It has also been noted by the Committee that common people are made to pay twice for the disposal of same garbage, as in, people pay to the local bodies for collection of garbage from their home and again a high rate of electricity has been imposed on them to compensate the producer of electricity from waste. This is a kind of double taxation for the same service. This practice of ensuring 15% to 20% profit to the producer of electricity from waste and taxing common people twice for the same should be avoided.

When asked by the Committee about the efforts of the Government in the field of Waste to Energy, the Ministry furnished the following information

"Manual on Municipal Solid Waste Management Ministry of Urban Development (MOUD) and Central Public Health & Environmental Engineering Organization (CPHEEO) in collaboration with GIZ have prepared a revised manual for Municipal Solid Waste Management (MSWM). The Ministry of Urban Development (MoUD), Government of India had developed a Guidance Manual for MSW for all Urban Local Bodies which is based on learnings from 14 years' experience gained in India, post the notification of MSW management and Handling Rules in 2000. This revised manual on MSWM is

designed to support decision makers at State and Urban Local Body levels, technical staff experts and academia involved in the proper management and implementation of all MSWM related activities. The manual reflects upon recent technological, managerial, financial and policy level developments.

To Do Activity

Where in the World Do I Recycle It?

Introduction

Overview

In this activity, students will use multiple sources of information to research reuse and recycling options for a variety of household goods.

Objectives

Students will

1. learn about resources they can use to research reuse and recycling options for common household materials.

2. use reference materials to identify three items that are recyclable in their community and locate where they can be recycled.

Teacher Background

StopWaste.Org's Recycling Guide is a resource guide filled with references to locations that accept

materials for reuse and recycling. The "Recycling A–Z" directory lists reuse and recycling businesses and facilities that accept different categories of materials, from aerosol cans to wood and yard trimmings. The guide also provides a table of recycling information for residents that lists recycling service providers and what they collect by city.

Materials

Students

❑From home three items that can be recycled
❑"Where in the World Do I Recycle It?" worksheet(one per student)
❑"Website Directions" handout(one per student)
❑StopWaste.Org Recycling Guide the "Reuse and Recycling Services Directory "pages (one per student)

Teacher

❑Various discarded items to supplement student supplies
❑Rubric overhead
❑Rubrics (one per student)

Preparation

Collect a wide variety of discarded items, and bring to class for students to research, e.g., eyeglasses, batteries, motor oil, etc.

Discussion

1. Ask the students whether anyone in their family has ever thrown something away because they sure whether it could be recycled. Have them share some examples. Look around the classroom, and point out objects such as aluminium cans, batteries, books, eyeglasses, paint, lightbulbs and paper

notebooks. Tell them that these items often get discarded after use because people do not know how or where to reuse or recycle them.

2. Remind students that all these items were made from natural resources. Recycling keeps these valuable resources out of the landfill. When the items get recycled, they are remanufactured into new products. Recycling is the process of turning something old into something new.

3. Explain that many cities have different practices for accepting materials for recycling. Ask students to describe what their recycling bins look like and share examples of what they put in their bins. Point out the similarities and differences in what students can recycle at home depending on where they live.

4. Tell the class that not all cities recycle things the same way. Students must first identify their community or city where they live before discovering whether a certain material can be recycled. The goal of this activity is to become knowledgeable in using reference materials to find out what is recyclable in their community.

5. Show an overhead of the lesson rubric, and review the expectations for this lesson.

Procedure
Homework (day before activity)

1. Assign students to bring in three items from home that may or may not be collected for recycling in their community.

Day of Activity

1. Inform the students that they will determine whether the items brought in from home can be recycled in their community by conducting research on a website or using a Recycling Guide.

2. Each student should have at least three items to research (pass out items as needed).

3. Tell the students they will be using the Stop Waste. Org Recycling Guide or online version to conduct their research. Explain that this is a comprehensive guide to reuse and recycling resources.

4. Model how to use the printed guide by looking up an item such as aluminium cans to determine whether it can be recycled in the city where their school is located.

5. Pass out the StopWaste.Org Recycling Guide to each student or if using a computer, ask students to go to**www.StopWaste.Org**, and pass out the directions for using the website.

6. Pass out “Where in the World Do I Recycle It? ” worksheet to each student.

7. Using various resources, have students answer the questions on the worksheet.

8. When they are finished, call on students to report something new they learned through their research.

Wrap-Up

1. Discuss and emphasize the wide variety of materials that can be recycled based on the students' findings.

2. Ask students to share their findings and explain the importance of recycling materials with friends and family.

Final Assessment Idea

Have students create a poster for the classroom or their home that shows family members what they can recycle in the city where they live.

Summary

- On site processing is one of the most effective and sustainable ways to achieve resource recovery.
- Conversion technologies can recover materials otherwise destined for disposal.
- Recycling is processing used materials (waste) into new, useful products.
- Waste Management offers a variety of organic treatment and remediation solutions for recycling industrial by products.
- For power generation through Sewage Treatment Plants (STPs), financial assistance up to 50% of the incremental capital cost for generation of power from biogas being generated at STPs is provided.

Model Questions

Q1. What are conversion technologies?

Q2. How paper waste is recycled?

Q3. What are the latest government schemes for power generation from waste in India?

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Block 2

Water Security RM

Swachhta Action Plan

सत्यमेव जयते

Mahatma Gandhi National Council of Rural Education

Department of Higher Education

Ministry of Human Resource Development, Government of India

Hyderabad - 500004

Where there is Rural Wellbeing there is Universal Prosperity

Contents

Chapter 1 - Water Issues

Introduction

Water is essential for domestic purposes, agricultural, industrial, energy production, ecological sustainability and these uses are highly inter-linked in competition to each other use. Water consumption pattern in India is around 90% in agriculture, 6% in domestic and 4% for industrial use. Usage of water by industrial and domestic purposes generates wastewater that may cause pollution, however agriculture usage largely remains consumptive. Irrigation being a consumptive user does not generate significant volume of runoff in Indian context and thus runoff water broadly feed to the aquifer system. The non-consumptive user like household municipal and industrial sector consume a small part of water and waste water generated in the process return to aquatic system and pollute it. There is need to understand the consumers, pollution of return water and to make a synergy between them in a business model based on techno economic feasibility to restore water quality for optimum uses.

The fresh water resources comprising of rivers, lakes and aquifer system are sustaining through inflow from water sheds.Water shed retain the rain water through trees, bushes and grass land which infiltrate to subsurface and surface runoff proliferate by gravity action. Degradation of water shed in terms of tree cutting, cattle grazing, damming and overexploitation leading to less infiltration of rain water. Abstraction of surface and ground water in excess to the infiltration is reducing outflow from the water shed that ultimately reduce perennial flow in the rivers and streams in plains.

Efforts are required to make the users aware about water conservation, prevention and control of pollution to sustain it for optimum management of aquatic resources.

Objectives

- To understand the availability of fresh water, consumptive and non-consumptive uses
- Partially non consumptive uses virtually deteriorate the quality of water in the form of domestic sewage and industrial effluents.
- To orient the non-consumptive uses by better planning mechanism to reduce wastewater generations
- To design the process for wastewater treatment to meet the present and perspective requirement for sustainability of water resources

1.1 Overview of Water Security

Water security is defined as, "the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks". It is concerned with the responsibility for water and integrating water resources management across all sectors viz. planning, health, agriculture, energy, industry, tourism, education and finance. Release of sewage and industrial effluents into rivers, streams and ponds lead to water pollution and the water becomes unusable for its required use. Contamination of a drinking water system can cause epidemic leading to illness, disease, or even death.

A water resource can be contaminated, damaged or disrupted through intentional actions or by an accident. Intentional contamination poses one of the most serious threats to a water system because of the intent to harm human health, aquatic ecology and its unlimited number of user for beneficial purposes. When a contamination incident happens, it is critical to act quickly and effectively to protect public health and the environment. Water security planning is critical because of the increased threat of accidental spillages and intentional discharges from effluent storages in specific groups of industries not been able to manage the treatment of wastewater due to economic reasons. There are many ways in which water systems can be threatened by contamination or be intentionally contaminated. Responding to contamination threats and contamination incidents requires careful planning and preparation.

Should We Be Concerned About Contamination Threats and Contamination Incidents?

Contamination of water resources could impact the loss of public confidence; disrupt the water supply system, shortage of clean water to consumers; disrupt businesses and services that depend on organised water supply. This may create a need to remediate and replace portions of the water system to make it safe, which could in turn create water shortages or outages; result in significant costs for remediation or replacement; and impact other critical infrastructures that rely on safe water, due to interdependencies.

How Serious Could Intentional Water Contamination Be?

There are many ways in which water can be intentionally contaminated, just as there are many different contaminants. Each contaminant has different effects on humans, animals and the environment, depending on its concentration (level) and toxicity (harmfulness).Examples of Possible Contaminants are Pathogenic microorganisms that can impact human health, such as salmonella, E. coli and Cryptosporidium whereas chemicals, toxic metals and organic compounds such as arsenic, cadmium, mercury, dioxin & furans, pesticides, chloramines, VOCs and radioactive isotopes can cause short term as well as long term illnesses. Some of the toxic chemicals persist in water for a long time before they break down into less harmful chemicals and biochemical. Depletion of oxygen in river or lake water due to shock loading of Industrial effluent and municipal wastewater discharges inadvertently lead to fish kill and disrupt intake of water supply systems.

The intentional water contamination is prevailing in the rivers and lakes in the vicinity of all the urban areas disposing treated partially treated and untreated municipal wastewater. Industries are also disposing effluents which are leading to pollution of aquatic resources.

1.2 Inequitable Global Distribution of Water

Water is vital to the existences of all living organisms, but this valued resource is increasingly being threatened as human populations grow and demand more water of high quality for domestic purposes and economic activities. The distribution of water on the Earth’s surface is extremely uneven. Only 3% of water on the surface is fresh; the remaining 97% resides in the ocean. Of freshwater, 69% resides in glaciers, 30% underground (aquifers), and less than 1% is available in lakes, rivers, and swamps. Looked at another way, only one percent of the water on the Earth’s surface is usable by humans and other terrestrial life forms, and 99% of the usable quantity is in the subsurface aquifers. The Distribution of the Earth's Water is depicted in Figure 1.1

Precipitation is the renewable source of freshwater in the surface water courses and subsurface aquifers. The rainfall map (Map 1.1) pinpoints uneven global distribution of precipitation across the continents. The white areas on the map had annual rainfall under 400 mm for a year based on a finding of the study during 2011-12 makes them semi-arid or arid regions whereas more severe rainfall events to characterize in wet regions.

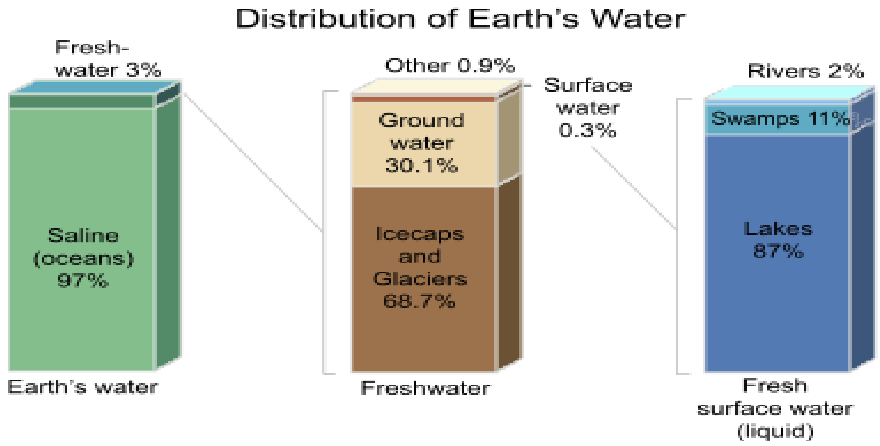
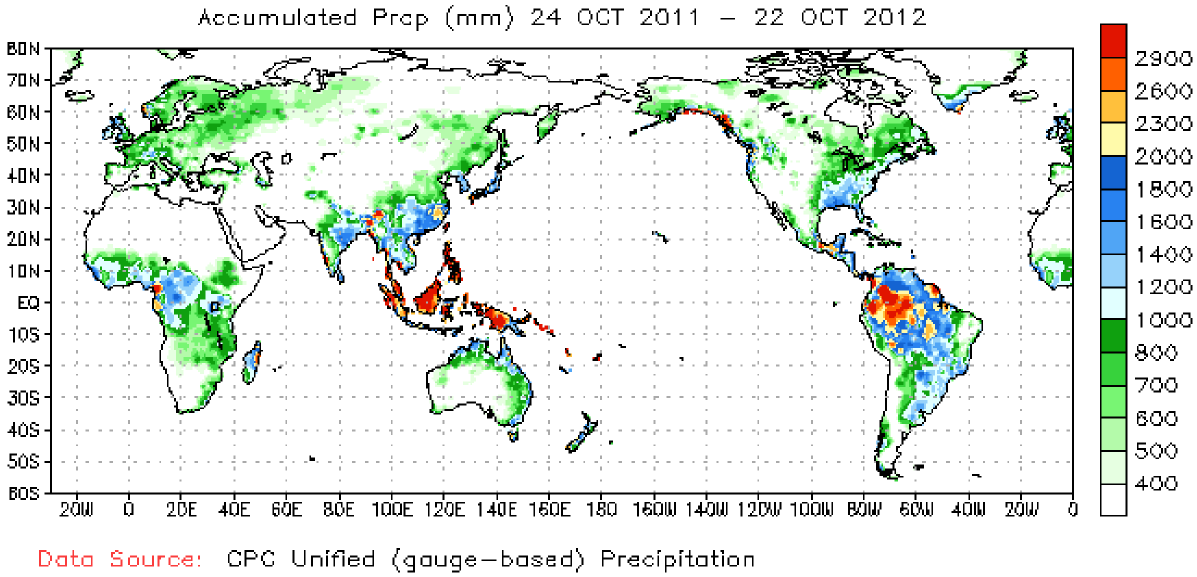


Figure 1.1: Distribution of the Earth's Water (Credit: Timothy Bralower)

Availability of Water for Beneficial Uses

The world's population is growing by about 80 million people a year, implying increased freshwater demand of about 64 billion cubic meters a year. The expected areas of population growth and decline in a time frame of 2000-2080 (Map 1.2) have been highlighted in the United Nations World Water Development Report 3. An estimated 90% of the 3 billion people who are expected to be added to the population by 2050 will be in developing countries, many in regions where the current population does not have sustainable access to safe drinking water and adequate sanitation. The significant world population growth will be in sub-Saharan Africa (32%) and South Asia (30%). Together, these regions are expected to account for half of world population in 2100. Freshwater need is expected to increase due to growing population with longer life expectances and globalization of trade. According to the International Energy Agency, the world will need almost 60% more energy in 2030 than the prevailing demand. Water is needed for the production of energy of all types, so expansion of energy supply will affect water resources. Virtual water is goods and services with substantial water content either in the finished product or in its production. The global volume of virtual water flows in commodities substantially. Adequate investments in water management, infrastructure and services can yield a high economic return by avoiding costs related to water pollution, contamination and disasters. Gains from globalization have not been evenly distributed.



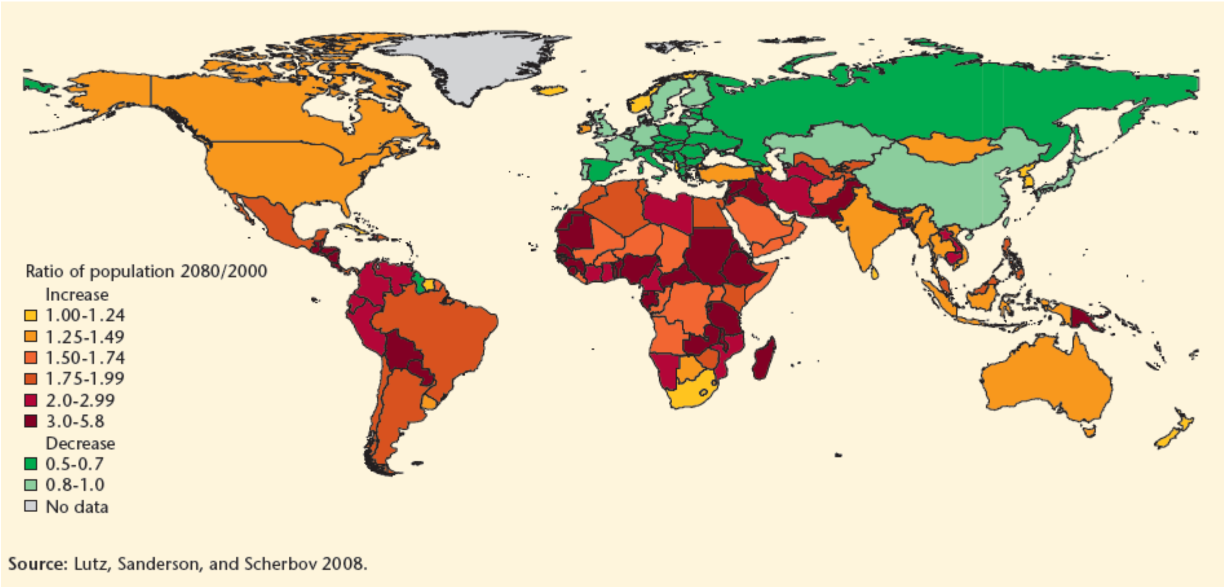
Map 1.1: Uneven Global Distribution of Precipitation across the Continents

Competition for water use exists at all levels and is forecast to increase with competing demands for water in almost all countries due to increasing population and economic activities. It is estimated that in 2030, 47% of world population will be living in areas of high water stress. More than 1 billion people living in arid and semi-arid parts of the world have access to little or no renewable water resources. There is a consensus among climate scientists that global warming will intensify, accelerate or enhance the global hydrologic cycle leading to further uneven distribution either by draughts or intense events of rainfall.

Indian Scenario

India receives 4000 Km3 of water through rainfall on a geographical area of about 329 Million Hectare; of this three fourth part occurs only during monsoon. The surface flow is estimated as 1880 Km3. The annual replenlishable ground water resources are about 600 Km3 of which the annual usable resources are 420 Km3. Inland water resources include both fresh and brackish water bodies.

Inland water resources of the country are classified as rivers and canals; reservoirs; tanks and ponds; beels, oxbow lakes, derelict water; and brackish water. In India, rivers and canals run throughout the country with total length extending to 1.9 lakh kilometers and the total water bodies other than rivers and canal cover an area of around 7.31 Million Hectare (M. ha).State wise details of inland water resources are given in Table 1.1. The river basins of Brahmaputra, Ganga, Indus and Godavari putting



Map 1.2: Expected areas of population growth and decline, 2000-2080

together cover more than half of the area of the country. The whole of the west coast stretching 1500 km between Surat in Gujarat and Cape Comorin in Tamilnadu are fed by fourteen medium and eighteen minor river basins. On the east coast of Peninsular India there are three pockets, which are out of any major river basins. These three pockets are; the area south of River Cauvery starting from Madurai to Cape Comorin; the area between Pennar and Cauvery basin wherein Chennai and Pondicherry are located; and the area between Mahanadi and Godavari basins in Orissa coast.

There is a tremendous variation both in the quantity of discharge from a major basin to minor one and also in the quality of discharge from region to region. While freshwater is naturally occurring water with low concentration of salt, brackish water has a salt concentration varying between that of freshwater and marine water.

All the major river basins are not perennial. Only four of the thirteen major basin posses areas of high rainfall, i.e. Brahmaputra, Ganga, Mahanadi and Brahmini having annual average discharge of a minimum of 0.47 million cubic meter per Km2, and they are perennial. Six basins (Krishna, Indus, Godavari, Narmada, Tapi and Subernrekha) occupy the area of medium rainfall and have annual average discharge of a minimum of 0.26 million cubic meter per Km2, and the remaining four (Cauvery, Mahi, Sabarmati and Pennar) occupy the area of low rainfall and have annual average discharge between of 0.06 and 0.24 million cubic meter per Km2. Thus, many of the major river basins also go dry during summer leaving no available water for dilution of waste water discharged in them.

Table 1.1: State wise inland water resources of India

S. No.	States/Union Territories	Rivers & Canals (kms.)	Reservoirs (Lakh Ha)	Tanks & Ponds (Lakh Ha)	Flood Plain Derelict Water Bodies (Lakh Ha)	Brackish Water (Lakh Ha)	Total Water Bodies (Lakh Ha)
1	Andhra Pradesh (including Telengana)	11514	2.34	5.17	-	0.6	8.11
2	Arunachal Pradesh	2000	-	2.76	0.42	-	3.18
3	Assam	4820	0.02	0.23	1.1	-	1.35
4	Bihar	3200	0.6	0.95	0.05	-	1.6
5	Chhattisgarh	3573	0.84	0.63	-	-	1.47
6	Goa	250	0.03	0.03	-	.	0.06
7	Gujarat	3865	2.43	0.71	0.12	1	4.26
8	Haryana	5000		0.1	0.1	-	0.2
9	Himachal Pradesh	3000	0.42	0.01	-	-	0.43
10	Jammu & Kashmir	27781	0.07	0.17	0.06	-	0.3
11	Jharkhand	4200	0.94	0.29	-	-	1.23
12	Karnataka	9000	4.4	2.9	-	0.1	7.4
13	Kerala	3092	0.3	0.3	2.43	2.4	5.43
14	Madhya Pradesh	17088	2.27	0.6	-	-	2.87
15	Maharashtra	16000	2.99	0.72	-	0.12	3.83
16	Manipur	3360	0.01	0.05	0.04	-	0.1
17	Meghalaya	5600	0.08	0.02	.	-	0.1
18	Mizoram	1395	-	0.02	-	-	0.02
19	Nagaland	1600	0.17	0.5	.	-	0.67
20	Odisha	4500	2.56	1.23	1.8	4.3	9.89
21	Punjab	15270		0.07	-	-	0.07
22	Rajasthan	5290	1.2	1.8	-	-	3
23	Sikkim	900	-	-	0.03	-	0.03
24	Tamil Nadu	7420	5.7	0.56	0.07	0.6	6.93
25	Tripura	1200	0.05	0.13	-	-	0.18
26	Uttar Pradesh	28500	1.38	1.61	1.33	-	4.32
27	Uttarakhand	2686	0.2	0.006	0.003	-	0.209
28	West Bengal	2526	0.17	2.76	0.42	2.1	5.45
29	Andaman & Nicobar Islands	-	0.00367	0.0016	-	0.33	0.33527
30	Chandigarh	2	-	-	-	-	0
32	Daman & Diu Dadra Nagar Haveli	54	0.05	-	-	-	0.05
32	Daman & Diu Dadra Nagar Haveli	12	-	-	-	-	0

33	Delhi	150	0.04	-	-	-	0.04
34	Lakshadweep	-	-	-	-	-	0
35	Puducherry	247	-	.	0.01		0.01
	Total	195095	29.26	24.33	7.98	11.55	73.12

Rainfall pattern study by India Meteorology Department revealed that on an average Meghalaya has received the highest rainfall of around 3179.74 mm of annual rainfall over the period of 2012 to 2016 followed by Goa and Andaman & Nicobar Islands. The percent departure in annual rainfall from the normal rainfall is assessed and the Southwest monsoon rainfall and annual rainfall of India for the period from 2000 to 2016 has been shown in Table 1.2 along with their departures from the normal rainfall. The rains have been deficient in most of the years with exceptions being 2005, 2010 and 2013.Most of the monsoon in India is under the influence of South-West monsoon from June to September.

River basin is the most important unit of analysis for any water-related study. River basin, also called catchment area of the river, is the area from which the rain will flow into that particular river. India can be divided into 20 river basins. Central Water Commission (CWC) has the responsibility of planning, development and management of surface water resources of the country. Table 1.3 depicts the river-

Table 1.2: South-West Monsoon and Annual Rainfall along with departure in India

Year	SW-Monsoon Rainfall (mm)		Annual Rainfall (mm)	
	Rainfall	% Departure	Rainfall	% Departure
2000	798.1	-10%	1035.4	-13%
2001	818.8	-8%	1100.7	-7%
2002	700.5	-21%	935.9	-21%
2003	902.9	2%	1187.3	0%
2004	807.1	-9%	1106.5	-7%
2005	874.3	-1%	1208.3	2%
2006	889.3	0%	1161.6	-2%
2007	943	6%	1179.3	-1%
2008	877.8	-1%	1118	-6%
2009	698.3	-21%	953.7	-20%
2010	911.1	3%	1215.5	2%
2011	901.3	2%	1116.3	-6%
2012	823.9	-7%	1054.7	-11%
2013	937.4	6%	1242.6	5%
2014	781.7	-12%	1044.7	-12%
2015	765.8	-14%	1085	-9%
2016	864.4	-3%	1083.2	-9%

basin wise catchment area, average water resources potential river-basin wise according to the Reassessment studies conducted by CWC. The total water resource potential, which occurs as a natural runoff in these rivers, is estimated to be about 1869 BCM. Water availability is highest in Brahmaputra basin (537.24 BCM) followed by Ganga Basin (525.02 BCM).

In India, industrialisation and urbanisation have not yet reached the peak levels considering ever increasing demands of the growing population. This translates to a mounting pressure on the freshwater in the country. The water resources are being increasingly stressed not only by over-abstraction, but also by pollution and climate change. So, the prospects arising from improved water management, both

Table 1.3: River Basin Water Availability

S.no	Basin	Catchment Area (sq.km)	Average Water Resources Potential (BCM)	Utilisable Surface Water Resource (BCM)
1)	Indus (up to Border)	3,21,289	73.31	46
2)	Ganga- Brahmaputra- Meghna			
	a) Ganga	8,61,452	525.02	250
	b) Brahmaputra	1,94,413	537.24	24
	c) Barak & Others	41,723	48.36	
3)	Godavari	3,12,812	110.54	76.3
4)	Krishna	2,58,948	78.12	58
5)	Cauvery	81,155	21.36	19
6)	Subarnarekha	29,196	12.37	6.8
7)	Brahmani-Baitarani	51,822	28.48	18.3
8)	Mahanadi	1,41,589	66.88	50
9)	Pennar	55,213	6.32	6.9
10)	Mahi	34,842	11.02	3.1
11)	Sabarmati	21,674	3.81	1.9
12)	Narmada	98,796	45.64	34.5
13)	Tapi	65,145	14.88	14.5
14)	West Flowing Rivers from Tapi to Tadri	55,940	87.41	11.9
15)	West Flowing Rivers from Tadri to Kanyakumari	56,177	113.53	24.3
16)	East Flowing Rivers between Mahanadi and	86,643	22.52	13.1
17)	East Flowing Rivers between Pennar and Kanyakumari	1,00,139	16.46	16.5
18)	West Flowing Rivers of Kutch & Saurashtra including Luni	3,21,851	15.1	15
19)	Area of inland drainage in Rajasthan	1,39,917.04	-	-
20)	Minor rivers draining into Myanmar (Burma) and Bangladesh	36,202	31	-
Total			**1869.37**	**690.1**

Note: *: Combining Subarnarekha and other small rivers between Subarnarekha and Baitarani

in terms of quality and quantity is indispensable in the context of Indian economy. However, the per capita availability of water has been estimated to decrease over the decades in India, as shown in Table 1.4.

Table 1.4: Per Capita Water Availability in India

Year	**Population (Million)**	**Per Capita Water Availability (Cubic Meter/Year)**	**Status**
1951	361	5178	
1955	395	4732	
1991	846	2210	
2001	1027	1820	
2011	1211	1544	water stressed
Year	Projected Population (Million)	Anticipated Per capita water availability (cubic meter/year)	
2015	1326	1441	water stressed
2021	1345	1421	water stressed
2031	1463	1306	water stressed
2041	1560	1225	water stressed
2051	1628	1174	water stressed

As per Falkenmark Water Stress Indicator, a per capita availability of less than 1700 cubic meters (m3) is termed as a water-stressed condition, while in per capita availability falls below 1000 m3; it is termed as a water scarcity condition. India is currently facing water stressed situation and is moving towards the water scarcity situation since the gap between water demand and water supply is gradually getting widened highlighting the dire need to manage water resources for a sustainable future. The per-capita availability across the river basins of the country is observed that Krishna, Cauvery, Subarnarekha, Pennar, Mahi, Sabarmati, Tapi, East Flowing Rivers and West Flowing Rivers of Kutch and Saurashtra including Luni are some of the basins, fall into the category of "water scarce"- out of which the scarcity can be said to be acute in Cauvery, Pennar, Sabarmati, East Flowing rivers and West Flowing Rivers of Kutch and Saurashtra including Luni with a per capita availability of water less than or around 500 cubic meter.

Use Specific Water Demand

The demand for freshwater for various purposes has been increasing and have been assessed by National Commission on Integrated Water Resources Development (NCIWRD) in 2000. This assessment is based on the assumption that the irrigation efficiency will increase to 60%. The demand for water by various uses is given in Table 1.5.

Table 1.5: Projected Water Demand in India (By Different Use)

Sector	Water Demand in Km3 (or BCM)								
	Standing Sub Committee MoWR, RD & GR			National Commission on Integrated Water Resources Development (NCIWRD)					
	2010	2025	2050	2010		2025		2050	
				Low	High	Low	High	Low	High
Irrigation	688	910	1072	543	557	561	611	628	807
Drinking Water	56	73	102	42	43	55	62	90	111
Industry	12	23	63	37	37	67	67	81	81
Energy	5	15	130	18	19	31	33	63	70
Other	52	72	80	54	54	70	70	111	111
Total	**813**	**1093**	**1447**	**694**	**710**	**784**	**843**	**973**	**1180**

Ground Water

Total replenishable ground water potential of the country, has been estimated by Ministry of Water Resources as 431 Km3 cubic kilometer per year. After making provision for drinking, industrial and other purposes (other than irrigation), which is about 16 percent of total potential, the potential available for irrigation is 360 Km3 per year. The figure for net draft of ground water considering the present utilisation indicates that substantial portion of total potential (about 68 percent) is still remaining untapped. An indicator of whether or not the abstraction of groundwater is sustainable is the depth to water level. With more extraction of ground water, the depth to water level increases and the water table moves downward. Such a change is a cause of major concern for agriculture and irrigation in particular (scenario of groundwater depletion is depicted in Figure 1.2). The depleting groundwater is also negatively affecting India's farmland. According to Agriculture Census 2010-1110, net area irrigated by groundwater is 63.63% (45.17% by tube wells and 18.46% by wells). Since in India, agriculture is dependent on irrigation which in turn is highly dependent on ground water resources, thus depleting resources are reducing the country's cultivated land hence, aggravating the water woes of the nation.

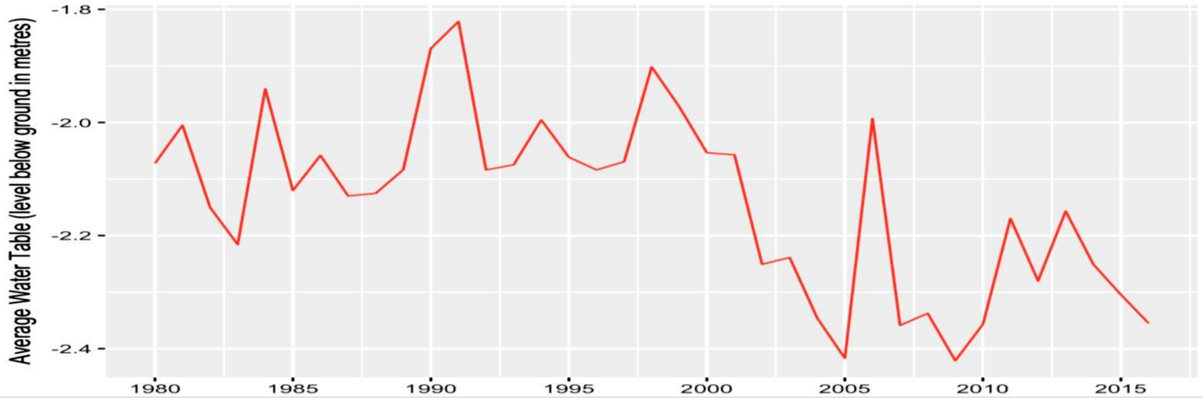


Figure 1.2: Groundwater Depletion in India

1.3 Water Quality and Consequences of Water Pollution

Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and to any human need or purpose. The issue of water availability is closely linked with water quality. The water quality management in India is performed under the provision of Water (Prevention and Control of Pollution) Act, 1974. The basic objective of this Act is to maintain and restore the wholesomeness of national aquatic resources by prevention and control of pollution. The Act does not define the level of wholesomeness to be maintained or restored in different water bodies of the country. The Central Pollution Control Board (CPCB) has defined the wholesomeness in terms of protection of human uses, and thus, taken human uses of water as base for identification of water quality objectives for different water bodies in the country. It was considered ambitious to maintain or restore all natural water body at pristine level. Planning pollution control activities to attain such a goal is bound to be deterrent to developmental activities and cost prohibitive. Since the natural water bodies have got to be used for various competing as well as conflicting demands, the objective is aimed at restoring and/or maintaining natural water bodies or their parts to such a quality as needed for their best uses. Thus, a concept of "designated best use" (DBU) was developed. According to this concept, out of several uses a water body is put to, the use which demands highest quality of water is termed as "designated best use", and accordingly the water body is designated. Primary water quality criteria for different uses have been identified. A summary of the use based classification system is presented in Table 1.6.

Table 1.6. Use Based Classification of Surface Waters in India

Designated Best Use	Quality Class	Primary Quality Criteria
Drinking water source without conventional treatment, but with chlorination	A	6.5 to 8.5 (1); 6 or more (2); 2 or less (3); 50, not >5% 200. and not >20%-50 (4); NIL (5 - 8)
Outdoor bathing (organised)	B	6.5 to 8.5 (1); 5 or more(2); 3 or less (3); 500, not >5%-2000, and not >20%-500(4); NA (5- 8)
Drinking water source with conventional treatment	C	6.5 to 8.5 (1); 4 or more (2); 3 or less (3); 5000, not >5%-20000, and not >20%-5000 (4); NA (5 – 8)
Propagation of wildlife and fisheries	D	6.5 to 8.5 (1); 4 or more (2); NA (3 - 4); 1.2 (5); NA (6 - 8)
Irrigation, industrial cooling, and controlled waste disposal	E	6.0 to 8.5 (1); NA (2 - 5); 2250 (6); 26 (7); 2 (8)

(1) pH, (2) dissolved oxygen, mg/l (3) BOD,(20c) mg/l (4)total coliform (MPN/100ml)(5)free ammonia mg/l, (6) electrical conductivity in micromhos/cm, (7) Sodium adsorption ratio, and (8) boron mg/l, NA = Not applicable

The entire water resources of the country were classified according to their designated best uses by Central Pollution Control Board (CPCB). For identification of the water bodies or their parts where water quality is at variance with water quality criteria, measurement of water quality carried to identify the water bodies or their parts which are in need of improvement (restoration). Based on monitoring of aquatic resources, large numbers of water bodies were identified as polluted for taking appropriate measures to restore their water quality. Today almost all policies and programmes on water quality management are based on this concept including the Ganga Action Plan, National River Action Plans and National Ganga River Basin Plan. Water quality testing is an important part of environmental monitoring. When water quality is poor, it affects not only aquatic life but the surrounding ecosystem as well.

Water quality monitoring carried by CPCB revealed that organic matter & bacterial population of fecal origin continue to dominate the water pollution problem in India. The Organic pollution as measured through Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) is considerably high, water bodies are saprobic followed by eutrophicated near large urban centres due to the discharge of partly treated or untreated wastewater. This results in depletion of oxygen in these stretches of water bodies.

The rivers and lakes in hilly part of the country are not affected significantly by such pollution, as there are no large urban centres. Although, high BOD is associated with low Dissolved Oxygen (DO), but many times DO measurement does not reflect such conclusion due to the fact that the DO is measured during daytime when the photosynthetic effects are prominent. In such stretches of water bodies, the diurnal variation in dissolved oxygen is quite large. The dissolved oxygen during daytime increases to super saturation level whereas at night at the same place the dissolved oxygen goes as low as below detection limit.

The pathogenic pollution is also one of the major water pollutants in Indian water bodies the main cause for water borne disease. The majority of surface water sources are contaminated with high levels of Faecal Coliform bacteria, which are indicators of pathogenic pollution.

The water quality of major rivers varied widely with respect to DO, BOD, Total Coliform (TC) and Faecal Coliform (FC). The level of DO is observed more than 4 mg/l in river Tapi, Narmada, Brahmini, Brahmaputra, Subarnarekha and Beas throughout the year, whereas the lowest values are observed in stretches of river Yamuna (0.1 mg/l), Sabarmati (0.6 mg/l), Mahanadi (1.3 mg/l) Ghaggar (2.6 mg/l) and Godavari (3.1 mg/l) at few locations downstream of urban settlements due to discharge of untreated/partially treated municipal wastewater, which is responsible for high oxygen demand.

Very high values of Biochemical Oxygen Demand (BOD) are observed in river(s) Sabarmati (475 mg/l) followed by Ghaggar (180 mg/l), Godavari (78mg/l), Satluj (45mg/l),Yamuna (36 mg/l), Cauvery (27mg/l), Ganga (17mg/l), Krishna and Tapi (10 mg/l each), Mahanadi (8mg/l) and Brahmani (6mg/l). The relatively low values of BOD are measured in river(s) Mahi, Narmada, Brahmaputra and Beas.

In respect of Total Coliform and Faecal Coliform Numbers, river Yamuna is leading with highest count of 2.6 billion MPN/100 ml and 1.7 million MPN/100 ml respectively, followed by Sabarmati (28 million and 2.8 million), Ganga (25 million and 11 million), Brahmaputra (240,000 and 24,000), Cauvery (160,000 and 28,000), Brahmani(90,000 and 60,000),Satluj (35,000 and 3500),Krishna (33,300 and 10,000), Mahanadi (30,000 and 17,000), Baitarni (22,000 and 11,000), Ghaggar (14,000 and 2500) and Godavari (5260 and 3640) at certain locations. The river Mahi, Tapi and Narmada are relatively clean rivers as the number of Total Coliform and Faecal Coliform count are relatively less than 2400 MPN/100 ml and 210 MPN/100 ml respectively. The results of conductivity, pH, temperature, nitrogen, phosphate and major ions measurement revealed that conductivity is conforming to the irrigation requirement in most of the rivers except estuarine parts. The minimum level of conductivity observed in upper stretches of the rivers ranging between 28-320 micromhos/cm. In estuarine region due to tidal influence the conductivity shoots up ranging between 11050 micromhos/cm for Krishna estuary to 53100 micromhos/cm for Cauvery estuary.

The nutrients like nitrates & phosphate are enriched downstream of major towns along the rivers due to discharge of wastewater & solids. In such stretches eutrophication at various levels was observed. The pH was observed in the range of 6-9 in all the rivers except Sabarmati & Amlakhadi, where it was abnormally low 1.5 to 2.5 due to discharge of industrial wastewater. The hardness varies between 50-300 mg/L in most of the rivers. However, some river stretches are having hardness as high as 1000 to 3000 (Ambika, Mandovi, Khari, Par & Bhadar). Similarly, alkalinity varies between 50-200 mg/L. Conductivity, total dissolved solid, sodium & chloride showed parallel pattern in most of the rivers. The conductivity in Himalayan rivers & upper stretches of rivers in Kerala is observed very low (20 to 150 micromhos/cm). The rivers in plane are having conductivity in the range of 150-700 micromhos /cm. However, some stretches of the river or their tributaries showed high level of conductivity (800-2800 micromhos/cm). Similarly, rivers in Kerala, Himachal Pradesh & Upper Stretches of most of the rivers are having dissolved solids, sodium & chloride in the range of 50 to 700 mg/L, 6 to 400 mg/L & 10 to 500 mg/L respectively. However in some minor rivers like Ambika, Amlakhadi, Bhadar, Khari, Mandovi & Par were found abnormally high. An abridged status of Water Quality of Indian Rivers is presented in Table 1.7.

Table 1.7: Water Quality of Indian Rivers

River	Range of Water Quality							
	Temp. ^{0}C	**PH**	**Conductivity (µmhos/cm)**	**DO (mg/l)**	**BOD (mg/l)**	**COD (mg/l)**	**Total Coliform (MPN/100 ml)**	**Faecal Coliform (MPN/100 ml)**
Ganga	3-34	6.4-9.0	19-2720	2.7-11.5	0.5 – 16.8	1-30	300-25x10^5	20-11x10^5
Yamuna	3-34	6.7-9.8	56-1959	0.1-22.7	1.0 – 36	1-112	27-26.3x10^6	11-17.2x10^5
Sabarmati	12-32	2.9-8.6	269-13530	0.6-7.9	0.8 – 475	4-1794	210-28x10^5	28-28x10^5
Mahi	19-34	7.1-9.2	175-5720	0.2-8.5	0.1 – 3.0	9-163	3-2400	3-75
Tapi	20-40	7.4-9.0	76-700	4.8-8.8	0.6 – 10.0	8-40	40-2100	2-210
Narmada		6.9-9.3	102-1341	5.8-9.8	0.1 – 3.8	6-47	9-2400	2-64
Godavari	22-35	7.0-	118-1400	3.1-	0.5 –	3-96	8-5260	2-3640

		9.0		10.9	78.0			
Krishna	18-33	6.8-9.5	28-11050	2.9-10.9	0.2 – 10.0	3-88	17-33300	3-10000
Cauvery	21-37	2.0-9.2	31-53100	0.1-12.6	0.1 – 26.6	**30**	39-160000	2-28000
Mahanadi	18-38	7.3-8.9	114-15940	1.3-10.4	1.0 – 7.6	7-39	15-30000	50-17000
Brahmani	20-38	7.0-8.4	81-376	5.2-9.8	1.5 – 6.0	8-13	80-90000	40-60000
Baitarni	24-36	7.3-8.3	54-78400	6.8-9.3	2.0 – 6.8	7	900-22000	700-11000
Subarnarekha	18-36	6.5-8.0	113-355	5.2-8.5	0.2 – 12.0	4-96	150-1800	70-540
Brahmaputra	15-32	6.5-9.0	104-684	1.1-10.5	0.1 – 3.9	6-11	360-240000	300-24000
Pennar	-	7.5-8.7	364-978	6.0-9.3	1.0 – 2.9	14-16	-	-
Satluj	9-32	6.8-8.8	131-819	3.8-11.4	0.1 – 45.0	1-80	8-35000	2-3500
Beas	3-32	7.1-8.7	53-517	5.2-11.5	0.3 – 5.0	1-13	2-2400	2-1600
Ghaggar	11-33	7.0-9.5	320-1012	2.6-9.6	1-180	4-560	43-14000	9-2500
Amlakhedi	27-32	1.7-7.2	7160-16770	0-0	485 – 1561.6	1821-3860	28-1100	3-28
Kali East	15-30	7.2-8.7	24-1930	6.7-11.9	1.9 – 67.0	66-421	2100-48000000	100000-360000

Ground Water Quality and Health of Rural Population

The rural population of India comprises more than 900 million people residing in about 1.42 million habitations spread over 15 diverse ecological regions. Rural India is characterised by non-uniformity in level of awareness, socio-economic development, education, poverty, practices and rituals which add to the complexity of providing drinking water to such a large population is an enormous challenge. The health burden of poor water quality is enormous. It is estimated that around 37.7 million Indians are affected by waterborne diseases annually, 1.5 million children are estimated to die of diarrhoea alone and 73 million working days are lost due to waterborne disease each year. The resulting economic burden is estimated at about 4000 crore rupees a year.

The problems of chemical contamination are also prevalent in India with 1, 95,813 habitations in the country are affected by poor water quality. The major chemical parameters of concern are fluoride and arsenic. Iron is also emerging as a major problem with many habitations showing excess iron in the water samples. The provision of clean drinking water has been given priority in the Constitution of India, with Article 47 conferring the duty of providing clean drinking water and improving public health standards to the State.

The government has undertaken various programmes since independence to provide safe drinking water to the rural masses. Till the 10th plan, an estimated total of about one lakh crore spent on providing safe drinking water. One would argue that the expenditure is huge but it is also true that despite such expenditure lack of safe and secure drinking water continues to be a major hurdle and a national economic burden. On one hand the pressures of development is changing the distribution of water in the country, access to adequate water has been cited as the primary factor responsible for limiting development.

The average availability of water is reducing steadily with the growing population and it is estimated that by 2020 India will become a water stressed nation. Groundwater is the major source of water in our country with 85% of the population dependent on it. While accessing drinking water continues to be a problem, assuring that it is safe is a challenge by itself. Water quality problems are caused by pollution and over-exploitation.

The rapid pace of industrialisation and greater emphasis on agricultural growth combined with financial and technological constraints and non-enforcement of laws have led to generation of large quantities of waste and pollution. The problem is sometimes aggravated due to the non-uniform distribution of rainfall. Individual practices also play an important role in determining the quality of water.

Water quality is affected by both point and non-point sources of pollution. These include sewage discharge, discharge from industries, run-off from agricultural fields and urban run-off. Water quality is also affected by floods and droughts and can also arise from lack of awareness and education among users. The need for user involvement in maintaining water quality and looking at other aspects like hygiene, environment sanitation, storage and disposal are critical elements to maintain the quality of water resources.

The government policies and programmes have also undergone a series of transition ever since independence. To begin with, the emphasis was on setting up physical infrastructure in form of hand pumps. Thereafter one has seen a transition from technology measures to a socio technological approach seeking close participation of people. A national water policy was drafted in 1987 which was subsequently revised in 2002. For ensuring sustainability of the systems, steps were initiated in 1999 to institutionalise community participation in the implementation of rural drinking water supply schemes through the sector reforms project. Sector Reform ushers in a paradigm shift from “Government oriented supply driven approach” to “People oriented demand responsive approach”.

Water quality monitoring is now being considered an important part of the government programme. Since 2000, water quality monitoring has been accorded a high priority and institutional mechanisms have been developed at national, state, district, block and panchayat levels. The government has also outlined requisite mechanisms to monitor the quality of drinking water and devise effective Information, Education and Communication (IEC) interventions to disseminate information and educate people on health and hygiene.

The Government of India launched the National Rural Drinking Water Quality Monitoring and Surveillance Programme in February 2006. This envisages institutionalisation of community participation for monitoring and surveillance of drinking water sources at the grassroots level by gram panchayats and Village Water and Sanitation Committees, followed by checking the positively tested samples at the district and state level laboratories.

One major problem when it comes to addressing the problems related to water is that the provisions for water are distributed across various ministries and institutions. With several institutions involved in water supply, intersectoral coordination becomes critical for the success of any programme. When it comes to dealing with maintaining water quality, the users and in large the communities have to play a key role in maintaining hygiene near water sources. One has to improve the ways in which we collect and store water so as to avoid contamination while collection, storage and use. With the decentralisation of programmes for water supply it is essential that communities and institutions like panchayats are actively involved in the planning, implementation and execution of programmes for water supply. These institutions will also have to undertake the monitoring of water sources and be made aware so simple remedial measures. It is true that this will require training and capacity building at a large scale. There can be little doubt that water is a basic necessity for the survival of humans. There is interplay of various factors that govern access and utilisation of water resources and in light of the increasing demand for water it becomes important to look for holistic and people-centred approaches for water management.

Consequences of Water Pollution

Almost all human activities can and do impact adversely upon the water. Water Quality is influenced by both diffuse pollution from farming and point source pollution from urban and rural populations, sewage treatment, industrial discharge and farming as principal sources. For agriculture, the key pollutants include nutrients, pesticides, sediment and faecal microbes. Oxygen consuming substances and hazardous chemicals are more associated with point source discharges. The pollution can take many forms and have different effects on the users.

Faecal contamination from sewage makes water aesthetically unpleasant and unsafe for recreational activities, such as swimming, boating or fishing. Many organic pollutants, including sewage effluent as well as farm and food-processing wastes consume oxygen, suffocating fish and other aquatic life. This contamination can affect groundwater resources used for drinking water purposes.

Nutrients, such as nitrates and phosphates, from farm fertilizers to household detergents can 'over fertilize' the water causing the growth of large mats of algae; some of which can be toxic. When the algae die, they sink to the bottom, decompose, consume oxygen and damage ecosystems. Due to the percolation of nutrients to shallow aquifers the chemical conditions in those aquifers tend to change. Pesticides and veterinary medicines from farmland and chemical contaminants, including heavy metals, and some industrial chemicals led to threaten wildlife and human health. Some of these damage the hormonal systems of fish, causing ‘feminisation’.

Metals, such as zinc, lead and cadmium are extremely toxic. Copper complexes are less toxic, and cobalt and ferrous complexes are only weak toxicants. Concentrations of cyanides in waters intended for human use, including complex forms, are strictly limited because of their high toxicity. Organic micro-pollutants, such as pharmaceuticals, hormones and chemical substances used in products and households can also threaten health. Chlorinated hydrocarbons exist in the natural systems, several of which are highly toxic to humans. These molecules tend to stay in the environment for a longer time, and threaten to contaminate aquatic and soil systems.

Sediment runoff from the land can make water muddy, blocking sunlight and, as a result, kill wildlife aquatic life. Irrigation, especially when used improperly, can bring flows of salts, nutrients and other pollutants from soils into water. All these pollutants can also make the water unsuitable for drinking purposes.

Ecological quality and Water Quality are also influenced by the physical management of rivers and aquifers and the wider hydrological and hydrogeological environment of a river basin. Changes and disruptions in natural habitats, such as bank-side vegetation, can result from the physical disturbance through damming, canalization and dredging of rivers, construction of reservoirs, river bank management and other changes to the hydrological flow, sand and gravel extraction in coastal waters, and bottom trawling by fishing vessels, etc. Pebble riffles where salmon and other fish spawn can also be destroyed. Seasonal flow patterns that are vital to many species can also be changed, as well as the connectivity between habitats, a very important factor for the functioning of aquatic ecosystems and for the development of the different life stages of aquatic organisms. In urban agglomerations, storm water carrying contamination from streets and roofs can contribute to water pollution if discharged directly into water bodies.

Plants and animals aquatic life such as planktons and benthos in lakes, rivers and seas react to changes in their environment caused by changes in chemical Water Quality and physical disturbance of their habitat. Changes in species composition of organism groups like phytoplankton, algae, macrophytes, bottom-dwelling animals and fish can be caused by changes in the climate. They can also indicate changes in Water Quality caused by eutrophication, organic pollution, hazardous substances or oil, and hydrological regime.

Over time, with the advent of industrialization and increasing populations, the range of requirements for water has increased together with greater demands for higher quality water, such as for drinking and personal hygiene, fisheries, agriculture (irrigation and livestock supply), navigation for transport of goods, industrial production, cooling in fossil fuel (thermal, gas and later also in nuclear) power plants, hydropower generation, heat/cold storage in aquifers, recreational activities such as bathing or fishing and nature conservation like wetlands. Fortunately, the largest demands for water quantity, such as for agricultural irrigation and industrial cooling, require the least in terms of water quality (i.e. critical concentrations may only be set for one or two variables). Drinking water supplies and specialized industrial manufacturers exert the most sophisticated demands on water quality but their quantitative needs are relatively moderate. In parallel with these uses, water has been considered the most suitable medium to clean, disperse, transport and dispose of wastes (domestic and industrial wastes, mine drainage waters, irrigation returns, etc.).

Each water use, including abstraction of water and discharge of wastes, leads however to specific, and generally rather predictable, impacts on the quality of the aquatic environment. In addition to these intentional water uses, there are several human activities which have indirect and undesirable, and sometimes devastating, effects on the aquatic environment. Examples are uncontrolled land use for urbanisation or deforestation and associated soil erosion, accidental or unauthorised release of chemical substances, and discharge of untreated wastes or leaching of noxious liquids from solid waste deposits. Similarly, the uncontrolled and excessive use of fertilisers and pesticides has long-term effects on ground and surface water resources. Restoration of the natural Water Quality after such events often takes many years, depending on the geographical scale and intensity of the event.

Pollution of groundwater arises commonly from the percolation of polluted water from the surface, but also from leaching from contaminated soil, dissolution from oil or dense non-aqueous phase liquids. When polluted water penetrates to the point of abstraction the consequences are serious. Because of the slow rate of travel of the water in the aquifer and the large volume of subterranean water there is usually a considerable time lag between the casual activity and the appearance of the pollutant in the abstracted water. This will vary according to the hydraulic conductivity, the hydraulic gradient and the porosity. For similar reasons the time required to flush out the polluted water will be long, even longer because of the "drag out" effect. Under such circumstances the recovery process is sometimes regarded as irreversible and the source abandoned.

The continuing increase in socio-economic activities world-wide has been accompanied by an even faster growth in pollution stress on the aquatic environment. Discharges from wastewater treatment plants and industry may cause pollution by oxygen consuming substances, nutrients and hazardous substances. The adverse impacts depend very strongly upon the degree to which (if at all) such discharges are treated before reaching waterways or whether such pollutants are degraded by the natural system itself.

By its very nature, the management of diffuse pollution is complex and requires the careful analysis and understanding of various natural and anthropogenic processes. The estimation of non-point diffuse loading from the different processes to a water body is not easy, because so many different factors affect quantity and temporal variations.

Modern day agricultural practices often require high levels of fertilizers and manure; leading to high nutrient (e.g. nitrogen and phosphorus) surpluses that are transferred to water bodies and groundwater through various diffuse processes. Excessive nutrient concentrations in water bodies, however, cause adverse effects by promoting eutrophication, with an associated loss of plant and animal species. In high nutrient waters with sufficient sunlight, algal slimes can cover stream beds, plants can choke channels, and blooms of plankton can turn the water murky green. Oxygen depletion, the introduction of toxins or other compounds produced by plants, reduced water clarity and fish kills can also result. Excess nutrient levels can also be detrimental to human health.

Pesticides used in agriculture are transported to both surface and groundwaters. Not only do they threaten both wildlife and human health, but also the excessive sediment runoff from agricultural land results in turbid waters and the clogging of spawning areas. This in turn leads to loss of aquatic habitats. Microbial pathogens from animal faeces also can pose a significant health risk. High concentrations can restrict the recreational and water supply uses of water, cause illness and loss of productivity in cattle, and limit shellfish aquaculture in estuaries.

In urban areas, where surface runoff is not connected to treatment works, pollutants deposited on to impervious surfaces (e.g. roads or pavements) are washed into nearby surface waters or percolate towards the shallow groundwater. Such pollutants include metals, pesticides, hydrocarbons, solvents, etc., as well as also those derived from various sources including the atmosphere and the abrasion of roads, tyres and brakes. In some urban areas, surface runoff is discharged into sewers, which then mixes with sewage on its way to treatment. During periods of large rainfall, the sewage system is unable to cope with the volume of water. As a result, the flow is directed away from the treatment works and discharged as a combined sewer overflow (CSO) to surface water. This causes pollution from not only sewer waste but also urban runoff. In this respect, urban diffuse pollution ultimately becomes a point source.

1.4 Causes and Types of Water Pollution

Water pollution is the contamination of natural water bodies (e.g. lakes, rivers, sea, ocean, aquifers, ground water etc.). This form of environmental degradation occurs when pollutants are directly or indirectly added into the water bodies without proper treatment to remove harmful compounds.
The causes of water pollution include a wide range of chemicals and pathogens as well as physical parameters. Contaminants may include organic and inorganic substances. Elevated temperatures can also lead to pollution of water. A common cause of thermal pollution is the use of water as a coolant by power plants and industrial manufacturers. Elevated water temperatures decrease oxygen levels, which can kill fish and alter food chain composition, reduce species biodiversity, and foster invasion by new thermophilic species.

If pollution comes from a single location, such as a discharge pipe attached to a factory, it is known as point-source pollution. If pollution comes from one single source but from many different scattered sources. This is called nonpoint-source pollution.

General sources of water pollution are point and non point contaminant sources. Point sources of water pollution include urban sewage and industrial effluent outfalls from factories etc. that discharge fluids of varying quality directly into water bodies.Non point sources of water pollution include contaminants that enter the water supply from soils/groundwater systems and from the atmosphere via rain water. Soils and groundwaters contain the residue of human agricultural practices (fertilizers, pesticides, etc.) and improperly disposed of human and industrial wastes. Atmospheric contaminants are also derived from human practices (such as gaseous emissions from automobiles, factories and even burning of waste material).

The substances which are responsible for causing water pollution are called water pollutants. Based on source, water pollutants can be classified as domestic wastes and sewage; surface run-off and industrial effluents. Domestic waste and sewage is the biggest polluter of surface and ground water sources in India. This is due to the big lacuna between the amount of sewage generation and the facilities to dispose it off. The problem is not only the lack of facilities; rather, the non-functioning of existing facilities / treatment plants is more critical.

The pollutants present on the surface of land, fertilizers, and pesticides added to the soils are washed down into natural water courses during rains. The flow of fertilizer rich water into streams and lakes gives rise to eutrophication. Excess of pesticides in water also adversely affect the aquatic life.

Effluents generated from industries which are directly disposed off into the water streams without any treatment cause of water pollution. Industrial wastes contain a number of toxic chemicals such as mercury (Hg), lead (Pb), cadmium (Cd), arsenic (As) etc. Several types of liquid effluents having toxic chemicals, acids and bases, etc. are also added into the rivers which kills fish and other aquatic life besides being toxic to human beings. Examples of large scale effluent addition into the rivers are Yamuna (near Okhla, Delhi), Gomti (near Lucknow), Ganga (near Kanpur), and Hoogli (near Kolkata), Musi (near Hyderabad), Godavari (near Nasik) etc.

Discharge of effluent above the normal range of temperature is called as thermal pollution. Thermal pollution occurs as a result of the entry of heated water from industries and power generation plants. Various processes involved in generating thermal pollution are water for cooling condensers, feeding boilers for steam generation, auxillary plant cooling, ash handling etc.

The immediate effect of an increase in temperature is a decrease in the oxygen concentration. A temperature rise of 10°C double the rate of many chemical reactions and so the decay of the organic matter, rusting of iron, and the solution rate of salts are accelerated. All organisms have a range of temperature tolerance beyond which they either die or move to more congenital conditions downstream.

Effects of Water Pollutants

Water pollution is very serious problem as it affects all spheres of life of human, animals, ecosystem, plants and economic loss. In countries where there are scanty facilities for treating waste water, people often get exposed to various water-borne diseases such as cholera, diarrhea, etc. In severe cases, there may be the outbreak of diseases like Hepatitis, tuberculosis, malaria, encephalitis, filariasis etc. As per the report of World Health Organization (WHO), approximately 3.4 million people die of water-borne diseases every year in the world. In developed countries, even where there are better purification practices, people still suffer from the health effects of water pollution. Excess nitrogen in drinking water also poses serious risks to infants.

Nutrient pollution from land flows down and contaminates the larger water body. It in turns, promotes the algae growth and subsequently growth of many more water organisms takes place. The excess growth of algae affects the fish and other aquatic organisms by absorbing and reducing their oxygen supply. Fishes also die off due to clogging of their gills as a result of algal growth. Thus, the aquatic ecosystems are affected very adversely disturbing all the food chains.

Animals, both aquatic and terrestrial, are prone to risks generated from the waste water. In a classic case of marine pollution in recent time, 16000 miles of a US coastline was affected by an oil spill. In this case, death of many animals has been reported and there was great loss to aquatic fauna. Animals are also affected by the solid waste thrown into the water bodies, as it harm them in many ways.

It is quite obvious that increasing water pollution lead to the excessive pressure on the existing treatment plants as well as the establishment of new treatment plants. Fishing industry is affected badly as the fishes die due to depletion of oxygen. Recreational and tourism sectors are also affected negatively as lots of money needs to be spent to clean up the water from algae blooms etc.

Water pollution in natural water bodies can be identified and quantified on the basis of various parameters, such as, dissolved oxygen (DO), biochemical oxygen demand (BOD), coliform organisms, pH etc. As per the water quality criteria, the DO levels in source water for drinking water treatment plant should be between 4-6 mg/L and BOD levels should be between 2-3 mg/L. Moreover Total Coliforms level should not exceed 5000 MPN/100 ml in water which is safe for various beneficial purposes as source water. If the water quality of any source is not complying with these criteria, the water cannot be used for drinking purpose without undergoing complete treatment and for mass bathing.

Water pollution can be controlled by diluting the water pollutants and accordingly discharge norms are devised but due to inadequate dilution availability treatment of wastewater are necessitated. The various methods for the control of water pollution can be adopted for sewage pollutants to be treated in sewage treatment plants before their discharge in natural water bodies or the pollution due to organic insecticides and pesticides can be reduced by the use of very specific and less stable chemicals in the manufacture of insecticides/pesticides. Moreover, use of bio-fertilizers needs to be promoted. Thermal pollution can be reduced by employing techniques such as cooling, cooling ponds, evaporative or wet cooling towers and dry cooling towers. Strict implementation of legislations for water treatment should be done. No solid waste should be dumped into water bodies. Dead bodies of animals/human should not be immersed in water sources. Bathing, washing of clothes, and idol immersion should be strictly restricted in natural water bodies.

Types of Water Pollution

The water pollutants are broadly categorized as organic pollutants, suspended organic and inorganic, inorganic dissolved salts and metals, Pathogenic microorganism and nutrients. There are industry specific pollutants based on the process and the product.

Organic pollutants are oxygen demanding wastewater comprising of municipal sewage, Industrial effluent from food processing industries, canning industries, slaughter houses, paper and pulp mills, tanneries, breweries, distilleries, etc. have considerable concentration of biodegradable organic compounds either in suspended, colloidal or dissolved form. These wastes undergo degradation and decomposition by bacterial activity. The Synthetic Organic Compounds such as pesticides, synthetic detergents, food additives, pharmaceuticals, insecticides, paints, synthetic fibers, plastics, solvents and volatile organic compounds (VOCs). Most of these compounds are toxic and resistant to microbial degradation. Even concentration of some of these in traces may make water unfit for different uses. The sewage and industrial effluents from agro based sector and agriculture run-off contains substantial concentration of nutrients like nitrogen and phosphorous. Disposal of wastewater from these sources stimulate the growth of algae and other aquatic weeds in receiving waters and reduces DO, leads to eutrophication.

The suspended organic and inorganic pollutants are comprised of food fiber in the sewage, plant residue in industrial effluents and inorganic silt particles. These are contributed in the water courses through municipal sewers and the runoff Presence of suspended solids block the sunlight penetration in the water, which is required for the photosynthesis by benthic flora and fauna. Settling of suspended solids in the rivers impair the aquatic life and impact diversity of the aquatic ecosystem undergoes decomposition leading to Creation of anaerobic conditions. The heavy metals and other inorganic pollutants contributed by sewage and industrial effluents also contaminate the water. These compounds are non-biodegradable and persist in the environment. These pollutants include mineral acids, inorganic salts, trace elements, metals, metals compounds, complexes of metals with organic compounds, cyanides, sulphates, etc. The accumulation of heavy metals may have adverse effect on aquatic flora and fauna and may constitute a public health problem where contaminated fish and other organisms are used for food.

The pathogenic microorganisms are largely discharged through sewage and discharge as a major source or through the wastewater from industries like slaughterhouses. Viruses and bacteria can cause water borne diseases, such as cholera, typhoid, dysentery, polio and infectious hepatitis in human.

Besides the organic matter discharged in the water body through sewage and industrial wastes, high concentration of heavy metals and other inorganic pollutants contaminate the water. These compounds are non-biodegradable and persist in the environment. These pollutants include mineral acids, inorganic salts, trace elements, metals, metals compounds; complexes of metals with organic compounds, cyanides, sulphates, etc. The accumulation of heavy metals adversely affects to aquatic flora and fauna and constitutes a public health problem where contaminated organisms are used for food. Ministry of Environment Forests and Climate Change notified general discharge standards under Environment (Protection) Act, 1986 for various recipient water systems with maximum allowable concentration for pollutants to regulate the sources of pollution.

1.5 Biohazard, Radiation, Security Threat

Biohazard

Biohazard due to bio-medical waste is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities pertaining thereto or in the production or testing of biological products. It include wastes like human anatomical waste, animal waste, microbiology & biotechnology waste, waste sharps, discarded medicines & cytotoxic drugs, soiled waste, solid waste, liquid waste, incineration ash, chemical wastes. These wastes are potentially hazardous because of the potentially infectious in nature as it may pose a serious threat to human health, if its management is indiscriminate and unscientific. Earlier, bio-medical waste management was not an integral part of the health care programme. The negligence on the part of health care waste management is evident from the sporadic epidemics experienced in different parts of the Country. There should be emphasis on segregation of bio-medical waste at source of generation. Segregation of wastes at source of generation helps to minimize mixing of bio-medical waste with that of the sewage and municipal solid waste generated within the health care facilities; to reduce volume of waste to be handled/treated; to minimize cost of treatment; to minimize toxic emissions; and to facilitate effective recovery of useful plastics etc. Bio- Medical waste is divided into ten waste categories and the category-wise bio-medical waste treatment and disposal option by following the type of colour coded container or bag.

Biological Hazards and Superbugs

Swine flu, bird flu, HIV-Aids, re-emergence of polio, Nipah virus, Hepatitis-C, are biohazards one might have heard of. Biological hazards are frank and opportunistic pathogens, such as bacteria, viruses, fungi, protozoa or helminthes. They may get released into the water, or increase in number due to a hazardous event- an incident or a situation. Biological hazard may happen at any point or all over the water system- from catchment area to the consumer. The risk depends on the time frame, population exposed, the magnitude of harm, and its consequences. It is not practical or necessary to completely eliminate microorganisms from drinking water. However, the number of pathogens should be kept under acceptable levels. Contamination by pathogens originating from faecal matter- of human and animal origin- needs to be prevented. This is possible by avoiding back-flow of water after it is disinfected.

Emergence of 'superbugs' like MRSA bacteria (Methicilin resistant Staphylococcus aureus); E. coli related urinary tract infections, drug-resistent Salmonella, is increasing every year. Pharmaceutical pollution, improper hospital waste management and rampant use of antibiotics without medical prescription are some of the reasons why superbugs are on the rise.

Chemical Hazards

Chemical hazards too can compromise water security. Examples are chemicals from the catchment, such as nitrates, arsenic, fluoride and pesticides, chemicals from reservoir storage, such as algal toxins, cleaners, liner chemicals, lubricants, etc, or chemicals from the water treatment process, such as flocculants, pH adjusters, by-products of disinfectants and also chemicals from distribution systems, for instance copper lead, petroleum or cleaners . Physical biohazards could be sloughed off biofilm containing millions of bacteria, as well as sediments and re-suspended particulates with pathogens attached to them.

To prevent such risks, a water safety plan team should be in place. They should study influencing factors such as variation in weather, accidental or deliberate contamination, waste water treatment practices, control practices at the source of pollution, water treatment practices, sanitation, hygiene, distribution and maintenance practices, receiving and storage practices as well as intended use of water.

Radiation Pollution

Any activity related to the nuclear fuel cycle, that produces or uses radioactive materials generates radioactive waste. The management of radiation emitting radioactive material is a matter of concern and is what sets nuclear wastes apart. Public acceptance of nuclear energy largely depends on the public assurance for safe management of radioactive wastes. Not all nuclear wastes are particularly hazardous or hard to manage as compared to other toxic industrial wastes. It is also a time of heightened global concern about nuclear energy after the earthquake and the fear of the radioactive releases from the affected damaged reactors in Japan. In accordance with international guidelines, a coherent comprehensive and consistent set of principles and standards are being practiced all over the world for waste management system.

Radioactive wastes are generated during various operations of the nuclear fuel cycle. Mining, nuclear power generation, and various processes in industry, defense, medicine and scientific research produce byproducts that include radioactive wastes. Radioactive waste can be in gas, liquid or solid form, and its level of radioactivity can vary. The waste can remain radioactive for a few hours or several months or even hundreds of thousands of years. Depending on the level and nature of radioactivity, radioactive wastes can be classified as exempt waste, Low & Intermediate level waste and High Level Waste

Radiation is generated through detonation of nuclear weapons as well as during electricity generation in nuclear power plants. The presence of radiation pollution is difficult to sense, but the effects are devastating. It causes cancer, genetic disorders and leads to death.

Liquid wastes have generally high volumes and low levels of radioactivity. They are further classified as short lived and long lived wastes. Low level nuclear waste usually includes material used to handle the highly radioactive parts of nuclear reactors (i.e. cooling water pipes and radiation suits) and waste from medical procedures involving radioactive treatments or x-rays.

Significant quantum of solid LIL wastes of diverse nature gets generated in different nuclear installations. They are essentially of two types viz. primary wastes comprising of radioactively contaminated equipment (metallic hardware) spent radiation sources etc. and secondary wastes resulting from different operational activities, protective rubber and plastic wears, cellulosic and fibrous material, organic ion exchange resins filter cartridges and others.

The air in the working area and the environment is free from radioactive contamination. The off gas ventilation system in nuclear power plants play an important role in ensuring clean air. High level radioactive liquid waste (HLW) containing most (~99%) of the radioactivity in the entire fuel cycle is produced during reprocessing of spent fuel. Issue of the long lived radioactive waste has been the focal point of debate for the success of nuclear power. Planning for management of high level radioactive liquid waste waste thus takes into account the need for their effective isolation from the biosphere and their continuous surveillance for extended periods of time spanning several generations. To meet this objective in the long term, waste isolation systems comprising multiple barriers are employed so as to prevent the movement of radionuclides back to the human environment.

The primary objective should be of protecting human health, environment and future generations, the overall philosophy for safe management of radioactive wastes in India, is based on the concept of “Delay and Delay”; “Dilute and Disperse” and “Concentrate and Contain”.

The effective management involves segregation, characterization, handling, treatment, conditioning and monitoring prior to final disposal. Proper disposal is essential to ensure protection of the health and safety of the public and quality of the environment including air, soil, and water supplies. Radiological hazards associated with short lived wastes <30 years half life get significantly reduced over a few hundred years by radioactive decay. The high level wastes contain large concentration of both short and long lived radionuclide’s, warranting high degree of isolation from the biosphere and usually calls for final disposal into geological formation (repository).A key idea was that long-term disposal would be best carried out by identifying suitable sites at which the waste could be buried, a process called deep geological disposal.

Low level waste is comparatively easy to dispose of. The level of radioactivity and the half life of the radioactive isotopes in low level waste are relatively small. Storing the waste for a period of 10 to 50 years will allow most of the radioactive isotopes in low level waste to decay, at which point the waste can be disposed of as normal refuse.

This concerns management and disposal of highly radioactive materials created during production of nuclear power. High level radioactive waste is generally material from the core of the nuclear reactor or nuclear weapon. The waste includes uranium, plutonium, and other highly radioactive elements made during fission. Most of the radioactive isotopes in high level waste emit large amounts of radiation and have extremely long half-lives (some longer than 100,000 years) creating long time periods before the waste will settle to safe levels of radioactivity. The management of high level waste in the Indian context encompasses three stages viz. Immobilisation of high level liquid waste into vitrified borosilicate glasses; engineered interim storage of the vitrified waste for passive cooling & surveillance over a period of time, qualifying it for ultimate disposal; and Ultimate storage/disposal of the vitrified waste in a deep geological repository.

Summary

There are competing users of water and the irrigation remains one of the biggest users in India. The requirement of food for growing population shall be a management issue and the resource allocation for various users shall be a matter of concern. Irrigation being a consumptive user does not return water back in the system however a part of it gets feed to the aquifer system. The non consumptive user like household municipal users and industrial sector largely consume a small part of water and largely used water in the form of waste water return to aquatic system and pollute it. There is need to understand the consumers, pollution of return water and to make a synergy between them by in a business model based on techno economic feasibility.

To Do Activities

- Understand availability of fresh water in time and space at global level
- Understand population density, population growth and reducing per capita water availability.
- Understand the priority of development authorities on the resource consumption and efforts for restoration.
- Discuss on the perpetual difficulties in control of water pollution despite concerted efforts on allocating physical and financial resources.
- Develop passion among the youngsters for management of environment in sustainable manners
- Develop self help groups on raising the issues related to environmental degradation.

Self Assessment Questions

1. Whether the availability of water will always remain same despite increasing population?
2. How to augment water resources by reuse and recycling in the densely populated riparian system?
3. What are the sources of pollution and how to handle non consumptive users?
4. What are options of maintaining water balance among the competitive users?
5. How to deal with the climate change and extremities of floods and draughts to fulfill the requirement of water?

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Chapter 2 Waste Water Management

Introduction

Wastewater invariably generate when water is put to use for domestic as well as industrial sector. The sources of pollution are categorized as point and non-point. Point sources impacting the water resources in a significant manner whereas non-point sources are contributing only during the monsoon season only in the large part of Indian sub-continent. Thus the control of pollution from point sources is the prime requirement and accordingly required to be prioritized.

Water pollution from untreated municipal wastewater is an enormous problem in India with grave implications for public health as well as environmental quality. Even the big cities are struggling to put in place expensive wastewater treatment systems and associated infrastructure. It is implausible that such expensive infrastructure can contribute meaningfully to treat wastewater so that the water quality of recipient system is maintained for designated uses.

Low-cost, decentralized, bio-treatment systems have potential to improve the water qualityin terms of removing pollutants from municipal wastewater. Moreover, they are low-cost, quick to deploy, and easy to operate and maintain, making them ideal for India's sanitation context. They can be used extensively in rural areas, small towns, peri-urban areas of large cities, industrial townships or institutional campuses, as well as for certain types of industries such as agro-food/beverage.

Urbanisation in India is growing at a rapid pace and there may be significant enhancement in wastewater generation by middle of twenty first century. The pollution of aquatic resources shall further increase significantly from present levels unless concerted efforts are made by public authorities, communities and individuals in planning, execution and implementation of projects in right earnest besides raising awareness.

Objectives

- To understand the requirement of treatment of wastewater
- To understand the improvement of wastewater quality by various treatment methodologies
- To know treatment plant components and technologies evolution over the decades
- To understand the role of individuals in in contribution of load reduction in sewage treatment plants
- To know how to develop low cost decentralised sewage treatment technologies

2.1 Individual Responsibility towards Waste Water Production

Every person who uses water for daily activities including defecation invariably generate sewages. Whether we accept it or not, the same waste water returns to us, bringing with it a myriad of problems. It is advantageous to prevent water pollution at source. As an individual there are a few things that we can habituate ourselves to do which can reduce water pollution substantially. A pit latrine was the first system developed to improve the sanitation from age old practice of open defecation. These toilets are considered a temporary sanitation facility until a new system for hygienically treating excreta (e.g. a sewerage system or individual sewage treatment system) is constructed in each household in urban and rural hamlets. The toilets are classified roughly into four types according to application viz. a toilet in a detached house; a common toilet in an office or community; a public toilet for unspecified users; and a mobile toilet for mass gathering, congregations or during disaster.

A septic tank system, a typical on-site treatment facility that consists of a septic tank and a soak pit is further improvement of sanitation at individual household level that employs technologies of anaerobic treatment and letting the treated sewage penetrate the ground. It shows stable performance, provided that the water temperature is kept suitable to digestion and the soil has good permeability. However, the septic tank has a BOD reducing rate of up to 50%, so if underground penetration is not feasible due to high groundwater levels, rocky strata, non-availability of land for soak-pit, another method must be employed to hygienically treat sewage passing through the septic tank such as anaerobic filter and contact aeration. When this system is applied to an urban area with high population density, care must be taken not to have an effect on the surrounding environment.Conventional septic tanks system, if properly designed and with proper septage removal frequency is maintained then it can effectively remove about 40-50% organic matter measured as BOD and 50-70% Total Suspended Solids.

Due to rise in groundwater pollution related episodes, unavailability of space for soakage pits and under rocky strata, soakage pits are avoided and the effluent is commonly discharged to open storm water drains. It is causing another type of pollution menace such as unsightly conditions, eutrophication, odour, vector and water related diseases. Some of the interim solutions are the improved design of septic tanks such as anaerobic baffled reactor or the post treatment of septic tank effluents by anaerobic filters. Both configurations can partially solve the pollution related problems by increasing the overall BOD removal to more than 70%. These systems can lessen the burden of organic pollution without any extra energy cost. The capital cost of these systems may not be more than 20-30% of the conventional septic tank cost.

Nevertheless, due to the limitation of anaerobic sewage treatment, these systems cannot bring down the BOD and TSS levels up to the sewage discharge standards. Hence, alternate solution could be the aerobic type post treatment such as contact aeration. This system can bring down effluent BOD to less than 30 mg/l and TSS to less than 50 mg/l but at the expense of electrical power requirement for operating air blower with power.

One such system is the Japanese type Johkasou system. This system is an integrated septic tank comprising of anaerobic filter followed by contact aeration, final settling tank and effluent disinfection facility. However, due to high installation and operation and maintenance cost, these systems are not affordable by economically poor communities. This onsite sewage treatment system has also been upgraded for removal of nitrogen by providing internal recirculation. There are many other similar package treatment systems elsewhere which can also be used.

Manual Scavenging

The Manual Scavenging and Construction of Dry Latrines (Prohibition) Act, 1993 was enacted under Entry 6 of the State List (Public health and sanitation; hospitals and dispensaries). However, the intent of prohibition of Manual Scavenging is much broader than mere 'public health and sanitation', and is inextricably linked to the Constitutional guarantee to abolish untouchability in all its practices and forms for which the power to enact was directly derived from the Fundamental Rights & Directive Principles of State Policy. This is a social welfare legislations anchored in the fundamental rights enshrined in the Indian Constitution (Articles 15, 17, 21, 23).The practice of manual scavenging involves manual handling/carriage of human excreta by a person. It serves as a primary instrument to eradicate practice of manual scavenging. The Act defines manual scavenger as "a person engaged in or employed in manual carriage of human excreta". The definition of manual scavenging as per the Act, 1993 does not specifically cover manual cleaning of septic tanks and sewers cleaning, though it may be implied as "a person engaged or employed, whether by an individual or an urban local body or any other public or private agency, for manual cleaning, carrying or disposing untreated human excreta, including a latrine, a tank, a drain carrying sewage or a sewer line and railway track". There are established technologies that convert human excreta into manure in a scientific manner. Sewerage services should be human centric and made free from all forms of hazard and squalor by the urban local bodies. The Honourable Supreme Court of India and the Honourable High Courts across the Country have enforced a ban on manual cleaning of sewers and drains. Therefore, cleaning of sewers and septic tanks has to be done using mechanical devices. All urban local bodies should make efforts for mechanization of cleaning of sewers and onsite systems including septic tanks, etc. The sanitation workers shall be provided adequate protective devices and welfare measures. They shall be given proper training related to safety and health aspects. As an individual there are a few things that we can habituate ourselves to do which can reduce water pollution substantially.

There has been no major effort to create community awareness over the years either about the likely perils due to poor sewage management or the simple steps that every citizen can take which will help in reducing sewage generation and promote effective management of its generation and treatment. The degree of community sensitization and public awareness is low. There is no system of segregation of black water (from toilets) and grey water (other liquid wastes) at household level. In most of cities and towns no proper service connections have been provided to the toilets connecting to sewer collection system.

The recent initiative of Government of India towards Swacch Bharat Abhiyan has sensitized the public at large for developing facilities for open defecation free society. There is financial support to economically poor communities from government and the resultant outcomes are encouraging.

2.2 Community Responsibility towards Waste Water Disposal

Sanitation can be perceived as the conditions and processes relating to people's health, especially the systems that supply water and deal with human waste. Such a task would logically cover other matters such as, solid wastes industrial and other special/hazardous wastes and storm water drainage. However, the most potent of these pollutants is the sewage. When untreated sewage accumulates and is allowed to become septic, the decomposition of its organic matter leads to nuisance conditions including the production of obnoxious gases. In addition, untreated sewage contains numerous pathogens that dwell in the human intestine tract. Sewage also contains nutrients, which can stimulate the growth of aquatic plants, and may contain toxic compounds or compounds that are potentially mutagenic or carcinogenic. For these reasons, the immediate and nuisance-free removal of sewage from its sources of generation, followed by treatment, reuse, or dispersal into the environment in an eco-friendly manner is necessary to protect public health and environment.

The primary responsibility of sewage management lies with municipal authorities and accordingly infrastructure has to be developed for communities. In view of inadequate resources available with municipal authorities, development of facilities for collection and treatment of sewage from households has not taken place appropriately to the required levels.

The pollution of aquatic resources has highlighted the need to develop facilities for collection and treatment of municipal sewage. The Ministry of Environment Forests & Climate Change has notified rules for all the new construction projects for development of residential facilities beyond a certain area is required to provide sewage treatment plants as an integrated part of the project.

Communities should insist on first-level sewage treatment before letting out their waste water. If the treated water is of a quality suited for reuse in gardens, it should be used within the community. This way, the fresh water requirement can be reduced. There are many modern, compact and efficient versions of wastewater treatment plants available in the market today.

It is often the case that the drains open into the nearest river or lake without being treated. As individual home owners, or residents of a colony, one needs to ensure that water from your toilets move through a properly constructed septic tank before being let out into the common sewers. Ensure that no solid waste enters the drainage through your residential premises. Under no circumstances waste water be allowed to pollute the groundwater or be let into storm water drains.

If the community finds an individual or group polluting the waters, it should be reported to the pollution control board or civic body with evidence. The community elders should have a discussion with the polluting party and convince them that pre-treating their effluent is good for the entire community. Water is a common property- using clean water is everyone’s right, keeping it clean is everyone’s duty.

The complex question faced by the design and practicing engineers is: What levels of treatment must be achieved in a given type of treatment and beyond those prescribed by discharge standards have to ensure protection of the health of the community and the environment? The answer to this question requires detailed analyses of local conditions and needs, application of scientific knowledge and engineering judgment based on past experience, and consideration of Central, State, and Local regulations. In some cases, a detailed assessment is required. The reuse and disposal of sludge are vexing problems for some urban local bodies and need careful consideration.

2.3 Municipal Responsibility of Treating Waste Water

The Sewage treatment is mandated for municipal authorities under the provisions of Water (Prevention & Control of Pollution) Act 1974 and Environment (Protection) Act 1986 to solve the issues associated with the collection, treatment, disposal, and reuse of treated sewage. The ultimate goal is the protection of public health in a manner commensurate with environmental, economic, social, and political concerns. To protect public health and environment, it is necessary to have knowledge of constituents of concern in sewage and impacts of these constituents when sewage is dispersed into the environment. The transformation and long-term fate of these constituents in treatment processes, treatment methods which can be used to remove or modify the constituents found in sewage, and methods for beneficial use or disposal of solids generated by the treatment systems need careful deliberation.

Till late seventies sewerage and sanitation was not accorded due priority by urban local bodies. The impetus of International Drinking Water Supply and Sanitation Decade (IDWSSD), 1981-90, had produced considerable efforts in urban areas in the country to improve health by investment in water supply and sanitation programmes.These often comprise, in sewerage and sanitation sub-sector, construction of sewers, on-site sanitation facilities using various types of latrines. Under certain hydrological conditions,unsewered sanitation can cause severe groundwater contamination by pathogens and nitrate, which may largely negate the expected health benefits of such programs. In some circumstances, therefore, the low-cost-technologies may be incompatible.

Though the targets fixed for sewerage and sanitation coverage during the decade at the beginning of the IDWSSD were laudable, but could not be achieved due to resource constraints and other impending reasons. Due to these reasons, condition of sanitation has gone from bad to worse till a concept of river action plan have been introduced for highlighting the pollution of rivers by disposal of untreated sewage and a comprehensive action was taken to intercept and treat municipal sewage.

Wastewater Generation and Treatment

Sewerage and sewage treatment is a part of public health and sanitation, and according to the Indian Constitution, falls within the purview of the State List. Since this is non-exclusive and essential, the responsibility for providing the services lies within the public domain. The activity being of a local nature is entrusted to the urban local bodies, which undertake the task of sewerage and sewage treatment service delivery, with its own staff, equipment and funds. In a few cases, part of the said work is contracted out to private enterprises. Cities and towns which have sewerage and sewage treatment facilities are unable to cope-up with the increased burden of providing such facilities efficiently to the desired level. Issues and constraints that are encountered by the urban local bodies responsible for providing sewerage and sanitation facilities are compounded due to various reasons.

The main cause of water pollution is the unintended disposal of untreated, partly treated and non-point sources of sewage and more important is its effect on human health and environment. The reasons for the above cited position are almost all local bodies not being financially resourceful to self-generate the required capital funds and looking up to the State and Central Governments for outright grant assistance. Lack of institutional arrangements and capacity building to conceive planning, implementation, procurement of materials, operate and maintain the sewerage system and sewage treatment plants at desired level of efficiency.

The sewage generated and collected from the residential areas terminates far away beyond the boundaries of the urban local body and is a “out of sight, out of mind” syndrome. The high cost of infrastructure investment, continual replacement and on-going O&M costs of centralized sewerage system facilities take these systems beyond the financial grasp of almost any urban local body in the country.

It is also necessary to recognize that the practice of piped sewer collection is basically an inheritance from advanced countries with high water usages, which ensures adequate flushing velocities in their high per capita water supply rates and do not result in night-soil lumps settling down in pipes and do not result in choking and hydrogen sulphide gas generation. In the Indian scenario, the per capita supply is low and inequitable in many cities and that too intermittent and this results in settling down of night-soil, choking, gasification etc., which necessitates very often the extreme remedies of cutting open the roads to access and break open the pipes for rectification, etc.

While the conventional sewerage may be an effective system for sewage collection and transportation and treatment, it also remains as a highly resource-inefficient technology. Consequentially, high capital cost and continuing significant costs for operation and maintenance of this system prohibit its widespread adoption in all sizes of urban areas in the country.

Every municipality is responsible for the laying and maintenance of sewage lines as well as for the treatment of sewage in Sewage Treatment Plants. However, most municipalities are only able to treat a fraction of the sewage the town generates. Waste water collection takes place through a series of drains. The construction and maintenance of these drains is the responsibility of municipal authorities, house owners and business owners. Care needs to be taken that the drains are not damaged, cracked or leaking, to prevent contamination of soil and ground water.

Over the years, there has been continuous migration of people from rural and semi-urban areas to cities and towns. The proportion of population residing in urban areas has increased from 27.8% in 2001 to 31.80% in 2011. The number of towns has increased from 5,161 in 2001 to 7,935 in 2011. The uncontrolled growth in urban areas has left many Indian cities deficient in infrastructural services as water supply, sewerage, storm water drainage, and solid waste management.
Most urban areas inhabited by slums in the country are plagued by acute problems related to indiscriminate disposal of sewage. Due to deficient efforts by town/city authorities, sewage and its management has become a tenacious problem and this is notwithstanding the fact that the large part of the municipal expenditure is allotted to it. It is not uncommon to find that substantially a large portion of resources is being utilized on manning sewerage system by Urban Local Bodies for their operation and maintenance. Despite this, there has been a progressive decline in the standard of services with respect to collection, transportation, treatment and safe disposal of treated sewage as well as measures for ensuring safeguard of public health & hygiene and environment. In many cities and towns in the country, a large quantity of sewage remains unattended giving rise to insanitary conditions in especially densely populated slums which in turn results in an increase in morbidity especially due to pathogens, parasitic infections and infestations in all segment of population particularly with the urban slum dwellers.

It is estimated by Central Pollution Control Board that about 62000 million liters per day (mld) of wastewater was generated by 422 million urban population in 2015 in India. The municipal wastewater treatment capacity developed so far was about 23277 mld accounting for 37% of wastewater generation capacity developed in urban centres. In view of the population increase, demand of freshwater for all the uses will increase proportionately. It is estimated that the projected wastewater from urban centres may cross 120,000 mld by 2051. A time series information extracted from publication of CPCB is is presented in Table 2.1. Besides, the rural water supply schemes in various States are progressing at steady pace and the piped water supplies are in all probability likely to generate substantial volume of wastewater for which an alternative technology and planning is required.

Table 2.1 Wastewater Generation from Urban Areas

Year	Urban Population (million)	Municipal Wastewater Generation (mld)	Sewage Treatment Capacity (mld)
1977-78	72.8	7007	2823
1989-90	122.7	12145	2512
1994-95	151.6	16662	4099
2003-04	243.5	26254	7044
2009	316.15	38254	11787
2015	422	62000	23277
2051	1000 (Estimated)	120000 (Estimated)	

Central Pollution Control Board publication on inventorisation of sewage treatment plants in India during 2015 depict that there were 816 STPs established in India by public health agencies, of which only 522 were operational. The capacity development for treatment of sewage is although a basic issue however the performance of treatment units as well as functioning of STPs cannot be overlooked. The enormous volume of untreated sewage disposed in the aquatic resources is the main cause of pollution of rivers and lakes. The large numbers of STPs created under Central Funding schemes like Ganga Action Plan, Yamuna Action Plan of National River Action Plan are not fully operated. The operation & maintenance and power cost in some of the typical sewage treatment plants is presented in Table 2.2.

Table 2.2: STP - O&M and Power Costs of treated sewage (per m3)

Sewage Treatment Plant	Design Capacity (MLD)	Sewage Treatment Technology	Operation & Maintenance Cost		Electrical Power Cost - Lacs			Total Cost Rs./m3	Remarks
			Annual-Rs Lacs	Rs / m3	Electrical Units/Day	Cost per Day-Lacs	Cost Rs./m3		
Sen Nursing Home & Delhi Gate Nala Plants-Delhi	2 x 10	Densadeg + Biofor	126	1.73	5,680	0.26	1.28	3.01	With chemical dosing
STP at Raja canal-Bangalore	40	Extended aeration	83	0.57	7,863	0.3	0.74	1.31	With Nitrification & Denitrification
TTP at V Valley-Bangalore	60	Biotower + Densadeg + Biofor-F	269	1.14	8,650	0.32	0.54	1.68	With Chlorination
STP at Rithala-Delhi	182	HLASP + Biofor-F	550	0.87	15,000	0.9	0.38	1.25	No Chlorination
TTP at Lalbagh-Bangalore	1.5	Classical Tertiary Treatment+ UV+Cl	28	5.11	1450	0.05	3.63	8.74	From Raw sewage to TTP + Chlorination
TTP at Cubbon park-Bangalore	1.5	MBR + UV+Cl	30	5.48	1650	0.06	4.13	9.61	From Raw sewage BOD/TSS<3, Coliform<23mpn

The economic growth of India has progressed significantly for infrastructure development in a number of sectors however the rural population is devoid of basic infrastructural facilities. It is required to give parity in terms of water supply and sanitation besides other sectors. This process of change is likely to generate huge volume of wastewater in rural areas as well. It would be appropriate to design water and wastewater management plans optimally, so that competing pressure on water resources can be eased.

There is need to plan strategies and give thrust to policies giving equal weightage to augmentation of supplied water and development of wastewater treatment facilities, recycling, recovery, recharging and its storages. The future of urban water supplies for potable uses will grossly depend on efficient wastewater treatment systems, as the treated wastewater of upstream urban centers will be the source of water for downstream cities.

Time and Money Loss in terms of DALYs

The Disability-Adjusted-Life-Years (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. Originally developed by the WHO, it is becoming increasingly common in the field of public health and health impact assessment. It extends the concept of potential years of life lost due to premature death to include equivalent years of 'healthy' life lost by virtue of being in states of poor health or disability. In doing so, mortality and morbidity are combined into a single common-matrix. As per the WHO report, 80% of the diseases in human being are water-borne and water-related. It is mainly due to water pollution or water contamination and water logging. Though water logging may be location and weather specific but water pollution and contamination is a common phenomenon which can occur at any place at any point of time if community and authorities are not careful about adverse impact of indiscriminate disposal of sewage. The indiscriminate disposal of human excreta or sewage from habitations contain micro-organisms (pathogens) causing water pollution and harbouring vectors which act as carriers of pathogens. The occurrence of such diseases depends upon various factors relating to illiteracy, personal hygiene, standard of living, malnutrition, and adulteration of food items, lack of community awareness and many other factors related to environmental pollution. No doubts that these factors play important role in occurrence of diseases but unsafe disposal of untreated or partially treated sewage plays a vital role in aggravating the chances of occurrence of these communicable diseases. The burden of water related diseases in India during 1990 was published in World development Report 1993 (Table 2.3). If we merely consider the economic value of life year at the average per capita income of $ 300 per year, the annual loss of 30.51 million DALYs is worth of 30.51×300 = $ 9.153 billion (Exchange rate during 1993, $1 = INR 40). Improvements in water supply and sanitation including management of municipal solid waste can substantially reduce the incidences and severity of these diseases, as well as infant mortality associated with diarrhea.

Table 2.3: Burden of Water Related Diseases in India, 1990 (In millions of DALYs)

Diseases	Female	Male	Total
Diarrheal Diseases	14.39	13.64	28.03
Intestinal Helminthes	1	1.06	2.06
Trachoma	0.07	0.04	0.11
Hepatitis	0.17	0.14	0.31
Total – water-borne and water-related Diseases	15.63	14.88	30.51

Reduction in morbidity from better water supply and sanitation including safe disposal of municipal solid waste was estimated as 26% for diarrhoea, 27% for trachoma, 29% for ascaris, 77% for schistosomiasis, and 78% for dracunculiasis. Mean reduction in diarrhoea-specific mortality was 65%, while overall child mortality was reduced by 55%. It is evident that environmental pollution by liquid and solid wastes adversely affects the environment and human health directly or indirectly resulting in loss of life and heavy financial burden on exchequers.

The problem of sanitation is much worse in urban areas due to increasing congestion and density in cities. Indeed, the environmental and health implications of the very poor sanitary conditions are a major cause for concern. The study of Water and Sanitation Program (WSP) of World Bank observes that when mortality impact is excluded, the economic impact for the weaker section of the society accounting 20% of the households is the highest. The National Urban Sanitation Policy (NUSP) of 2008 has laid down the framework for addressing the challenges of city sanitation. The Policy emphasizes the need for spreading awareness about sanitation through an integrated city-wide approach, assigning institutional responsibilities and due regard for demand and supply considerations, with special focus on the urban poor.

As per 2011 Census, the households having latrine facility within premises was 81.4% which includes 72.6% households having water closets and 7.1% households having pit latrines and 1.70% households having other latrines (connected to open drains, night soil removed by human etc., which was unsafe). Out of 72.6% households, 32.70% households were having water closets with piped sewer system, 38.20% households were having water closets with septic tank and 1.70% households were having water closets with pit latrines (ventilated improved pit/open pit etc.). The remaining household are both sharing public latrines and defecating in open.

2.4 Conventional Waste Water Treatment and Issues Facing Present Day STPs

Sewage, before being discharged of either in river streams or on land, has to be treated so as to make it safe. The degree of treatment required, however, depends upon the characteristics of the source of disposal. Sewage can be treated in different ways. Treatment processes are broadly classified as Preliminary treatment, Primary treatment, Secondary (or Biological) treatment and Tertiary treatment

Wastewater Treatment Technologies

Wastewater Treatment Plant is a facility designed to receive the waste from domestic, commercial and industrial sources and to remove materials that damage water quality and compromise public health and safety when discharged into water receiving systems. The Principal objective of waste water treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment.

Conventional wastewater treatment processes

Conventional wastewater treatment consists of a combination of Physical, chemical, and biological processes and operations to remove solids, organic matter and, sometimes, nutrients from wastewater.

Preliminary treatment

The objective of preliminary treatment is the removal of coarse solids and other large materials often found in raw wastewater. Preliminary treatment consists solely in separating the floating materials (like dead animals, tree branches, papers, pieces of rags, wood etc.) and also heavy settleable inorganic solids. It also helps in removing the oils and greases etc. from sewage. The processes used in preliminary treatment are Screening (for removing floating papers, plastic pouches, polythene bags, rags, clothes etc.), Grit chambers or Detritus tanks (for removing grit and sand), Skimming tanks (for removing oils and greases).Removal of these materials is necessary to enhance the operation and maintenance of subsequent treatment units.

Primary treatment

The objective of primary treatment is the removal of settle able organic and inorganic solids by sedimentation, and the removal of materials that will float (scum) by skimming. This is usually accomplished by sedimentation in settling basins. The organic solids, which are separated out in the sedimentation tanks (in primary treatment) are often stabilized by anaerobic decomposition in a digestion tank or are incinerated. The residue is used for landfills or soil conditioners. The liquid effluent from primary treatment often contains a large amount of suspended organic material. It also has a high biochemical oxygen demand (BOD).The processes used in primary treatment are sedimentation (for removing part of the organic matter from the sewage effluent), sedimentation aided with coagulation.

Secondary treatment

The objective of secondary treatment is the further treatment of the effluent from primary treatment to remove the residual organics and suspended solids. In most cases, secondary treatment follows primary treatment and involves the removal of biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes. Aerobic biological treatment is performed in the presence of oxygen by aerobic microorganisms (principally bacteria) that metabolize the organic matter in the waste water, thereby producing more microorganisms and inorganic end-products (principally CO_2, NH_3, and H_2O).Several aerobic biological processes are used for secondary treatment differing primarily in the manner in which oxygen is supplied to the microorganisms and in the rate at which organisms metabolize the organic matter. Common high-rate processes include the activated sludge processes, trickling filters or bio filters, oxidation ditches, and rotating biological contractors (RBC). A combination of two of these processes in series (e.g. bio filter followed by activated sludge) is sometimes used to treat municipal wastewater containing a high concentration of organic material from industrial sources.

Various commonly used treatment technologies in India for treatment of sewage and industrial effluents are summarised herewith.

I. Activated Sludge Process

The most common suspended growth process used for municipal wastewater treatment is the activated sludge process. The municipal wastewater treatment is the BOD-removal. The removal of BOD is done by a biological process, such as the suspended growth treatment process. This biological process is an aerobic process and takes place in the aeration tank, in where the wastewater is aerated with oxygen. By creating good conditions, bacteria will grow fast. The growth of bacteria creates flocks and gases. These flocks will removed by a secondary clarifier. In the activated sludge process, the dispersed-growth reactor is an aeration tank or basin containing as suspension of the wastewater and microorganisms, the mixed liquor. The contents of the aeration tank are mixed vigorously by aeration devices which also supply oxygen to the biological suspension. Aeration devices commonly used include submerged diffusers that release compressed air and mechanical surface aerators that introduce air by agitating the liquid surface. Hydraulic retention time in the aeration tanks usually ranges from 3 to 8 hours but can be higher with high BOD_5 wastewaters. Following the aeration step, the microorganisms are separated from the liquid by sedimentation and the clarified liquid is secondary effluents. A portion of the biological sludge is recycled to the aeration basin to maintain a high mixed-liquor suspended solids (MLSS) level. The remainder is removed from the process and sent to sludge processing to maintain a relatively constant concentration of microorganisms in the system. Several variation of the basic activated sludge process, such as extended aeration and oxidation ditches, are in common use, but the principal are similar:

II. Trickling Filters

A trickling filter or bio filter consists of a basin or tower filled with support media such as stones, plastic shapes, or wooden slats. Wastewater is applied intermittently, or sometimes continuously, over the media. Microorganisms become attached to the media and form a biological layer or fixed film. Organic matter in the wastewater diffuses into the film, where it is metabolized. Oxygen is normally supplied to the film by the natural flow of air either up or down through the media, depending on the relative temperatures of the wastewater and ambient air. Forced air can also be supplied by blowers but this is rarely necessary. The thickness of the biofilm increases as new organisms grow. Periodically, portions of the film 'slough off the media. The sloughed material is separated from the liquid in a secondary clarifier and discharged to sludge processing. Clarified liquid from the secondary clarifier is the secondary effluent and a portion is often recycled to the bio filter to improve hydraulic distribution of the wastewater over the filter.

III. Rotating Biological Contactors

Rotating biological contactors (RBCs) are fixed-film reactors similar to bio filters in that organisms are attached to support media. In the case of the RBC, the support media are slowly rotating discs that are partially submerged in flowing wastewater in the reactor. Oxygen is supplied to the attached biofilm from the air when the film is out of the water and from the liquid when submerged, since oxygen is transferred to the wastewater by surface turbulence created by the discs rotation. Sloughed pieces of biofilm are removed in the same manner described for bio filters.

High-rate biological treatment processes, in combination with primary sedimentation, typically remove 85 % of the BOD_5 and SS originally present in the raw wastewater and some of the heavy metals. Activated sludge generally produces an effluent of slightly higher quality, in terms of these constituents, than bio filters or RBCs. When coupled with a disinfection step, these processes can provide substantial but not complete removal of bacteria and virus. However, they remove very little phosphorus, nitrogen, non-biodegradable organics, or dissolved minerals.

IV. Upflow Anaerobic Sludge Blanket (UASB) Process

UASB is an anaerobic process whilst forming a blanket of granular sludge and suspended in the tank.

Wastewater flows upwards through the blanket and is processed by the anaerobic microorganisms. The upward flow combined with the settling action of gravity suspends the blanket with the aid of flocculants. The blanket begins to reach maturity at around 3 months. Small sludge granules begin to form whose surface area is covered in aggregations of bacteria. In the absence of any support matrix, the flow conditions create a selective environment in which only those microorganisms, capable of attaching to each other, survive and proliferate. Eventually the aggregates form into dense compact biofilms referred to as "granules". Fine granular sludge blanket acts as a filter to prevent the solids in the incoming wastes to flow through as the liquid part does. So if the hydraulic retention time (HRT) does not change, which is limited to 1-3 days (the bigger the digester, the shorter time it is, because the size costs money), the solid retention time (SRT) can be 10-30 days or more for more effective digestion, depending on the shape of the digestion chamber. It means that the digester becomes much more efficient without having to increase the size, which costs money. Standing and hanging baffles are used, with a conic separation with a small outlet at the center will be much more effective to keep the anaerobic sludge blanket in the lower part of the digester. This will act as a very good filter to retard the flow of solids in the wastes and prolong the solid retention time for more bacterial action. However, the digester will be more economic if the loading can be increased for a specific size of digester with the conic separation.

Bio-Chemical Activities in UASB Digesters Bacterial actions are in 3 phases in the digester and they occur in sequence:

a) Hydrolysis or solubilization - The first phase takes 10-15 days, and until the complex organics are solubilized, they cannot be absorbed into the cells of the bacteria where they are degraded by the endoenzymes;
b) Acidogenesis or acetogenesis - The result from stage one utilized by a second group of organisms to form organic acids;
c) Methanogenesis - The methane-producing (methanogenic) anaerobic bacteria then use the product of (2) to complete the decomposition process.

I. Waste Stabilization Ponds

Waste water stabilization pond technology is one of the most important natural methods for wastewater treatment. Waste stabilization ponds are mainly shallow man-made basins comprising a single or several series of anaerobic, facultative or maturation ponds. Theprimary treatment takes place in the anaerobic pond, which is mainly designed for removing suspended solids, and some of the soluble element of organic matter (BOD). During the secondary stage in the facultative pond most of the remaining BOD is removed through the coordinated activity of algae and heterotrophic bacteria. The main function of the tertiary treatment in the maturation pond is the removal of pathogens and nutrients (especially nitrogen). Waste stabilization pond technology is the most cost-effective wastewater treatment technology for the removal of pathogenic micro-organisms. The treatment is achieved through natural disinfection mechanisms. It is particularly well suited for tropical and subtropical countries because the intensity of the sunlight and temperature are key factors for the efficiency of the removal processes.

a. Anaerobic ponds

These units are the smallest of the series. Commonly they are 2-5 m deep and receive high organic loads equivalent to100 g BOD/m3 d. These high organic loads produce strict anaerobic conditions (no dissolved oxygen) throughout the pond. In general terms, anaerobic ponds function much like open septic tanks and work extremely well in warm climates. A properly designed anaerobic pond can achieve around 60% BOD removal at 20 C. One-day hydraulic retention time is sufficient for wastewater with a BOD of up to 300 mg/l and temperatures higher than 20C. Designers have always been preoccupied by the possible odour they might cause. However, odour problems can be minimised in well-designed ponds, if the SO42- concentration in wastewater is less than 500 mg/l. The removal of organic matter in anaerobic ponds follows the same mechanisms that take place in any anaerobic reactor.

b. Facultative ponds

These ponds are of two types: primary facultative ponds receive raw wastewater, and secondary facultative ponds receive the settled wastewater from the first stage (usually the effluent from anaerobic ponds). Facultative ponds are designed for BOD removal on the basis of a low organic surface load to permit the development of an active algal population. This way, algae generate the oxygen needed to remove soluble BOD. Healthy algae populations give water a dark green colour but occasionally they can turn red or pink due to the presence of purple sulphide-oxidising photosynthetic activity. This ecological change occurs due to a slight overload. Thus, the change of colouring in facultative ponds is a qualitative indicator of an optimally performing removal process. The concentration of algae in an optimally performing facultative pond depends on organic load and temperature, but is usually in the range 500 to 2000 μg chlorophyll per litre. The photosynthetic activity of the algae results in a diurnal variation in the concentration of dissolved oxygen and pH values. Variables such as wind velocity have an important effect on the behaviour of facultative ponds, as they generate the mixing of the pond liquid. As Mara et al. indicate, a good degree of mixing ensures a uniform distribution of BOD, dissolved oxygen, bacteria and algae, and hence better wastewater stabilization.

c. Maturation ponds

These ponds receive the effluent from a facultative pond and its size and number depend on the required bacteriological quality of the final effluent. Maturation ponds are shallow (1.0-1.5 m) and show less vertical stratification, and their entire volume is well oxygenated throughout the day. Their algal population is much more diverse than that of facultative ponds. Thus, the algal diversity increases from pond to pond along the series. The main removal mechanisms especially of pathogens and faecal coliforms are ruled by algal activity in synergy with photo-oxidation.On the other hand, maturation ponds only achieve a small removal of BOD, but their contribution to nitrogen and phosphorus removal is more significant.

II. Aerated Lagoons

The mechanical-biological purification of the waste water takes place in one or more aerated lagoons according to the size of the plant, which are followed by an non-aerated sedimentation and polishing pond. The sewage coming from the canalisation is normally led directly into the first aerated lagoon without mechanical pre-purification. So the continuous disposal of screenings, sand and sedimentation sludge and its maintenance efforts can be omitted. Coarse stuff, sand and heavy sludge settle in the inlet zone while dissolved contaminant are distributed in the whole first lagoon. Liable to putrefy matter should mainly be stabilized by aerobic processes to avoid odours and digested sludge coming up to the water surface. According to our experience sludge at the inlet zone of the first aerated waste water lagoon has to be removed at regular intervals of several years. To exhaust and bring the sludge out liquid manure-vacuum-tankers are used. Floating solids are retained by a scum board in the inlet area. They should be removed once or twice a week with a rake.

III. Oxidation Ponds

Oxidation Ponds are also known as stabilization ponds or lagoons. They are used for simple secondary treatment of sewage effluents. Within an oxidation pond heterotrophic bacteria degrade organic matter in the sewage which results in production of cellular material and minerals. The production of these supports the growth of algae in the oxidation pond. Growth of algal populations allows furthur decomposition of the organic matter by producing oxygen. The production of this oxygen replenishes the oxygen used by the heterotrophic bacteria. Typically oxidation ponds need to be less than 10 feet deep in order to support the algal growth. In addition, the use of oxidation ponds is largely restricted to warmer climate regions because they are strongly influenced by seasonal temperature changes. Oxidation ponds also tend to fill, due to the settling of the bacterial and algal cells formed during the decomposition of the sewage. Overall, oxidation ponds tend to be inefficient and require large holding capacities and long retention times. The degradation is relatively slow and the effluents containing the oxidized products need to be periodically removed from the ponds.

IV. Karnal Technology

The Karnal Technology involves growing tree on ridges 1m wide and 50cm high wand disposing of the untreated sewage in furrows. The amount of the sewage/ effluents to be disposed off depends upon the age, type of plants, climatic conditions, soil texture and quality of effluents. The total discharge of effluent is so regulated that it is consumed within 12-18 hours and there is no standing water left in the trenches. This technique utilizes the entire biomass as living filter for supplying nutrients to soil and plant; irrigation renovates the effluent for atmospheric re-charge and ground storage. Further, as forest plants are to be used for fuel wood, timber or pulp, there is no chance of pathogens, heavy metals and organic compounds to enter into the human food chain system, a point that is a limiting factor when vegetables or other crops are grown with sewage. Though most of the plants are suitable for utilizing the effluents, yet, those tree species which are fast growing can transpire high amounts of water and are able to with stand high moisture content in the root environment are most suitable for such purposes. Eucalyptus is one such species, which has the capacity to transpire large amounts of water, and remains active throughout the year. Other species suitable for this purpose are poplar and leucaena. Out of these three species, eucalyptus seems to be the best choice as poplar remains dormant in winter and thus cannot bio-drain effluent during winter months. However, if area is available and the volume of effluent is small, a combination of popular and eucalyptus is the best propagation. This technology for sewage water use is relatively cheap and no major capital is involved. The expenditure of adopting this technology involves cost of making ridges, cost of plantation and their care.

This system generates gross returns from the sale of fuel wood. The sludge accumulating in the furrows along with the decaying forest litter can be exploited as an additional source of revenue. As the sewage water itself provides nutrients and irrigation ameliorates the sodic soil by lowering the pH, relatively unfertile wastelands can be used for this purpose. This technology is economically viable as it involves only the cost of water conveyance from source to fields for irrigation and does not require highly skilled personnel as well. This technology seems to be most appropriate and economical viable proposition for the rural areas as this technology is used to raise forestry, which would aid in re-storing environment and to generate biomass.

V. Duckweed

Duckweeds (aquatic plants) are the world smallest and simplest flowering plants. Duckweeds are floating plants that grow on the surface of still or slow moving waters during warmer weather. Because duckweeds usually reproduce by budding, they can multiply very quickly and cover the entire surface of a pond in a short span of time. Small numbers of duckweeds will not harm a pond, but large numbers will block sunlight from entering the pond and upset the ponds oxygen balance, placing the fish population in danger. The Lemna spp. are the most common duckweeds. Lemna grow up to 4 mm wide and have a single root dangling from the leaf of the plant. Duckweeds do not have true leaves or stems; the roundish, flattened leaflike part of the plant is called a frond. Another type, watermeal (Wolffia spp.), are the smallest of the duckweeds. These plants are so tiny that they look like grains of green meal floating on the water surface. They are generally less than 1 mm wide and barely visible as individuals. This type of duckweed does not have roots. Many times control is necessary because the duckweeds reproduce rapidly and can cover a pond causing oxygen problems.

VI. Fluidized Bed Reactor

Aerobic fluidized bed reactors (FBRs) are used as a new technology in wastewater treatment. An aerobic fluidized bed reactor with granulated activated carbon (GAC) as carrier material can be operated under different conditions, including batch-loading, semi continuous loading, and continuous loading. The basic idea behind the Fluidized Bed Reactor is to have a continuous operating non-clogging bio film reactor which requires (1) no back-washing, (2) has low head loss and (3) high specific bio film surface area. This is achieved by having the biomass to grow on small carrier elements that move with the liquid in the reactor. The movement within the reactor is generated by aeration in the aerobic reactor. These bio-film carriers are made of special grade plastic density close to that of water. The fluidized bed reactor employs fixed film principle and makes the treatment process more user friendly because it does not require sludge recycle i.e. synonymous with conventional ASP. The absence of sludge recycle frees the operator from the enormous task of measurement and monitoring MLSS levels in the tank and adjusting recycle rations continuously, due to fluctuating inlet COD loads. FBR produces small quantity of sludge which requires no further treatment. Fluidized Bed Reactor technology is used in small Sewage Treatment Plants for treating city wastewater, industrial sewage treatment plant from food waste, paper waste and chemical waste etc. Due to fixed film nature, these plants accept shock loads much better than those employed for suspended growth process. Fluidized Bed Reactors are generally tall (6 m and above), thereby reducing cross-sectional area further.

VII. Sequential Batch Reactor

In this process, the raw sewage free from debris and grit shall be taken up for biological treatment for removal of organic, nitrogen and phosphorus. The activated sludge bio-system is designed using Advanced Cyclic Activated Sludge Technology which operates on extended aeration activated sludge principle for the reduction of carbonaceous BOD, Nitrification, Denitrification as well as phosphorus removal using energy efficient fine bubble diffused aeration system with automatic control of air supply based on oxygen uptake rate.

In this form, the sequences of fill, aeration, settle and decant are consecutively and continuously operated all in the same tank. No secondary clarifier system is required to concentrate the sludge in the reactor. The return sludge is recycled and the surplus is wasted from the basin itself. The complete biological operation is divided into (a) Fill Aeration (b) Settlement and (c) Decanting. These phases in a sequence constitute a cycle. During the period of a cycle, the liquid volume inside the Reactor increases from a set operating bottom water level. During the Fill-Aeration sequence mixed liquor from the aeration zone is recycled into the Selector. Aeration ends at a predetermined period of the cycle to allow the biomass to flocculate and settle under quiescent conditions. After a specific setting period, the treated supernatant is decanted, using a moving weir Decanter. The liquid level in the Reactor is so returned to bottom water level after which the cycle is repeated. Solids are separated from the reactor during the decanting phase. The system selected is capable of achieving the (i) Bio-degradation of organics present in the wastewater by Extended Aeration Process (ii) Oxidation of sulphides in the wastewater (iii) Co-current nitrification and denitrification of Ammonical nitrogen in the aeration zone and (iv) Removal of phosphorous

Tertiary Treatment

Tertiary wastewater treatment is employed when specific wastewater constituents which cannot be removed by secondary treatment must be removed. The treatment processes are necessary to remove nitrogen, phosphorus, additional suspended solids, refractory organics, heavy metals and dissolved solids. Because advanced treatment usually follows high-rate secondary treatment, it is sometimes referred to as tertiary treatment. However, advanced treatment processes are sometimes combined with primary or secondary treatment (e.g., chemical addition to primary clarifiers or aeration basins to remove phosphorus) or used in place of secondary treatment (e.g., overland flow treatment of primary effluent).

The septic tank is a kind of sedimentation tank which directly receives raw sewage and removes about 60 - 70% of the dissolved matter from it. Septic tanks are generally provided in areas where sewers have not been laid and for serving to the sanitary disposal of sewage produced from isolated communities, schools, hospitals, other public institutions etc. The improved design of septic tank in the form of an Imhoff tank does not allow incoming sewage to get mixed up with the sludge produced, and the outgoing effluent is not allowed to carry with it large amount of organic load, as in the case of septic tank. These are very economical and do not require skilled supervision during operations.

Issues Facing Present Day STPs

Operation and maintenance of existing plants and sewage pumping stations is a neglected field, as nearly 39% plants are not conforming to the general standards prescribed under the Environmental (Protection) Rules for discharge into streams. STPs are usually run by personals that do not have adequate knowledge of running the STPs and know only operation of pumps and motors. The operational parameters are not regularly analyzed hence the day-to-day variation in performance is not evaluated at most of the STPs. Thus, there is a need that persons having adequate knowledge and trained to operate the STPs be engaged to manage STPs and an expert be engaged to visit the STPs at least once a month and advice for improvement of its performance. In a number of cities, the existing treatment capacity remains underutilized while a lot of sewage is discharged without treatment in the same city. Auxiliary power back-up facility is required at all the intermediate (IPS) & main pumping stations (MPS) of all the STPs.

In treatment schemes employing activated-sludge-process, plant operators must recognize the importance of using Solids Retention Time (SRT) as a plant control parameter because treatmentefficiency, sludge production, oxygen requirements and nutrients requirements are all dependent on SRT. Moreover, SRT being the ratio of total suspended solids in the system and that wasted per day, it is most simple to operate plants on the basis of SRT. Operation of a conventional activated-sludge-process near 5 day SRT is recommended, as it will provide sufficient safety factor. If a plant based on conventional activated-sludge-process receives low strength sewage than it was designed for, then operator has a choice to either operate the plant at higher than 5 day SRT, or he may opt for energy saving by operating fewer aerators provided mixing requirements of the plant are still fulfilled. But all this manoeuvring requires a basic knowledge of intricacies of aerobic biological treatment, which an operator must be equipped with. It is also necessary to recognize the importance of return flow and waste sludge flow measurement, in addition to influent flow measurement, as without this it is difficult to have proper control on plant operation and it is not possible to use SRT as a plant control parameter.

The Central Pollution Control Board has carried out inventorisation of and performance assessment of sewage treatments in India over the years on a number of occasions. The findings of the latest study indicate that out of 816 STPs having capacity of 23277MLD in 28 States/UTs of India only 522 STPS are operational, 79 STPs are Non-operational, 145 STPs are under construction and 70 STPs are proposed for construction.

There are various reasons for non-performance of STPs as per the design criteria and the capacity utilisation remained considerably at low level. Among the various reasons, few of the reasons are continuous supply of power, alternate power supply facility was not available in most of the cases fund shortage was an important factor in poor operation and maintenance of STPs, sludge handing appeared to be most neglected area in STPs operation, utilization of biogas generated from UASB reactors or sludge digesters was not adequate, there was no gas generation and utilization in few STPs in spite of having anaerobic reactors/digesters, only few STPs have the gas generated and was being utilized as domestic fuel or as fuel for gas engine or duel fuel generator, lack of proper laboratories at site was another area that needed attention and in majority of the cases, operation of the STPs was looked after by contractors who deputed unqualified or less qualified staff at site, which was an important factor responsible for poor operation of STPs.

In the first-of-its-kind success, the creation and maintenance of sewage treatment infrastructure under Hybrid Annuity based PPP model has taken off, with National Mission of Clean Ganga has planned for construction and maintenance of Sewage Treatment Plants (STPs) in two major cities in Ganga river basin - Varanasi and Haridwar.Under this model, the development, operation and maintenance of the sewage treatment plants will be undertaken by a Special Purpose Vehicle (SPV) to be created by the winning bidder at the local level. As per this model, 40% of the Capital cost quoted would be paid on completion of construction while the remaining 60% of the cost will be paid over the life of the project as annuities along with operation and maintenance cost (O&M) expenses.

One of the most important features of this model is that both the Annuity and O&M payments are linked to the performance of the STP. This will ensure continued performance of the assets created due to better accountability, ownership and optimal performance. Hybrid Annuity based PPP model has been adopted for the first time in the country in sewage management sector.

2.5Water Reclamation

Water can be reclaimed if Treated waste water does not let out into the environment rather recycled and reused. Municipal wastewater can be recycled for irrigation purposes or for usage in industry / thermal power station as utility water (cooling tower/boiler). The wastewater may be given some form of terminal treatment before its application on land. The remaining nutrients, organics and water enter into the natural system of recycling and used by plants and microbes of soil or retained by soil. In the process excess water percolates through the soil medium, gets renovated and ultimately recharges the groundwater. The principal of reuse /recycling of wastewater differ from the age-old sewage farming practices as the present technology, called "Land Treatment" means controlled application of pre-treated wastewater on land surface to achieve a designated degree of treatment through natural bio-geochemical process wastewater reuse. The land treatment processes are slow rate treatment of applied wastewater based on assimilative capacity of soil; economic return from reuse of water and nutrients to produce marketable crops; and water conservation. Other processes are rapid infiltration for groundwater recharge; recovery of renovated water; overland flow for wastewater treatment with the help of low permeable and on sloping land; recycle of renovated water from the system and crop production.

New generation of sewage treatment technologies such as membrane bioreactor (MBR) can treat the waste water near to the quality of river. With a suitable renovation this treated sewage can also recharge flood plain of riverine system to get a perennial flow on the river. It is pertinent to mention that cost for activated sludge process is around Rupees 90 lakhs to 1 crore for 1 MLD sewage while that of membrane bioreactor it is Rupees 1.3 – 1.5 crore for 1 MLD sewage. If the treated sewage of MBR technique is recycled to industry the chances of payback is encouraging. In fact there shall be a paradigm shift with respect to sewage management; i.e from sewage treatment to sewage reuse and recycling.

There are several opportunities for improving wastewater irrigation practices via improved policies, institutional dialogues and financial mechanisms, which would reduce the risks in agriculture. Effluent standards combined with incentives or enforcement can motivate improvements in water management by household and industrial sectors discharging wastewater from point sources. Segregation of chemical pollutants from urban wastewater facilitates treatment and reduces risk. Strengthening institutional capacity and establishing links between water delivery and sanitation sectors through inter-institutional coordination leads to more efficient management of wastewater and risk reduction.

Health Aspects

Undesirable constituents in wastewater can harm human health and the environment. Hence, wastewater irrigation is an issue of concern to public agencies responsible for maintaining public health and environmental quality. For diverse reasons, many developing countries are still unable to implement comprehensive wastewater treatment programs. Therefore in the near term, risk management and interim solutions are needed to prevent adverse impacts from wastewater irrigation. A combination of source control, and farm-level and post-harvest measures can be used to protect farm workers and consumers. The WHO guidelines revised in 2006 for wastewater use suggest measures beyond the traditional recommendations of producing only industrial or non-edible crops, as in many situations it is impossible to enforce a change in the current cash crop pattern or provide alternative vegetable supply to urban markets.

Developed economies regard wastewater treatment as vital to protect human health and prevent the contamination of lakes and rivers. But for most developing countries this solution is prohibitively expensive. In this case, applying wastewater to agricultural lands is a more economical alternative and more ecologically sound than uncontrolled dumping of municipal and industrial effluents into lakes and streams. Obviously the short-term benefits of wastewater irrigation could be offset by the health and environmental impacts. The first step is to scientifically evaluate these. Once the actual risks are clear, we can work to reduce them. This means, for example, finding affordable ways of monitoring the presence of harmful contaminants in wastewater, such as heavy metals that can accrue in soil and crops. It means looking at farming practices and crops grown to find ways of minimizing risks of infection for farmers.

The raw domestic wastewaters normally carry the full spectrum of pathogenic microorganisms - the causative agents of bacterial, virus and protozoan diseases endemic in the community and excreted by diseased and infected individuals. While recycling and reuse of wastewater for agriculture, industry and non-potable urban purposes can be a highly effective strategy for developing a sustainable water resource in water short areas, nutrient conservation and environmental protection, it is essential to understand the health risks involved and to develop appropriate strategies for the control of those risks. There is need to concentrate on the control of pathogenic microorganisms from wastewater in agricultural reuse since this is the most widely practiced form of reuse in India. However, more and more water specialists, natural resource planners and economists see water as an economic good and, as time goes on, there will be an increased motivation to divert recycled wastewater from low income agriculture to areas where the added value of water is greater, such as industrial and non-potable urban uses including public parks, green belts and golf courses. As time goes on and water shortages in arid areas increase, there will undoubtedly be an expansion of the reuse of purified wastewater for industrial and a wide variety of urban non-potable purposes. Concern for human health and the environment are the most important constraints in the reuse of wastewater. While the risks do need to be carefully considered, the importance of this practice for the livelihoods of countless small holders must also be taken into account. There is need for research on wastewater irrigation is to maximize the benefits to the poor who depend on the resource while minimizing the risks. Many wastewater irrigators are not landowning farmers, but landless people that rent small plots to produce income-generating crops such as vegetables that thrive when watered with nutrient-rich sewage. Across the country these wastewater micro-economies support countless poor people. Stopping or over-regulating these practices could remove the only income many landless people have.

Reuse of treated sewage for toilet flush has been recognized as a means of water conservation especially in high rise apartments, office complexes, multiplexes, etc. Generally, this flushing consumes about 3 to 4 flushes per day per person and its volume will be about 20 to 30 litres daily. When a 135 lpcd is supplied, by reusing 30 litres per day per person, we still have to deal with 110 litres per capita daily and this has to be disposed outside the house. But then, the entire 135 lpcd has to be treated before we can recover the 30 lpcd for toilet flush. Alternatively, there has to be twin sewerage within the house so that milder grey water can be separately collected and treated with less strenuous effort before reuse for flush. Such a system is least advisable especially in modern urban habitations where the potential dangers of cross connection in plumbing and nuisance value of dealing with a STP within the dwelling boundary are matters of great reluctance either to be enforced or to be embraced by the occupants. That brings matters to two options namely, condominiums to have such a facility as a centralized option for the entire condominium or a habitation to have a dual pipeline from the STP back all the way to the dwellings supplying such toilet flush grade water. Obviously, such a new dual pipeline all over the habitation is almost next to impossible to be designed, implemented and attended to in O&M because, here is a system that will deliver as little as 30 lpcd and its design as a gravity pipeline discharging in short stints for rare timings in a 24 hours cycle calls for a pressurized system. The net result of all this is the fact that these are possible only in the case of condominiums and entirely new layouts. In India, the rule of culture far more outweighs the practicalities and culturally, no one can be forced to avail a water supply originating from the refuse of the neighbour and receive it into his habitation.

Summary

The wastewater generation and its management is one of the herculean task for government agencies.The role of individuals, in water use efficiency, reduce the burden on increasing volumes of wastewater thereby reducing available fresh water in the aquatic resources. There are various treatment technologies available to meet the requirement of recipient water resources.The cost benefit analysis of each technologies must be understand in the interest of health impacts on common citizens which are dependent on utilization of polluted aquatic resources. Impact of polluted water on fresh water resources has far reaching consequences on the food chain and biomagnifications in the aquatic life especially fishes. The centralized versus decentralized treatment technologies should be assessed based on the pollution load generated in a metropolitan city or a township of few thousand people.It is therefore importance of treatment technologies should be evaluated and accordingly applied on case by case basis with merits and demarits.

To Do Activities

- Plan a visit to sewage treatment plant and understand contribution of each household becomes huge volume
- Understand the requirement of various units and their functions.
- Understand requirement of electricity,manpower and laboratory on round the clock basis without interruption
- To know requirement of resources for operation and maintenance besides civil construction cost.
- To know the utility and benefits of treatment of wastewater as a renewable resource
- To understand the design parameters and imposition of stringent standards in view of growing volume of wastewater generation and reduction in river flows

Self Assessment Questions

1. What are the sewage treatment technologies
2. What is the efficiency of various sewage treatment technologies?
3. How can we improve the efficiency of sewage treat plants

4. Why there is gap in generation of sewage and treatment capacity?
5. How can be make the sewage treatment plant sustainable with business modal?
6. What kind of management policies are required to modify present system of operation and maintenance with PPP modal or Hybrid annuity modal.

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Chapter 3 Alternative Technologies for Waste Water Treatment

Introduction

The disposal of partially treated and untreated effluents into rivers and lakes from urban areas are responsible for deterioration of water quality. The available water resources are rapidly depleted due to increased water demands whereas the available water is getting deteriorated due to disposal of domestic and industrial effluents. Although, the sewage treatment capacity increased in urban areas in India however this increase is not adequate to keep pace with escalating generation of wastewater which results in a large volume of untreated or partially treated wastewater discharge leading to pollution of water resources.

The conventional mechanised wastewater treatment systems are rather expensive in terms of installation as well as O&M costs whereas the alternative treatment technologies can be established and operated with relatively less cost. There are different types of alternative technologies for waste water treatment practiced in India and the most experienced include, Waste Stabilization Ponds, Sewage fed Aquaculture, Constructed Wetlands, Polishing Ponds, Duckweed Ponds, and Karnal Technology.

Sewage fed aquaculture system in conjunction with pisciculture is one such technology which has the potential of offering effective wastewater treatment besides providing economic returns as well as generating employment opportunities in the rural areas. The traditional practices of recycling effluent through agriculture, horticulture and aquaculture have been in used various parts of India. The practices of using waste as a resource for the sustainable rural and urban development is not only help in treating the wastewater but also make the system long-lasting. Moreover, the practices of using wastewater for resources recovery not only reduces the pollution load into the natural water bodies but also make a continuous system of food production irrespective of any environmental disparity such as rainfall or drought.

Objectives

- To understand the functioning of conventional wastewater treatment plants and options of non conventional methodologies
- To know the merits of non conventional alternative technologies for small townships having various management issues including financial resources.
- To evaluate the pros of cons of alternative technologies to meet the requirement of treated water discharge norms in contrast to requirements of recipient aquatic system

3.1 Alternative Technologies for Waste Water Treatment

The conventional sewage treatment plants and effluent treatment plants are the optimum requirement for treatment of wastewater from urban centers. The urban centers have diversified settlements having septic tanks that release supernatant water to open drains which in turn meet bigger drains and outfalls in rivers untreated. The drain outfalls from urban areas and the discharges from small towns as well as rural habitation are not getting treated in view of lack of sewage treatment plants facility.

The facility development for conventional STPs is cost intensive affair. The huge gap in generation of sewage and infrastructure development for treatment throughout the country may take long time and perpetual growth of urban population may outpace the efforts. Thus, the alternative technologies for waste water treatment by in situ as well as ex situ methodologies are required to bridge the gap and to finally polish the treated wastewaters to meet the requirement of recipient water courses, rivers and streams.

The natural low-rate biological treatment systems are one of the alternative technologies for the treatment of organic wastewaters such as municipal sewage and tend to be lower in cost and less sophisticated in operation and maintenance. Although such processes tend to be land intensive by comparison with the conventional high-rate biological processes, they are often more effective in removing pathogens and do so reliably and continuously if properly designed and not overloaded.

Among the natural biological treatment systems available, stabilization ponds and land treatment have been used widely around the world. The nutrient film technique is a fairly recent development of the hydroponic plant growth system with application in the treatment and use of wastewater.

Wastewater Stabilization Ponds

Stabilization ponds are the most suitable wastewater treatment system for effluent use in agriculture. Stabilization ponds are the preferred wastewater treatment process in developing countries, where land is often available at reasonable opportunity cost and skilled labour is in short supply.

Wastewater stabilization pond systems are designed to achieve different forms of treatment in up to three stages in series, depending on the organic strength of the input waste and the effluent quality objectives. For ease of maintenance and flexibility of operation, at least two series of ponds in parallel are incorporated in any design. Strong wastewaters, with Biochemical oxygen Demand (BOD) concentration in excess of about 300 mg/l, will frequently be introduced into first-stage anaerobic ponds, which achieve a high volumetric rate of removal. Weaker wastes or, where anaerobic ponds are environmentally unacceptable, even stronger wastes up to 1000 mg/l BOD may be discharged directly into primary facultative ponds. Effluent from first-stage anaerobic ponds will overflow into secondary facultative ponds which comprise the second-stage of biological treatment. Following primary or secondary facultative ponds, if further pathogen reduction is necessary maturation ponds can be introduced to provide tertiary treatment.

Anaerobic Ponds

Anaerobic ponds are very cost effective for the removal of BOD, when it is present in high concentration. Normally, a single, anaerobic pond in each treatment scheme is sufficient if the strength of the influent wastewater is less than 1000 mg/l BOD. For high strength industrial wastes, up to three anaerobic ponds in series might be justifiable but the retention time in any of these ponds should not be less than 1 day.Anaerobic ponds normally have a depth between 2 meter and 5 meter and function as open septic tanks with gas release to the atmosphere. The biochemical reactions which take place in anaerobic ponds are the same as those occurring in anaerobic digesters, with a first phase of acidogenesis and a second slower-rate of methanogenesis.

Ambient temperatures in hot-climate countries are conducive to these anaerobic reactions and expected BOD removals for different retention times in treating sewage conservative removals of BOD in anaerobic ponds with linear interpolation for operating temperature between 10 and 20°C. Higher removal rates are possible with industrial wastes, particularly those containing significant quantities of organic settleable solids. Of course, other environmental conditions in the ponds, particularly pH, must be suitable for the anaerobic microorganisms bringing about the breakdown of BOD.

In certain instances, anaerobic ponds become covered with a thick scum layer, which is thought to be beneficial but not essential, and may give rise to increased fly breeding. Solids in the raw wastewater, as well as biomass produced, will settle out in first-stage anaerobic ponds and it is common to remove sludge when it has reached half depth in the pond. This usually occurs after two years of operation at design flow in the case of municipal sewage treatment.

Facultative Ponds

The effluent from anaerobic ponds require some form of aerobic treatment before discharge or use and facultative ponds often be more appropriate than conventional forms of secondary biological treatment for application in specific and geo-climatic conditions. Primary facultative ponds are for the treatment of weaker wastes and can be introduced in sensitive locations where anaerobic pond create odour. Solids in the influent to a facultative pond and excess biomass produced in the pond settle out forming a sludge layer at the bottom. The benthic layer become anaerobic and as a result of anaerobic breakdown of organics, releases soluble organic products to the water column.

Organic matter dissolved or suspended in the water column gets metabolized by heterotrophic bacteria, with the uptake of oxygen, as in conventional aerobic biological wastewater treatment processes. However, unlike in conventional processes, the dissolved oxygen utilized by the bacteria in facultative ponds is replaced through photosynthetic oxygen production by microalgae, rather than by aeration equipment. Especially in treating municipal sewage in hot climates, the environment in facultative ponds is ideal for the proliferation of microalgae. High temperature and ample sunlight create conditions which encourage algae to utilize the carbon dioxide released by bacteria in breaking down the organic components of the wastewater and take up nutrients (mainly nitrogen and phosphorus) contained in the wastewater.

To maintain the balance, necessary to, allow this symbiosis to persist, the organic loading on a facultative pond must be limited. Even under satisfactory operating conditions, the dissolved oxygen concentration in a facultative pond varies diurnally as well as over the depth. Maximum dissolved oxygen occurs at the surface of the pond and usually reach super saturation in tropical regions at the time of maximum radiation intensity. From that time until sunrise, DO will decline and may well disappear completely for a short period. For a typical facultative pond depth of 1.5 meter, the water column is predominantly aerobic at the time of peak radiation and predominantly anaerobic at sunrise. The pH of the pond contents vary diurnally as algae utilize carbon dioxide throughout daylight hours and respire, along with bacteria and other organisms, releasing carbon dioxide during the night.

Wind is considered important to the satisfactory operation of facultative ponds by mixing the contents and helping to prevent short-circuiting. Intimate mixing of organic substrate and the degrading organisms is important in any biological reactor but in facultative ponds wind mixing is considered essential to prevent thermal stratification causing anaerobiosis and failure. Facultative ponds should be orientated with the longest dimension in the direction of the prevailing wind. Although completely mixed reactor theory with the assumption of first-order kinetics for BOD removal can be adopted for facultative pond design. The removal of BOD in facultative ponds is related to loading and usually averages 70-80%. The retention time in a properly designed facultative pond will normally be 20-40 days and, with a depth of about 1.5m, the area required will be significantly greater than for an anaerobic pond. The effluent from a facultative pond treating municipal sewage in the tropics will normally have a BOD between 50 and 70 mg/l as a result of the suspended algae. On discharge to surface water, this effluent will not cause problems downstream if the dilution is of the order of approximately 10 times and any live algae in the effluent might well be beneficial as a result of photo synthetic oxygen production during daylight hours.

Efficiently operating facultative ponds treating wastewater will contain a mixed population of flora but flagellate algal genera such as Chlamydomonas, Euglena, Phacus and Pyrobotrys will predominate. Non-motile forms such as Chlorella, Scenedesmus and various diatom species will be present in low concentrations unless the pond is underloaded. Algal stratification often occurs in facultative ponds, particularly in the absence of wind-induced mixing, as motile forms respond to changes in light intensity and move in a band up and down the water column. The relative numbers of different genera and their dominance in a facultative pond vary from season to season throughout the year but species diversity generally decreases with increase in loading. Sometimes, mobile purple sulphur bacteria appear when facultative ponds are overloaded and sulphide concentration increases, with the danger of odour production. High ammonia concentrations also bring on the same problem and are toxic to algae, especially above pH 8.0.
Maintenance of properly designed facultative ponds will be limited to the removal of scum mats, which tend to accumulate in downwind corners, and the cutting of grass on embankments. To ensure efficient operation, facultative ponds should be regularly monitored but, even where this is not possible, they have the reputation of being relatively trouble-free.

Maturation Ponds
The effluent from facultative ponds treating municipal sewage or equivalent input wastewater will normally contain at least 50 mg/l BOD and if an effluent with lower BOD5 concentration is required it will be necessary to use maturation ponds. For sewage treatment, two maturation ponds in series, each with a retention time of 7 days, have been found necessary to produce a final effluent with BOD < 25 mg/l when the facultative pond effluent had a BOD < 75 mg/l.

A more important function of maturation ponds, however, is the removal of excreted pathogens to achieve an effluent quality which is suitable for its downstream reuse. Although the longer retention in anaerobic and facultative pond systems will make them more efficient than conventional wastewater treatment processes in removing pathogens, the effluent from a facultative pond treating municipal sewage will generally require further treatment in maturation ponds to reach effluent standards imposed for reuse in unrestricted irrigation. Faecal coliform bacteria are commonly used as indicators of excreted pathogens and maturation ponds can be designed to achieve a given reduction of faecal coliforms (FC). Protozoan cysts and helminth ova are removed by sedimentation in stabilization ponds and a series of ponds with overall retention of 20 days or more will produce an effluent totally free of cysts and ova.

Reduction of faecal coliform bacteria in any stabilization pond (anaerobic, facultative and maturation) is generally taken as following first-order kinetics. Maturation ponds will be aerobic throughout the water column during daylight hours and the pH will rise above 9.0. The algal population of many species of non-flagellate unicellular and colonial forms will be distributed over the full depth of a maturation pond. Large numbers of filamentous algae, particularly blue-greens, will emerge under very low BOD loading conditions. Very low concentrations of algae in a maturation pond will indicate excessive algal predation by zooplankton, such as Daphnia sp, and this will have a deleterious effect on pathogen die-off, which is linked to algal activity.

Overland Treatment of Wastewater

In overland flow treatment, effluent is distributed over gently sloping grassland on fairly impermeable soil. Ideally, the wastewater moves evenly down the slope to collecting ditches at the bottom edge of the area and water-tolerant grasses are an essential component of the system. This form of land treatment requires alternating applications of effluent (usually treated) and resting of the land, to allow soil reaction and grass cutting. The total area utilized is normally broken up into small plots to allow this form of intermittent operation and yet achieve continuous treatment of the flow of wastewater.

Basic site characteristics and design features for overland flow treatment pointed out that steeper land slopes might be feasible at reduced hydraulic loadings. The ranges given for field area required and application rates cover the wastewater quality from raw sewage to secondary effluent, with higher application rates and lower land area requirements being associated with higher levels of pre-application treatment. Although soil permeability is not critical with this form of land treatment, the impact on groundwater should not be overlooked in the case of highly permeable soils.

The application rate for wastewaters will depend principally on the type of soil, the quality of wastewater effluent and the physical and biochemical activity in the near-surface environment. Rational design procedures, based on the kinetics of BOD removal, have been developed for overland flow systems. The cover crop is an important component of the overland flow system since it prevents soil erosion, provides nutrient uptake and serves as a fixed-film medium for biological treatment. Crops best suited to overland flow treatment are grasses with a long growing season, high moisture tolerance and extensive root formation. Suspended and colloidal organic materials in the wastewater are removed by sedimentation and filtration through surface grass and organic layers. Removal of total nitrogen and ammonia is inversely related to application rate, slope length and soil temperature. Phosphorus and trace elements removal is by sorption on soil clay colloids and precipitation as insoluble complexes of calcium, iron and aluminum. Overland flow systems also remove pathogens from sewage effluent at levels comparable with conventional secondary treatment systems, without chlorination. The overland flow projects both for wastewater and effluent quality and for application rates should always be incorporated into the design.

Macrophyte Treatment

Maturation ponds which incorporate floating, submerged or emergent aquatic plant species are termed macrophyte ponds and these have been used in recent years for upgrading quality of effluents from stabilization ponds. Macrophytes take up large amounts of inorganic nutrients (especially N and P) and heavy metals (such as Cd, Cu, Hg and Zn) as a consequence of the growth requirements and decrease the concentration of algal cells through light shading by the leaf canopy and, possibly, adherence to gelatinous biomass which grows on the roots.

Floating Aquatic Macrophyte Systems

Floating macrophyte species, with their large root systems, are very efficient at nutrient stripping. Although several genera have been used in pilot schemes, including Salvinia, Spirodella, Lemna and Eichornia In tropical regions, water hyacinth doubles in mass about every 6 days and a macrophyte pond can produce more than 250 kg per hectare per day (dry weight). Nitrogen and phosphorus reductions up to 80% and 50% have been achieved. In Tamil Nadu, India, studies have indicated that the coontail, Ceratophyllum demersum, a submerged macrophyte, is very efficient at removing ammonia (97%) and phosphorus (96%) from raw sewage and also removes 95% of the BOD. It has a lower growth rate than Eichornia crassipes, which allows less frequent harvesting.

In such macrophyte pond systems, apart from any physical removal processes which might occur (especially sedimentation) the aquatic vascular plants serve as living substrates for microbial activity, which removes BOD and nitrogen, and achieves reductions in phosphorus, heavy metals and some organics through plant uptake. The basic function of the macrophytes in the latter mechanism is to assimilate, concentrate and store contaminants on a short-term basis. Subsequent harvest of the plant biomass results in permanent removal of stored contaminants from the pond treatment system.

The nutrient assimilation capacity of aquatic macrophytes is directly related to growth rate, standing crop and tissue composition. The potential rate of pollutant storage by an aquatic plant is limited by the growth rate and standing crop of biomass per unit area. Fly and mosquito breeding is a problem in floating macrophyte ponds but this can be partially alleviated by introducing larvae-eating fish species such as Gambusia and Peocelia into the ponds.

The pathogen die-off is poor in macrophyte ponds as a result of light shading, lower dissolved oxygen and pH compared with algal maturation ponds. Macrophyte ponds can serve a useful purpose in stripping pond effluents of nutrients and algae and at the same time produce a harvestable biomass. Floating macrophytes are fairly easily collected by floating harvesters. The harvested plants might be fed to cattle, used as a green manure in agriculture, composted aerobically to produce a fertilizer and soil conditioner, or can be converted into biogas in an anaerobic digester, in which case the residual sludge can then be applied as a fertilizer and soil conditioner.

Emergent Macrophyte Treatment Systems

In recent years, natural and artificial wetlands and marshes have been used to treat raw sewage and partially-treated effluents. Natural wetlands are usually unmanaged, whereas artificial systems are specially designed to maximize performance by providing the optimum conditions for emergent macrophyte growth. The key features of such reed bed treatment systems are:

The growth rate and pollutant assimilative capacity of emergent macrophytes such as Phragmites communis and Scirpus lacstris are limited by the culture system, wastewater loading rate, plant density, climate and management factors. As the emergent macrophytes have more supportive tissue than floating macrophytes, they might have greater potential for storing the nutrients over a longer period. Consequently, frequent harvesting might not be so necessary to achieve maximum nutrient removal although harvesting above-ground biomass once a year should improve overall nutrient removal efficiency.

Nutrient Film Technique

The nutrient film technique (NFT) is a modification of the hydroponic plant growth system in which plants are grown directly on an impermeable surface to which a thin film of wastewater is continuously applied. Root production on the impermeable surface is high and the large surface area traps and accumulates matter. Plant top-growth provides nutrient uptake, shade for protection against algal growth and water removal in the form of transpiration, while the large mass of self-generating root systems and accumulated material serve as living filters. The following mechanisms, taking place in three plant sections:

- Roughing or preliminary treatment by plant species with large root systems capable of surviving and growing in a grossly polluted condition. Large sludge accumulations, anaerobic conditions, trace metal precipitation and entrapment characterize this mechanism. A large portion of wastewater BOD and suspended solids would thereby are removed.
- Nutrient conversion and recovery due to high biomass production.
- Wastewater polishing during nutrient-limited plant production, depending on the required effluent quality.

Reed grass is used as the main test species and resulted in the production of better than secondary effluent quality at an application rate of 10 cm/d of settled domestic sewage and synthetic wastewater. The highest loading rates achieved are equivalent to treating the sewage generated by a population of 10,000 on an area of 2 hectare. Plants other than reed grass are also tested and those that flourished best in the nutrient film treatment system are cattails, bulrush, strawflowers, Japanese millet, roses, Napier grass, marigolds, wheat and phragmites.

Membrane Filtration

Filtration membranes are classified according to the pore size or the size of solute they screen out. Microfiltration membranes are porous membranes with pore sizes between 0.1 and 1 micron (1 micron=1000 nanometre). They allow almost all dissolved solids to get through and retain only solids particles over the pore size. Ultra-filtration membranes are asymmetric or composite membranes with pore sizes around between 0.005 and 0.05 micron. They allow almost mineral salts and organic molecules to get through and retain only macromolecules. Nano-filtration membranes are reverse osmosis with pore sizes around 0.001 micron. They retain multivalent ions and organic solutes that are larger than 0.001 micron. Reverse osmosis membranes are dense skin, asymmetric or composite membrane that let water get through and rejects almost all salts. Membranes can reduce contaminants to the levels required by specific reuse application. Membranes can be added in existing sewage treatment plant for design requirements. There are limitations of the membrane technology as the process is only possible after appropriate treatment and has high operation and maintenance cost. In case of Reverse Osmosis, disposal of rejects with high dissolved solids is a problem. Membrane filtration is largely used for polishing water for specific uses like industry process water and high salt aquifer water.

3.2 Summary of Waste Water Treatment Technologies

Urban wastewater treatment has received relatively less attention over many decades compared to plans and programmes focused on providing safe piped water supply through fresh water treatment. Water scarcity coupled with the bursting seams of our cities and towns have taken a toll on our health and environment. The pollution of our lakes and rivers by municipal and industrial wastewater discharges has reached dangerous levels and is now being recognized by concerned government agencies. The current urban wastewater management system is a linear treatment system that is based on disposal. The traditional system needs to be transformed into a sustainable, closed-loop urban wastewater management system that is based on the conservation of water and nutrient resources. A huge loss of life-supporting resources is the result of failed organic wastewater recovery. Wastewater management strategy should result in the reduction of organic matter and pathogens besides chemical contaminants in surface and groundwater to improve public health.

Effective wastewater treatment management system is well established in developed countries but is still limited in developing countries. Collection and conveyance of wastewater out of urban neighborhoods is not yet a service provided to all the population, and adequate treatment is provided only to a small portion of the collected wastewater. In view of population growth forecasts the order of priorities in the development of the coverage of wastewater treatment has to increase by adopting innovative strategy and affordable options.

A key component in any strategy aimed at increasing the coverage of wastewater treatment should be the application of appropriate wastewater treatment technologies that are effective, simple to operate, and low cost (in investment and especially in operation and maintenance). Appropriate technology processes are also more environment-friendly since they consume less energy and thereby have a positive impact on efforts to mitigate the effects of climate change. Also, with modern design, appropriate technology processes causing less environmental nuisance than conventional processes—for example they produce lower amounts of excess sludge and their odor problems can be more effectively controlled.

The problem with the current treatment technologies is that they are not sustainable. The conventional centralized system flushes pathogenic bacteria out of the residential area, using large amounts of water, and often combines the domestic wastewater with rainwater, causing the flow of large volumes of pathogenic wastewater. In fact, the conventional sanitary system simply transforms a concentrated domestic health problem into a diffuse health problem for the entire settlement and/or region. In turn, the wastewater must be treated where the cost of treatment increases as the flow increases. The abuse of water use for diluting human excreta and transporting them away from settled areas is increasingly questioned and being considered unsustainable.

Another reason many treatment systems in developing countries are unsustainable and unsuccessful is that they were simply copied from Western treatment systems without considering the appropriateness of the technology for the culture, land, and climate. Often, local engineers educated in Western development programs supported the choice of the inappropriate systems. Many of the implemented installations were later abandoned due to the high cost of running the system and repairs. On the other hand, conventional systems may even be technologically inadequate to handle the locally produced sewage.

Appropriate technology unit processes include (but are not limited to) preliminary treatment by rotating micro screens; grit chambers; lagoons treatment (anaerobic, facultative and polishing), including recent developments in improving lagoons performance; anaerobic treatment processes of various types, mainly, anaerobic lagoons, up flow anaerobic sludge blanket reactors, physicochemical processes of various types such as chemically enhanced primary treatment; constructed wetlands; stabilization reservoirs for wastewater reuse and other purposes; overland flow; infiltration-percolation and septic tanks.

Out of these processes, various combinations can be set up. Combinations can also include some other simple processes such as sand filtration and dissolved air floatation, which are not considered appropriate processes per se but are in fact appropriate processes. One interesting combined process is the generation of effluents suited for reuse in irrigation based on pretreatment by one of the mentioned unit processes followed by a stabilization reservoir.

Based on experience from past mistakes in sewage treatment technology developers should base the selection of technology upon specific site conditions and financial resources. One approach to sustainability is through decentralization of the wastewater management system. Non-centralized systems are more flexible and can adapt easily to the local conditions of the urban area as well as grow within the locality as its population increases. This approach leads to treatment and reuse of water, nutrients, and byproducts of the technology (i.e. energy, sludge, and mineralized nutrients) in the nearby location of the settlement.

Communities must take great care when reusing wastewater, since both chemical substances and biological pathogens threaten public health as well as accumulate in the food chain when used to irrigate crops or in aquaculture. In most cases, industrial pollution poses a greater risk to public health than pathogenic organisms. Therefore, more emphasis is being placed on the need to separate domestic and industrial waste and to treat them individually to make recovery and reuse more sustainable. The system must be able to isolate industrial toxins, pathogens, carbon, and nutrients.

Although municipal waste water treatment is given impetus under National River Conservation Plan of Ministry of Environment and Forest, and under Namami Gange programme of Ministry of Water Resources River Development and Ganga Rejuvenation, Government of India to provide sewage treatment plant to cities discharging wastewater to rivers. In spite of all these effort and various schemes, the gap between generation and treatment is still large.

3.3 Biological Nutrient Removal Systems

Nitrogen and phosphorus are the primary causes of eutrophication in surface waters. The most recognizable manifestations of this eutrophication are algal blooms that occur during the summer.

Chronic symptoms of over-enrichment include low dissolved oxygen, fish kills, murky water, and depletion of desirable flora and fauna. Excessive amounts of nutrients can stimulate the activity of microbes, which are harmful to human health. Majority of water body impairments are due to nutrient-related causes such as nutrients, oxygen depletion, algal growth, ammonia, harmful algal blooms, biological integrity, and turbidity. In efforts to reduce the nutrient impairments, point sources viz. industrial and municipal wastewater discharges be prescribed more stringent effluent limits for nitrogen and phosphorus. To achieve the stringent limits development of facilities, have to look beyond traditional treatment technologies.

Biological nutrient removal systems remove total nitrogen (TN) and total phosphorus (TP) from wastewater through the use of microorganisms under different environmental conditions in the treatment process. Total nitrogen comprises ammonia, nitrate, particulate organic nitrogen, and soluble organic nitrogen. The biological processes that primarily remove nitrogen are nitrification and de-nitrification. During nitrification ammonia is oxidized to nitrite by one group of autotrophic bacteria, most commonly Nitrosomonas. Nitrite is then oxidized to nitrate by another autotrophic bacteria group, the most common being Nitrobacter.

De-nitrification involves the biological reduction of nitrate to nitric oxide, nitrous oxide, and nitrogen gas. Both heterotrophic and autotrophic bacteria are capable of denitrification. The most common and widely distributed denitrifying bacteria are Pseudomonas species, which can use hydrogen, methanol, carbohydrates, organic acids, alcohols, benzoates, and other aromatic compounds for de-nitrification. In biological nutrient removal system, nitrification is the controlling reaction because ammonia oxidizing bacteria lack functional diversity, have stringent growth requirements, and are sensitive to environmental conditions.

Nitrification by itself does not actually remove nitrogen from wastewater rather, de-nitrification is needed to convert the oxidized form of nitrogen (nitrate) to nitrogen gas. Nitrification occurs in the presence of oxygen under aerobic conditions, and denitrification occurs in the absence of oxygen under anoxic conditions. The total phosphorus comprises soluble and particulate phosphorus. Particulate phosphorus can be removed from wastewater through solids removal. To achieve low effluent concentrations, the soluble fraction of phosphorus must also be targeted.

Biological phosphorus removal relies on phosphorus uptake by aerobic heterotrophs capable of storing orthophosphate in excess of their biological growth requirements. The treatment process can be designed to promote the growth of these organisms, known as phosphate-accumulating organisms in mixed liquor. Under anaerobic conditions, phosphate-accumulating organisms convert readily available organic matter e.g., volatile fatty acids to carbon compounds called poly hydroxy alkenoates. Phosphate-accumulating organisms use energy generated through the breakdown of polyphosphate molecules to create poly hydroxy alkenoates. This breakdown results in the release of phosphorus.

Under aerobic conditions in the treatment process, Phosphate-accumulating organisms use the stored poly hydroxy alkenoates as energy to take up the phosphorus that was released in the anaerobic zone, as well as any additional phosphate present in the wastewater. In addition to reducing the phosphate concentration, the process renews the polyphosphate pool in the return sludge so that the process can be repeated. Some Phosphate-accumulating organisms use nitrate instead of free oxygen to oxidize stored poly hydroxy alkenoates and take up phosphorus. These denitrifying Phosphate-accumulating organisms remove phosphorus in the anoxic zone, rather than the aerobic zone

Phosphorus can also be removed from wastewater through chemical precipitation. Chemical precipitation primarily uses aluminum and iron coagulants or lime to form chemical flocs with phosphorus. These flocs are then settled out to remove phosphorus from the wastewater. However, compared to biological removal of phosphorus, chemical processes have higher operating costs, produce more sludge, and result in added chemicals in sludge.

There are number of biological nutrient removal process configurations designed to remove only TN or TP, while others remove both. The configuration most appropriate for any particular system depends on the target effluent quality, operator experience, influent quality, and existing treatment processes, if retrofitting an existing facility. Biological nutrient removal configurations vary based on the sequencing of environmental conditions (i.e., aerobic, anaerobic, and anoxic) and timing. For biological nutrient removal systems to result in low total nitrogen and total phosphorus effluent concentrations, proper operation and control of the systems is essential.

Biological nitrogen removal reaction rates are temperature dependent. Nitrification and de-nitrification rates increase as temperature increases (until a maximum temperature is reached). In general, nitrification rates double for every 8 to 10°C rise in temperature. The effect of temperature on biological phosphorus removal is not completely understood, although rates usually slow at temperatures above 30°C. Dissolved Oxygen must be present in the aerobic zone for phosphorus uptake to occur. However, it is important not to over-aerate.

The nitrification and phosphorus removal rates decrease when pH levels drop below 6.9. Nitrification results in the consumption of alkalinity. As alkalinity is consumed, pH decreases. Thus, treatment plants with low influent alkalinity may have reduced nitrification rates. Filamentous growth can cause poor settling of particulate nitrogen and phosphorus in final clarifiers. However, many conditions necessary to achieve good biological nutrient removal rates, such as low dissolved oxygen, longer solids retention times, good mixing, also promote filament growth.

3.4 Sludge Management

Sludge in STPs generally refers to the biological organisms, settled organic matter and inert silt which have a tendency to decay and putrefy and as otherwise has its value as soil fillers in agriculture and bio methanation. The option for the bio methanation route and derive energy from the same by way of electricity by igniting the methane gas in specially designed gas engines is the ultimate alternative. In essence, it stipulates the quantity and volatile portion of the sludge solids given by the BOD load.

The sludge reuse is prevailing for bio methanation and using the methane gas to produce electricity in a number of STPs and the digested sludge is utilized as soil filler in agriculture and horticulture. The latter use as soil filler is not easily possible in metropolitan urban centers for want of the farm land. Transportation of the sludge outside the limits of the metropolitan area is never easy as the public there object to this due to odour nuisance. Hence, methods such as pellets to marketable soil fillers or composted organic fertilizers shall have to be practiced.

The practice of transporting of wet sludge in tankers and spraying onto agriculture fields are reported to be in vogue in various countries where such lands are in plenty. But this practice is not practiced in India because of the fact that in the arid temperatures in most parts of the country this may set off an unintentional cycle of airborne aerosol infection. Thus transportation if ever to be carried out shall have to be only in the form of dewatered sludge cake. The disposal shall have to be for eco-friendly purposes as agriculture or farm forestry or pellets for marketing as supplemented organic fertilizers. Another way of utilization of sludge as construction materials as porous pavements, bricks, etc. are being practiced in developed nations.

Faecal Sludge and Septage Management

Sludge generated in an on-site treatment facility should be regularly extracted and hygienically treated. The sludge treatment method includes (1) delivery to a sewage treatment facility and treatment with sludge generated in the sewage treatment process, (2) treatment in a special sludge treatment facility, (3) solar drying on a floor, and (4) treatment by a mobile dehydrating truck.

Areas which are not served by piped sewer systems can adopt on-site systems. The treatment can be either on-site or offsite like in the case of septage management. These are interim measures till a decentralised or a full sewerage system is implemented. It is strongly recommended that the town planning agencies / authorities / urban local bodies / metropolitan development authorities earmark adequate spaces for laying of sewer lines, construction of pumping stations and treatment plants.

On-site Sewage Treatment System and Sludge Handling

Unlike off-site centralized treatment (sewerage), on-site sewage treatment features individual and distributed treatment. The on-site treatment system includes a wide range of facilities, such as a basic sanitation facility like a pit latrine, a simple sewage treatment system that consists of a septic tank and a soak pit for anaerobic and penetrating treatment, and an advanced facility like Johkasou that treats sewage by sophisticated methods. In an urban area with high population density, a sewerage system intensively treats sewage collected from pipes laid over the wide area, while an on-site system treats sewage near to its source. Accordingly, the latter uses various kinds of treatment technologies according to treatment scale and the surrounding conditions. Sludge generated in each on-site treatment facility is collected and treated.

Basically the septage collected should be treated as it cannot be let into the environment directly. Because of this, a treatment facility should be set up or the septage added to an existing septage facility. This implies a near uniform loading on the facility through the all year round instead of peaking the discharge at certain days alone. This in turn demands the planned septage collection logistics round the year by the septage trucks. Hence the establishment of a septage collection unit becomes an adjunct to the decentralized sewerage system where septic tanks are the primary treatment at households.

The treatment of septage can be opted through existing STPs depending on the concentrations of BOD, flows and spare capacity available in them or a separate dedicated treatment facility for septage is developed. The pre-treatment of septage is needed to (a) ensure a flow equalization tank for the septage flow so that it can be loaded onto the STP at as much uniform flow as possible through the 24 hours, (b) a degritting facility to segregate the grit content and prevent it from getting into aeration units & pumps etc. and (c) separate the liquid stream and sludge stream. The equalization tank may be a relatively deeper tank equipped with sub surface mixers to maintain the contents in suspension and not surface aerators or diffused air systems which will create odour problems. The sludge-liquid separation facility can be a filter press or belt press or screw press or centrifuges depending on the feed solids concentration being within the capacity of this equipment.

Independent Septage Treatment Plant

When the distance or the capacity of the plant becomes a limiting factor, it is not a feasible option to transport and treat the septage to the sewage treatment facilities. In this case treatment plants specially meant for septage treatment becomes an attractive option.Independent septage treatment plants are designed specifically for septage treatment and usually have separate unit processes to handle both the liquid and solid portions of septage. These facilities include mechanical dewatering, sludge drying beds, Waste stabilization ponds, etc. The benefit of using these treatment plants is that they provide a solution to septage management.

Many septage treatment plants use lime to provide both conditioning and stabilization before the septage is dewatered. Dewatered sludge can be used as organic fertilizer after drying and composting. The remaining effluent/ filtrate/ supernatant can be released to another treatment process such as waste stabilization pond, anaerobic baffled reactor, constructed wetland or combination of these of extended aeration activated sludge where it can undergo further treatment and then finally can be safely discharged.

Choosing an appropriate septage management method relies not only on technical aspect but also on regulatory requirements. The management option selected should be in conformity with local, State, and Central regulations. Some of the factors that determine the process of selection include: land availability and site conditions, buffer zone requirements, hauling distance, fuel costs, labour costs, costs of disposal and other legal and regulatory requirements.

3.5 Disinfection

Disinfection of treated sewage is needed when the receiving water quality is affected by the bacterial consortium (Coliforms) after the discharge.

Disinfection by Chlorination

Chlorination is the most widely used technology in both water supply and sewage treatment. As the treated sewage is fresh from secondary aerobic biological treatment, the chlorination of such effluents does not result in hazards. In the case of effluents from anaerobic processes like UASB, the provision of an aerobic polishing treatment is mandatory before such chlorination. The usual dosage used is 10 mg/l and the detention time in the contact tank is 30 minutes. Suitable baffles are provided in these tanks to maximize the duration of contact. These tanks shall not be covered and free wind must be allowed to blow across the tank. The residual chlorine after the contact has been generally detected at 1 to 1.5 mg/l at the maximum and there are no offensive odours arising there from.

De-chlorination

Excess of residual chlorine if any is nullified by de-chlorination chemicals like Sulphur Dioxide (SO_2) gas or salts as Sodium Thiosulfate ($Na_2S_2O_3$), Sodium Sulphite (Na_2SO_3), Sodium Bisulfide ($NaHSO_3$), Sodium Metabisulphite ($Na_2S_2O_5$), Calcium Thiosulfate (CaS_2O_3), Ascorbic Acid (Vitamin C) and Sodium Ascorbate. Sodium Bisulfite is used by some utilities due to its lower cost and higher rate of de-chlorination. Sodium sulphite tablets are chosen by utilities due to ease of storage and handling, and its ease of use for dechlorinating constant, low flow rate releases. Sodium Thiosulfate is used for de-chlorination since it is less hazardous in handling and consumes less oxygen than sodium Bisulfite and sodium sulphite. Ascorbic acid and sodium Ascorbate are used because they do not impact DO concentrations. Also, chemicals such as Sodium Metabisulfite, Sodium sulphite and Sodium Thiosulfate may deplete DO of receiving streams under certain circumstances. Sodium Metabisulfite and ascorbic acid may decrease the pH of some waters. It is necessary to determine in the laboratory the choice of the chemical for the given sewage quality and keep stock of the chemical for a demand of at least a week.

Ultraviolet Radiation Disinfection

Ultraviolet rays are most commonly produced by a low pressure mercury lamp constructed of quartz or special glass which is transparent and produces a narrow band of radiation energy at 2637 A0 emitted by the mercury vapour etc. Though this is a standard chemistry, in actual practice, its efficiency is largely constrained by the requirements that (a) The water is free from suspended and colloidal substances causing turbidity, (b) The water does not contain light absorbing substances such as phenols, ABS and other aromatic compounds, (c) The water is flowing in thin film sheets and is well mixed and (d) Adequate intensity and time of exposure of UV rays is well mixed. The advantage of UV is that exposure is only for short periods, no foreign matter is actually introduced and no toxic and no odour is produced. Over exposure does not result in any harmful effects. The disadvantages are that no residual effect is available and there is lack of field test for assessing the treatment efficiency. Moreover, the apparatus needed is expensive.

Ozonation

It is a faintly blue gas of pungent odour. Being unstable, it breaks down to normal oxygen and nascent oxygen. This nascent oxygen is a powerful oxidizing agent and germicidal agent. Ozone is produced by the corona discharge of high voltage into dry air and being unstable has to be produced on-site. It poses more superior bactericidal properties than chlorine. As Ozone reacts with chemical impurities prior to attacking the microorganisms, it produces essentially no disinfectant unless ozone demand of water has been satisfied but much more rapid kills are achieved once free ozone residuals are available.The efficiency of its disinfection is unaffected by pH or temperature of the water over a wide range. Among the disadvantages are (a) its high cost of production, (b) its inability to provide residual protection against recontamination and (c) the compulsion for its generation onsite due to instability.

Relative Aspects of Disinfection Processes

In a recent finding the US Water Environment Federation (WEF) observed that "disinfection of wastewater protects the public from potential exposure to pathogenic microorganisms that would otherwise be present in wastewater effluent that is discharged into water bodies that may be used for recreation or drinking water. Wastewater disinfection has traditionally been accomplished using some form of chlorination. In fact, more than 60 percent of the 20,000 municipal wastewater

treatment plants in North America use chlorination as the primary method of disinfecting effluent. Although an effective disinfectant, chlorine (and related compounds) has come under increased scrutiny because of regulatory, safety and security issues.
An ongoing unpublished work observes states that after studying the performance of disinfectants pf chlorination, its variants, solar, UV, Ozone and Peraceitic acid, the faecal coliform removal was about the same at upto 4<5 log unit except in the case of solar where it was upto 2<3 and total coliforms < 1000 for all except UV at <100and Ozone at < 50. The occurrence and fate of disinfection by-products and related residuals are not readily available.

The relative evaluation of the efficiencies of disinfectants vs. their by-products is long engaging the attention worldwide and reported works are mostly in respect of surface waters, ground waters, surface runoff waters etc. and not precisely for treated sewage. Further the contents and compositions of relatively concentrated sewage in India are vastly different.

US-EPA-Design Manual-Municipal Wastewater Disinfection-EPA/625/1-86/021 observes that even otherwise, the issue of attention has been the disinfection by-products. Though it is contended that chlorination may result in by-products of Trihalomethanes, it needs to be realized that it is the case only when chlorination of humic substances takes place and a treated sewage from an aerobic plant does not purport humic substances. Moreover, the inherent alkalinity in sewage has a beneficial effect on THM formation potential because alkalinity scavenges any hydroxyl free radicals. In respect of UV the distribution of biologically stable water is realized by reducing the AOC concentration using GAC filtration after UV disinfection and as such UV by itself is not a complete treatment. In respect of Ozonation, the overall effect of ozone on effluent toxicity have found the effects to be variable as ozonation of secondary sewage can both decrease or increase effluent toxicity, although overall the effects are generally minor in nature, and considerable research is still needed on the formation of ozone-byproduct species and the effect of ozone on the treated sewage.

Summary

The sewage treatment technologies have gradually upgraded performance over the time from primitive oxidation ponds to sophisticated sequential batch reactor. There are options to select conventional wastewater treatment plants in contrast to non conventional methodologies in view of constraint of land availability in metropolitan and major urban centres. The merits of non-conventional alternative technologies for small townships cannot be overlooked in view of operation and maintenance aspects including requirement of optimum financial resources. The selection of technologies broadly depends on the requirement of norms and concentration of discharge. The understanding of treatment technologies vis a vis discharge of treated wastewater to meet the requirement of recipient water resources should be kept in mind while taking administrative as well as policy decisions.

To Do Activities

- Visit sewage treatment plants of varying capacity in small and big townships
- Understand ease of operation of non-conventional alternative treatment systems.
- How to maintain bio mass in the non-conventional treatment plants and periodic removal of sludge
- Resource management through low cost technology using phyto remediation technologies

- Management of water quality parameters in the rivers and streams by introducing alternative technologies in the changing climate patters

Self-Assessment Questions

1. How to select a treatment technology for treatment of sewage in a metropolitan city?
2. What are the merits and demerits of various wastewater technologies including alternative methodologies?
3. What are discharge norms to be achieved by wastewater treatment plants?
4. What are the limitations of alternative treatment technologies in view of constraint of land availability?
5. Whether alternative technologies can be introduced in situ in drains polluting rivers and drains?

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Chapter 4 Clean Water Solutions

Introduction

The traditional water conservation structures like tanks, lakes, ponds have been in use in India and served as sources of water for people by capturing rainfall and surface runoff. In past few decades many of these structures have been encroached and thus becoming dysfunctional. The usefulness of these structures still holds good and there has been initiatives across the country for revival of such systems.

When it comes to dealing with maintaining water quality, the users and in large the communities have to play a key role in maintaining hygiene near water sources. One has to improve the ways in which we collect and store water so as to avoid contamination while collection, storage and use. With the decentralisation of programmes for water supply it is essential that communities and institutions like panchayats are actively involved in the planning, implementation and execution of programmes for water supply. Panchayats shall also have to undertake the monitoring of water sources and be made aware of simple remedial measures. There is interplay of various factors that govern access and utilisation of water resources and in light of the increasing demand for water it becomes important to look for holistic and people-centered approaches for water management.

Once contamination is detected in a water source, there is need for treatment. In case of rural areas, modern water purification technologies might not be viable. In villages, it is important that simple technologies that are easy to use and can be operated without muchtechnical know-how be promoted. The price factor is also important as technologies with high operational and recurring costs might not be useful.

Rain Water Harvesting and subsequent recharge of groundwater can help lower the concentration of minerals in aquifers and release of water in the catchment area for augmenting river flow. There are various factors that govern access and utilisation of water resources and in light of the increasing demand for water it becomes important to look for holistic and people-centered approaches for water management.

Objectives

- To know the ancient water management systems and resources conservation
- To know the necessity of rainwater harvesting for enrichment of depleted aquifers in overexploited dark zones
- To know the role of watershed in maintaining ecosystem and harmonization of forestation and grassland development in sustaining flow in streams and rivers
- To know the extremities of draught and floods and management of water requirements
- To know the importance of recycling, reuse for maintaining requirement of environmental flows.
- To understand various options of river restoration and control of pollution
- To know the contribution of water reclamation by individuals and communities in maintain quantity and quality of aquatic resources.

4.1 Introduction and Ancient Water Technology

India is endowed with a rich and vast diversity of natural resources in general and water in particular. Watersheds play a critical role in the natural functioning of the ecosystem thus considered as one of the primary planning units in the field of natural resource management. It is not only the hydrological unit but also socio-political ecological entity, determining food, social, and economical security and provides life support services to people. Watershed management is a way of looking at relationships among people, land and water. The existence of the plant and animal kingdoms depends on water. Water is essential for irrigation, generation of hydro-electricity, navigation and industries. India has a rich heritage of water conservation.

On an average, every year India gets 4,000 billion cubic meters (BCM, 1 BCM = 1 cu km) of water by way of mostly rainfall and some snowfall. However, there are considerable spatial and temporal variations in the distribution of rainfall and hence in availability of water in time and space in the country. It is estimated that out of the 4000 BCM water, 1869 BCM is available water resource. Out of this the quantity that can be put to use (Utilizable) is only 1123 BCM (690 BCM from surface water resources and 433 BCM from ground water resources). The water demand in the year 2000 was 634 BCM and it is going to be 1093 BCM by the year 2025. Efforts, therefore, need to be made to increase the utilizable quantity by conservation, improving efficiencies and increasing supply sources.

The annual average rainfall of our country is about 118.28 cm. Mean (1901-2003) rainfall of July is 286.5 mm, which is the highest and contributes 24.2 % of annual average rainfall. The August rainfall is slightly lower and it contributes 21.2% of annual average rainfall. June and September rainfall are almost similar and they contribute 13.8 % and 14.2 % of annual average rainfall respectively. The mean south-west monsoon rainfall (87.72 cm) contributes 74.2 % of annual average rainfall. Contribution of pre-monsoon rainfall and post-monsoon rainfall in annual average rainfall is mostly the same (11%). Coefficient of variation is higher during the months of November, December, January and February.

Majority of this precipitation runs off to sea resulting water scarcity in summer seasons especially in dryland areas where there is no source of irrigation facility. In such cases many resorts to ground water over utilization to meet demands. It has led to declining of groundwater level in many parts of the country.

Floods may occur in the heavy rainfall areas whereas drought breaks out in the low rainfall areas. Sometimes the summer southwest monsoons break late and close earlier, and in some years break earlier and close earlier too. Again, at times it doesn't rain in the growing period of crops in the months of July and August. Sometimes late monsoons also damage crops; therefore, this monsoon rainfall is very uncertain.

As a result of such irregular, unequal and uncertain monsoon rainfall, natural calamities like flood and drought have their devastating effects in our country. About one third of the country's area is drought prone. The south and western parts comprising the states of Rajasthan, Gujarat, Andhra Pradesh, Madhya Pradesh, Maharashtra, Tamil Nadu and Karnataka are the drought prone states.

On the other hand, north and north eastern regions including states of Uttar Pradesh, Bihar, West Bengal and Assam are subjected to periodic flooding. This occurrence of flood and drought has adverse impact on food production and also causes substantial loss of fertile top soil and country's wealth. Therefore, integrated development and management of water resources of the country with scientific data base is a pre-requisite for achieving sustainable development.

Water resource development needs to be at both macro and micro levels. Construction of large dams and reservoirs for irrigation and power generation are covered under macro level whereas development programmes at watershed level primarily for conservation of soil and water resources are covered under micro level.

Ancient Water Technology

Ancient Indians understood the science and art of settlement planning, architecture and governance of natural resources. Kautilya's Arthasastra, written around 300 BC discussed about these aspects in detail. The kings provided fiscal incentives to the communities or individuals who built water systems.

Archaeologists have found evidence of early Indian hydraulic engineering. Sringaverapura tank near Allahabad is a remarkable system to convert floodwater of River Ganga into a set of desalting chambers, including water weirs, to clean the water for drinking. Dholavira, Gujarat of Indus Valley civilization had built lakes to harvest monsoon runoff for drainage system and drinking water. During early Harappan phase (2800–2600 BC), rain water-retaining devices (eg. gabarbands and Lothal) have been discovered in Baluchistan and Sindh Kohistan to store water for irrigation purposes.

In the 3rd century BC, drainage systems included soak-pits built of pottery ring are built in Ujjain and Taxila were used for the disposal of domestic wastewater which was canalized out from the houses through earthenware drain-pipes into soak-pits. British Gazettes written of these systems, at times with awe and mentioned India as a hydraulic society. Ingenious system of flood management of Bengal was famous in British era.

In South Asia, during the Sangam Period, rainwater harvesting was started to irrigate paddy fields, and fishing was practiced in lotus ponds. Domestic grey and black water were canalized through street-side drains, and cesspits were implemented in order to avoid the clogging of the system.

During the 1st century AD, a grand dam was built on the river Cauvery to protect the downstream populations from floods, and to provide water for irrigation purposes. Katta, sand bores called as Madakas in Karnataka, Pemghara in Odisha and Johads in Rajasthan, are the oldest systems used to conserve and recharge ground water. Desert city of Jaisalmer in Rajasthan is a best example of traditional Indian rain water harvesting. These are the real symbols of ancient India's scientific prowess.

Visvesvarayya, the architect of water management in modern India, took inspiration from the ancient civilizations. Not only in water management, ancient Indian technology adopted simple, effective and sustainable methods in the domain of water treatment too (eg. reducing fluoride levels by adding Tulasi, Vetiver, and Drumsticks). We must be proud of our water heritage and relearn its art and science. Taking a leaf out of the fascinating past of water management and conservation in India we must solve present water crisis.

4.2Rainwater Harvesting

Rain water harvesting is the technique of collection and storage of rain water at surface or in sub-surface aquifers, before it is lost as surface run-off. The augmented resource can be harvested in the time of need. Artificial recharge to ground water is a process by which the ground water reservoir is augmented at rate exceeding that under natural conditions of replenishment.
The need of rainwater harvesting is to overcome the inadequacy of waters to meet demands; arrest decline in ground water levels; enhance availability of ground water at specific place and time and utilize rain water for sustainable development; increase infiltration of rain water in the subsoil which has decreased drastically in urban areas due to paving of open area; improve ground water quality by dilution; increase agriculture production and improve ecology of the area by increase in vegetation cover, etc.

The advantages of rainwater harvesting are recharging cost to sub-surface reservoir is lower than surface reservoirs; aquifer serves as distribution system; no land is wasted for storage purpose and no population displacement; ground water is not directly exposed to evaporation and pollution; storing water underground is environment friendly; increases the productivity of aquifer; reduces flood hazards and effects rise in ground water levels; mitigates the effects of drought and reduces soil erosion.

Rainwater can be collected from drainage system, rivers, streams or building roofs, and the water collected is redirected to a deep pit (well, shaft, or borehole) or reservoir with percolation. Rainwater harvesting is one of the simplest and oldest methods of augmenting availability of pristine quality water by communities in water scarce regions worldwide. Rainwater harvesting systems can range in complexity, from systems that can be installed with minimal skills, to automated systems that require advanced setup and installation. The basic rainwater harvesting system is to connect all the water channels in the watershed to porous and permeable strata or for rooftop systems wherein all the outlets from the building's terrace are connected through a pipe to an underground tank that stores water.

Rainwater harvesting Systems are ideally sized to meet the water demand for the dry season, since it must be big enough to support daily water consumption. Specifically, the rainfall capturing area such as a building roof must be large enough to maintain adequate flow of water. The water storage tank size should be large enough to contain the captured water. Before a rainwater harvesting system is built, use of digital tools is useful. For instance, to detect if a region has a high rainwater harvesting potential, rainwater-harvesting GIS maps can be made using an online interactive tool, or, to estimate how much water is needed to fulfill a community's water needs. Tools like these can save time and money before a commitment to build a system is undertaken, in addition to making the project sustainable and long lasting.

The important aspects to be looked into for designing a rainwater harvesting system to augment ground water resources are hydrogeology of the area including nature and extent of aquifer, soil cover, topography, depth to water level and chemical quality of ground water. The availability of source water, one of the prime requisite for ground water recharge, assessed in terms of non-committed surplus monsoon runoff; area contributing run off, land use pattern (industrial, residential, green belt, paved areas, roof top area etc.) and hydro-meteriological characters like rainfall duration, general pattern and intensity of rainfall.

The potential areas for rainwater harvesting are where ground water levels are declining on regular basis; substantial amount of aquifer has been de-saturated; availability of ground water is inadequate in lean months; due to rapid urbanization, infiltration of rain water into subsoil has decreased drastically and recharging of ground water has diminished. The methods and techniques of rainwater harvesting in urban areas are roof top rainwater /storm runoff harvesting through recharge pit, recharge trench, tubewell and recharge well.

Urban Areas

In urban areas, rain water from roof tops of buildings, paved and unpaved areas flows to the drainage system and does not remain available in the locality of downpour. This water can be recharged to aquifer and can be utilized gainfully at the time of need. The rain water harvesting system needs to be designed in a way that it does not occupy large space for collection and recharge system.

The roof top rain water harvesting through recharge pit is feasible in alluvial areas where permeable strata is exposed on the land surface or at very shallow depth. The technique is suitable for buildings having water drainage pipes are constructed for recharging the shallow aquifers.) Recharge Pits may be of any shape and size and are generally constructed 1 to 2 meter wide and 2 to 3 meter deep which are back filled with column of boulders at the bottom, gravels in between and coarse sand at the top so that the silt content that will come with runoff will be deposited on the top of the coarse sand layer and can easily be removed. A mesh should be provided at the roof so that leaves or any other solid waste /debris is prevented from entering the pit and a desilting /collection chamber may also be provided at the ground to arrest the flow of finer particles to the recharge pit. The top layer of sand should be cleaned periodically to maintain the recharge rate. By-pass arrangement be provided before the collection chamber to reject the first showers.

In areas where the shallow aquifers have dried up and existing tube wells are tapping deeper aquifer, roof to rain water harvesting through existing tube well can be adopted to recharge the deeper aquifers.PVC pipes of 10 cm diameter are connected to roof drains to collect rainwater. The first roof runoff is let off through the bottom of drainpipe. After closing the bottom pipe, the rainwater of subsequent rain showers is taken through an online filter screen. The filter may be provided before water enters the tubewells. The filter may be onemeter in length. It’s diameter should vary depending on the area of roof. The filter may be divided into three chambers by erecting screens so that filter material is not mixed up. The first chamber maybe filled up with gravel , middle chamber with pebbles and last chamber with bigger pebbles .

Rural Areas

In rural areas, rain water harvesting can be taken up considering watershed as a unit. Surface spreading techniques are common since space for such systems is available in plenty and quantity of recharged water is also large. The techniques in forests and rural areas are gully plug, contour bund, gabion structure, percolation tank, check dam, recharge shaft and dug well recharge. The gully plugs are built using local stones, clay and bushes across small gullies and streams running down the hill slopes carrying drainage to tiny catchments during rainy season. Gully plugs help in conservation of soil and moisture. The sites for gully plugs may be chosen whenever there is a local break in slope to permit accumulation of adequate water behind the bunds.

The contour bunds are effective methods to conserve soil moisture in watershed for long duration. These are suitable in low rain fall areas where monsoon run off can be impounded by constructing bunds on the sloping ground all along the contour of equal elevation. Flowing water can be intercepted before it attains the erosive velocity by keeping suitable spacing between bunds. Spacing between two contour bunds depends on the slope the area as the permeability of the soil. Lesser the permeability of soil, the close should be spacing of bunds. Contour bunding is suitable on lands with moderate slopes without involving terracing.

The percolation tank is another artificially created surface water body, submerging in its reservoir a highly permeable land so that surface runoff is made to percolate and recharge the ground water storage. Percolation tank may be constructed preferably on second to third order streams, located on highly fractured and weathered rocks, which have lateral continuity downstream. The recharge area downstream may have sufficient number of wells and cultivable land to benefit from the augmented ground water. The size of percolation tank should be governed by percolation capacity of strata in the tank bed. The percolation tanks are mostly earthen dams with masonry structure only for spillway. The purpose of the percolation tanks is to recharge the ground water storage and hence seepage below the seat of the bed is permissible.

The Check dams are constructed across small streams having gentle slope. The site selected should have sufficient thickness of permeable bed or weathered formation to facilitate recharge of stored water within short span of time. The water stored in these structures is mostly confined to stream course and the height is normally less than 2 meter and excess water is allowed to flow over the wall. In order to avoid scouring from excess run off, water cushions are provided at downstream side. To harness the maximum run off in the stream, series of such check dams can be constructed to have recharge on regional scale.

Clay filled cement bags arranged as a wall are also being successfully used as a barrier across small nalas. At places, shallow trench is excavated across the nala and asbestos sheets are put on two sides. The space between the rows of asbestos sheets across the nala is backfilled with clay. Thus, a low-cost check dam is created. On the upstream side clay filled cement bags can be stacked in a slope to provide stability to the structure.

Tamil Nadu was the first State to made rainwater harvesting compulsory for every building to avoid groundwater depletion. The scheme was launched in 2001 and has been implemented in all rural areas of Tamil Nadu. It gave excellent results and following the experience other States took it as a role model. In Bangalore, adoption of rainwater harvesting is mandatory for a particular size of newly constructed building and the Bangalore Water Supply and Sewerage Board has constructed “Rain Water Harvesting Theme Park” with different type of rainwater harvesting models are demonstrated. In Rajasthan, rainwater harvesting has traditionally been practiced in the desert region whereas in Pune, rainwater harvesting is compulsory for any new housing society to be approved for habitation.

States of Andhra Pradesh, Gujarat, Haryana, Himachal Pradesh, Kerala, Madhya Pradesh, Maharashtra, Tamil Nadu, Ranchi Regional Development Authority, Bombay Municipal Corporation and Pimpri – Chinchwad Municipal Corporation, Municipal Corporation of Ludhiana, Improvement Trust, Jalandhar, Jaipur Municipal Corporation, Mussorie Dehradun Development Authority, and

Union Territories of Delhi, Daman & Diu and Puducherry have made necessary provision in their building bye-laws to make installation of rain water harvesting system mandatory. Andaman & Nicobar, Lakshadweep and Karnataka have initiated action for the purpose. Comprehensive Water Law be needs to be introduced for taking necessary measures for making roof top rain water harvesting mandatory throughout the country.

4.3 Solution for Flood Management

Floods have been recurrent phenomenon in many parts of India, causing loss of lives and public property and bringing untold misery to the people, especially those in the rural areas. There is also a larger economic impact, as they derail economic activities, thus affecting growth. Indian continent has peculiar climatic conditions since it has floods in some parts whereas drought in other parts. The trend of increasing damage and devastation brought by floods has posed a challenge to the Government as well as to the society at large. The approaches to flood management presently exercised in India need integrated strategy for policy and management related to floods.

The river systems and associated flood in in India can be broadly divided into Brahmaputra- Ganga basin; North West part of India comprising of Satluj, Beas, Ravi, Chenab and Jhelum rivers watershed region; and Central India and Deccan region comprising of Narmada, Tapi , Mahanadi, Godavari, Krishna and Cauvery river.

The rivers Brahmaputra & Barak and their tributaries covering eight states Assam, Arunachal Pradesh, Meghalaya, Mozoram, Nothern parts of West Bengal, Sikkim, Manipur, Tripura and Nagaland. The catchments of these rivers receive very heavy rainfall ranging from 110 to 635 centimeter a year which occurs mostly between the months of May to September. As a result, floods in this region are severe and quite frequent. Further, the rocks of the hills, where these rivers originate are fragile and susceptible to erosion thereby causing exceptionally high silt charge in the rivers. The predominant problems in this region are the flooding caused by spilling of rivers over their banks, drainage congestion and tendency of some of the rivers to change their courses.

The river Ganga and its numerous tributaries, of which important ones are the Yamuna, the Sone, the Ghaghra, the Gandak, the Kosi and the Mahananda, covers ten states viz. Uttarakhand, Uttar Pradesh, Bihar, Jharkand, South and Central parts of West Bengal, parts of Haryana, Himachal Pradesh, Rajasthan, Madhya Pradesh and Delhi. The normal annual rainfall in this region varies from 60 to 190 centimeter of which more than 80% occurs during the south west monsoon. The rainfall increases from West to East and from South to North.

The flood problem is mostly confined to the areas on the northern bank of the river Ganga. The damage is caused by the northern tributaries of the Ganga by spilling over their banks and changing their courses. Even though the Ganga is a mighty river carrying huge discharges of 57,000 to 85,000 cumec (2 to 3 million cusec), the inundation and erosion problems are confined to relatively few places. In general, the flood problem increases from the West to the East and from South to North.

The main rivers of north west region are the Sutlej, the Beas, the Ravi, the Chenab and the Jhelum, the tributaries of Indus, all flowing from the Himalayas. These carry quite substantial discharge during the monsoon and also large volumes of sediment. They change their courses frequently and leave behind tracts of sandy material. The region covers the State of Jammu and Kashmir, Punjab and parts of Himachal Pradesh, Haryana and Rajasthan. The flood problem is relatively less in this region as compared to Brahmaputra and Ganga basin.. The major problem is that of inadequate surface drainage which causes inundation and water logging over vast areas.

The important rivers in the central and southern region of the country are the Narmada, the Tapi, the Mahanadi, the Godavari, the Krishna and the Cauvery. These rivers have mostly well defined stable courses. They have adequate capacity within the natural banks to carry the flood discharge except in the delta area. The lower reaches of the important rivers on the East Coast have been embanked, thus largely eliminating the flood problem.

Statutory Provisions about Flood Management

The subject of flood control, unlike irrigation, does not figure as such in any of the three legislative lists included in the Constitution State list, Union list and concurrence list of India. However, Drainage and Embankments, are two of the measures specifically mentioned in entry 17 of List II (State List). The Regulation and development of inter-State rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by Parliament by law to be expedient in the public interest. Thus, the primary responsibility for flood control lies with the States. A number of States have already enacted laws with provisions to deal with matters connected with flood control works. Therefore, the subject “flood management” falls within the purview of the States. The schemes for flood control are planned, investigated and implemented by the States as per priorities within the State with their own resources and the role of central government is technical, advisory, catalytic and promotional in nature.

Existing Flood Management Mechanisms in India

In India, a two tier system of flood management exists. The State Government level mechanism includes the Water Resources Departments, State Technical Advisory Committee and Flood Control Board. In some States, the Irrigation Departments and Public Works Departments look after flood matters. The Central Government mechanism is governed through Central Water Commission, Brahmaputra Board, Ganga Flood Control Commission, Farraka Barrage Project Authority and National Disaster Management Authority and various expert committees to enable the State Governments in addressing flood problems in a comprehensive manner.

The Government of India while framing National Water Policy has laid significant emphasis on the management of floods. The policy elaborate that “adequate flood cushion should be provided in water storage projects wherever feasible to facilitate better flood management”. While it recognized that “physical flood protection works like embankments and dykes will continue to be necessary”, it laid emphasis on adoption of non -structural measures for the minimization of losses, such as flood forecasting and warning and flood plain zoning etc.

Presently, there are 878 Hydrological and Hydro-meteorological sites being operated by CWC across the country covering 20 river basins for gauge, discharge, sediment & water quality observations. The activity of flood forecasting comprises of Level Forecasting and Inflow Forecasting. The level forecasts help the user agencies to decide mitigating measures like evacuation of people and shifting people and their movable property to safer locations. The Inflow Forecasting is used by various dam authorities in optimum operation of reservoirs for safe passage of flood downstream as well as to ensure adequate storage in the reservoirs for meeting demand during non-monsoon period.

Flood Management Measures practiced in India

Different measures have been adopted to reduce the flood losses and protect the flood plains by government agencies. Depending upon the nature of work, flood protection and flood management measures may be broadly classified as Engineering or Structural Measures and Administrative or Non-Structural Measures

Engineering /Structural Measures

The engineering measures for flood control are artificially created reservoir behind a dam across a river; natural depression suitably improved and regulated; diversion of a part of the peak flow to another river or basin, where such diversion would not cause appreciable damage and constructing a parallel channel by passing a particular town/reach of the river prone to flooding.

The engineering methods of flood protection, which do not reduce the flood flow but reduce spilling, are embankments which artificially raise the effective river bank and thereby prevent spilling; and channel and drainage improvement works, which artificially reduce the flood water level so as to keep the same, confined within the river banks and thus prevent spilling.

The reservoirs can moderate the intensity and timing of the incoming flood. They store the water during periods of high discharges in the river and release it after the critical high flow condition is over, so as to be ready to receive the next wave. Their effectiveness in moderating floods would depend on the reservoir capacity available at that time for absorbing the flood runoff and their proximity to the likely damage centre.

The detention Basins are usually formed by utilizing natural depressions/ swamps and lakes by improving their capacity by constructing encircling embankments and providing suitable devices for regulating the release of stored waters. The Ghaggar detention basin in Rajasthan is a good example of detention basin concept. Depressions available upstream of Srinagar City, on the left bank of river Jhelum, the Mokama Tal area in Bihar and Ottu, Bhindawas, Kotla lakes in Haryana and various beels/haors of Barak basin are some examples of a few natural basins.

Embankments (including ring bunds and town protection works) confine the flood flows and prevent spilling thereby reducing the damage. These are generally cheap, quick and most popular method of flood protection and have been constructed extensively to give considerable protection at comparatively low costs. In many places, embankments are the only feasible method of preventing inundation. Embankments are designed and constructed to afford a degree of protection against floods of a certain frequency and intensity or against the maximum recorded floods till the time of their planning only (in the absence of detailed hydrological data for longer periods) depending upon the location protected and their economic justification. Apart from the raising and strengthening works, erosion along the embankments and natural banks of the river systems has been a serious problem on which considerable expenditure has been incurred in the past. Particular mention could be made of the erosion problem of the embankment systems in Assam, Bihar, Uttar Pradesh, Punjab and West Bengal. The embankments, under serious attack by the major rivers and their tributaries, have to be suitably protected by spurs, pitching and other suitable anti-erosion measures. On many embankment systems like the Kosi embankment and Piprasi-Pipraghat embankment on the Gandak in Bihar, the river attack is so severe that the protection measures required to be taken are large and cannot be covered under the normal maintenance works.

The channelisation of rivers in certain reaches, in the context of tackling the extensive meandering problems of the rivers is another option for controlling floods. The method of improving the channel by improving the hydraulic conditions of the river channels by desilting, dredging, lining etc., to enable the river to carry its discharges at lower levels or within its banks be adopted although having constraint of its high cost and other problems. Dredging operations of the Brahmaputra, which were undertaken in the early seventies on an experimental basis, were discontinued because of their prohibitive cost and limited benefits. Dredging in selected locations may perhaps be considered as a component of a package of measures for channel improvement to check the river bank erosion subject to techno-economic justification. It may be economically justifiable as a method for channel improvement where navigation is involved. Dredging is sometimes advocated for clearing river mouth or narrow constrictions.

The surface water drainage congestion due to inadequacy of natural or artificial drainage channels to carry the storm water discharge within a reasonable period causes damages is another component of river flooding. It is often difficult to distinguish between flood and drainage congestion situations. This problem is rather acute in Andhra Pradesh, Bihar, Haryana, Punjab, Orissa, Uttar Pradesh, Assam, West Bengal, J&K, Gujarat and Tamilnadu. Therefore, improvement of drainage by construction of new channels or improvement in the discharge capacity of the existing drainage system is required as an integral part of the flood management programme in the country.

Stress has to be laid on improving the existing natural drainage system in the flood plains so that what should essentially be flooding of a few days should not get prolonged for months. In this context, the importance of the system ‘dhars’ or ‘old channels’, which efficiently served the function of draining away the spillage and surface flows generated by local rains, must be revived. The blocking of these natural drainage channels, which is normally done in the name of “reclamation for development” because of paucity of land or vested interest, must be firmly discouraged. This applies also to all-natural depressions, which are targeted for reclamation.The adequacy of existing sluices and drainage channels should be reviewed in areas suffering from drainage congestion. If the capacities of existing sluices in embankments and drainage channels are inadequate, this should be improved by increasing the vents and improving outfall conditions.

The diversion of flood waters takes a part of the flood discharge to another basin or to the same basin downstream of the problem area or to a depression where it could be stored for subsequent release. This measure can be used to manage unusual floods around cities as in the case of flood spill channel near Srinagar and also in the lower reaches of a river near the sea as in the case of Krishna Godavari drainage scheme. Important schemes under execution and under planning are the outfall channel in Jammu and Kashmir, the Damodar in the lower reaches in West Bengal, the Thottapally Spillway diversion in Kerala, the Kolleru lake diversion into the sea in Andhra Pradesh, the Kama-Pahari drain in Rajasthan and the Hulwaa drain in Uttar Pradesh.

The watershed management measures include developing and conserving the vegetative and soil covers and also to undertake structural works like check-dams, detention basins, diversion channels, etc. In the watershed management of upper catchment, land treatment through afforestation and grass land development practices should be supplemented by structural works for retarding the water velocity and arresting silt.

Besides the structural measures the administrative methods or nonstructural measures endeavor to mitigate the flood damages by facilitating timely evacuation of the people and shifting of their movable property to safer grounds by having advance warning of incoming flood i.e. flood forecasting, flood warning in case of threatened inundation; and discouraging creation of valuable assets/ settlement of the people in the areas subject to frequent flooding i.e. enforcing flood plain zoning regulation.

Providing absolute protection to all flood prone areas against all magnitude of floods is neither practically possible nor economically viable. Such an attempt would involve stupendously high cost for construction and for maintenance. Hence a pragmatic approach in flood management is to provide a reasonable degree of protection against flood damages at economic cost through a combination of structural and non-structural measures.

The flood-plain zoning is a concept central to flood plain management and the fact that the flood plain of a river is essentially its domain and any intrusion into or developmental activity therein must recognise the river's 'right of way'. Flood-plain zoning measures aim at demarcating zones or areas likely to be affected by floods of different magnitudes or frequencies and probability levels, and specify the types of permissible developments in these zones, so that whenever floods actually occur, the damage can be minimised, if not avoided. Unfortunately, while all generally endorse this approach in principle, scant attention is given to it in actual practice, leading to increased flood damages.

Flood Proofing

Flood proofing measures adopted in India in the past, consisted in raising a few villages above pre-determined flood levels and connecting them to nearby roads or high lands. Under this programme, several thousand villages were raised in Uttar Pradesh in the fifties. In West Bengal and Assam also land-fills were attempted in villages to keep houses above flood levels even though nearby agricultural lands were liable to inundation.

Causes for annual floods are well-known and thus timely action should be planned based on lessons learned from the past experience. In view of climate change, varying precipitation intensity impact river flow patterns and thus the embankments and reservoirs must be designed to accommodate worst case scenarios. Works related to watershed management should be prioritized to minimize the runoff leading to flooding.

4.4 Watershed Management

Watersheds play a critical role in the natural functioning of the Earth thus considered as one of the primary planning units in the field of natural resource management. Watershed approach is more rational because land and water resources have optimum interaction and synergetic effect when developed on watershed basis. The hydrologic unit boundary is important for determining what areas are involved in contributing runoff, sediment, and pollutants.

The Watershed or hydrological unit is considered as scientific and appropriate base for necessary surveys and investigations for assessment of natural resources and subsequent planning and implementation of various development approaches. Drainage basin or hydrologic-unit maps are necessary tools for many water-resource studies such as flood assessments, water-quality sampling, water-use reporting, watershed protection, conservation planning, and resource management.

Watershed boundaries define the aerial extent of land surface from which the runoff flows to a defined drain, channel, stream or river at any particular point. It's a general phenomenon governed by the topography of the terrain.The boundary between two adjacent watersheds is called the drainage divide line. Pour point is the point at which the water flows out of the area. This is the lowest point in elevation along the boundary or the drainage lines. Depending on the size and topography, watersheds can contain numerous tributaries, such as streams and ditches, and ponding areas such as detention structures, natural ponds and wetlands. Boundary of any watershed plays an important role because hydrologic processes can be described, and to some degree controlled or managed within a watershed. As watershed boundaries are scalable, in that one can define a watershed large enough to exhibit or accommodate the ecological processes of interest. Multiple sizes of watersheds can be delineated, and they can be nested for hierarchical analysis.

Hydrological Units Delineation

The systematic delineation of river basins was first attempted in 1949 in which entire country has been distinctly, delineated into 6 water resources regions. These regions have been further divided into 66 major river catchments. It has been extensively used in the planning and development of surface water resources of the country. The hydrological units are delineated as water resource region, river basins, river sub-basin, watershed, sub-watershed, mini-watershed and micro-watershed. The recommended size of the watershed is in the range of 250 to 750 Sq. km. The Soil & Land Use Survey of India, Dept. of Agriculture and Cooperation published a National level Watershed Atlas on 1: 1 million scale based on the Irrigation Atlas of India during 2012. It contains hydrological units of the country categorised in five stages viz. region, basin, catchment, sub-catchment and watershed.

The river systems of the country have been divided into six water resources region viz., Indus drainage, Ganges drainage, Brahmaputra drainage, all drainage flowing into Bay of Bengal except the Ganges and Brahmaputra, all drainage flowing into Arabian Sea except the Indus and the ephemeral drainage in Rajasthan. These have been further divided into 37 basins and 117 catchments, 588 sub-catchments and 3851 watersheds. Watershed is a geographical unit with a common natural drainage outlet. The extent varies from 500 hectare for micro-watershed to 5000 hectare as sub-watershed For management purposes 5000 ha is considered as a unit of intervention. Over the years, the concept of watershed development has expanded from simple soil and water conservation to holistic natural resources development approach. Thus there is a paradigm shift from territory approach to a systemic approach of development.

Land resources are under tremendous pressure with growing needs of development and exploding population with attendant increase in the demand for food, fuel, fodder and fiber. The advent of modern age and newer forces, exacerbated by short-term gain driven motives often lead to over-exploitation of natural resources, including depletion of soil fertility and degradation of land resources.

Land being a non-renewable resource, is the central to all primary production systems. In India, the excessive demand of land for both agricultural and non-agricultural uses have resulted in the development of vast stretches of different kinds of wastelands such as salt-affected land, waterlogged areas, gullied/ravinous lands etc. Planned efforts are needed for their rehabilitation. Over the years, the country's landmass has suffered from different types of degradation caused by biotic and abiotic pressures.

An ever-increasing population places enormous demand on land resources which are indispensable for a country like India with 2.4 % of the worlds' geographical area supporting over 16 % of the world's population. Further, the country has 0.5 % of the worlds grazing lands but has over 18 % of world's cattle population. The tremendous pressure on land has led to conversion of forest lands into urban and industrial areas.

Plan for Water Shed Management to Conserve Water & Augment Flows

The water quality assessment of aquatic resources on long term basis provided information on the segments of rivers that are not meeting water quality criteria and have been identified as polluted. Assessment studies carried out on the sources of pollution in the rivers has highlighted the need for creation of infrastructure facilities (STPs /CETPs/ETPs) for management of wastewater in line with low flow or no flow of fresh water in the rivers and streams; and waste water flows make the river perennial.

In order to have a practical solution to augment non-monsoon availability of water, it is necessary to go through four phases for full scale water shed management in the upper reaches of catchment of the rivers and streams. The suggested phases for water shed management may be (1) Recognition phase (2) Restoration phase (3) Protection phase (4) Improvement phase.

1. Recognition Phase – Identification and Recognition of the problem, Analysis of the cause of the problem and its effect and Development of alternative solutions of problem.
2. Restoration Phase–includes two main steps viz. Selection of best solution to problems identified and Application of the solution to the problems of the land.
3. Protection Phase–takes case of the general health of the watershed and ensures normal functioning. The protection is against all factors which may cause determined in watershed condition.
4. Improvement phase–deals with overall improvement in the watershed and all land is covered. Attention is paid to agriculture and forest management and production, forage production and pasture management, socio economic conditions to achieve the objectives of watershed management.

A three-year plan for watershed development and restoration of river water quality may provide the insight and understanding to revive the forest cover, rejuvenate moisture content through water retention structures and augmenting flow in the drainage channels ultimately feeding to river valleys (Table 4.1).

Table 4.1: Watershed development plan for restoration of water quality of rivers

ACTIVITIES	TIMELINES FOR IMPLEMENTATION OF MODEL RESTORATION PLAN												
		QUARTER I			QUARTER II			QUARTER III			QUARTER IV		
RECOGNITION PHASE	Year	JAN	FEB	MAR	APL	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Gathering of information on identified polluted river stretch	I												
Reconnaissance survey sampling of river	II												
Assessment of water quality	III												
RESTORATION PHASE													
Preparation of Detailed Project Report	I												
Identification of sources of pollution	II												
In-situ bioremediation of drains	III												
PROTECTION PHASE													
Assessment of Treatment technologies, available river flow, prevailing discharge standards	I												
Setting up of sewage treatment plants (STPs)/Effluent treatment plants (ETPs)	II												
Setting up tertiary level sewage treatment facilities for grossly polluted stretches devoid of perennial fresh water flow	III												
IMPROVEMENT PHASE													
Augment river flow if feasible	III												

Rain-fed agriculture accounts for 68% of India's cropped area providing livelihoods to 480 million people. With huge tract of land in the country falling under arid and semi-arid climatic region, Watershed Management is the only viable option to harness production requirement in the agricultural sector especially in the rain fed un-irrigated areas of the Country.

The Department of Land Resources, Ministry of Rural Development is implementing the Integrated Watershed Development Programme with an objective to cover 55 million hectare of rain fed land by 2027. The program is being implemented in all the states of the country. The programme is financed by central and state government in the ratio of 90:10. The integrated water management programme is the second largest watershed programme in the world after China. The programme envisages restoring the ecological balance by harnessing, conserving and developing degraded natural resources such a soil, vegetative cover & water through watershed management initiatives. The outcomes of programme are prevention of soil run-off, regeneration of natural vegetation, rain water harvesting and recharging of the ground water table. This enables multi-cropping and the introduction of diverse agro-based activities, which help to provide sustainable livelihoods to the people residing in the watershed area.

Urban Watershed Management

Urban water management is now on the verge of a revolution in response to rapidly escalating urban demands for water as well as the need to make urban water systems more resilient to climate change. Growing competition, conflicts, shortages, waste and degradation of water resources make it imperative to rethink conventional concepts – to shift from an approach that attempts to manage different aspects of urban water cycle in isolation to an integrated approach supported by all stakeholders.

Integrated urban water management

The goals of urban water management are to ensure access to water and sanitation infrastructure and services; manage rainwater, wastewater, storm water drainage, and runoff pollution; control waterborne diseases and epidemics; and reduce the risk of water-related hazards, including floods, droughts, and landslides. All the while, water management practices must prevent resource degradation. Conventional urban water management strategies, however, have strained to meet demand for drinking water, sanitation, wastewater treatment, and other water-related services.

Some cities in the country face acute water shortages and deteriorating water quality. Integrated urban water management offers a set of principles that underpin better coordinated, responsive, and sustainable resource management practice. It is an approach that integrates water sources, water-use sectors, water services, and water management scales, alternative water sources, differentiates the qualities and potential uses of water sources. It views water storage, distribution, treatment, recycling, and disposal as part of the same resource management cycle and seeks to protect, conserve and exploit water at its source. It accounts for nonurban users that are dependent on the same water source that aligns formal institutions (organisations, legislation, and policies) and informal practices (norms and conventions) that govern water in and for cities.

Under integrated urban water management, supply management and demand management are complementary elements of a single process. There is no one-size-fits-all model nor is any single method sufficient. Rather, the mix of approaches reflects local socio-cultural and economic conditions. Transforming entrenched institutional practice in large cities can be difficult. The greatest opportunities for integrated urban water management to achieve results lie instead with small- and mid-sized cities, who's effects on water resources will become increasingly important in coming decades.

Water availability is not a matter of quantity alone; water quality can, in equal measure, determine how much is available for particular uses. Degraded urban water resources, often caused by inadequate treatment of wastewater, have consequences for ecosystems, health, and water-reliant livelihoods. Throughout history, sufficient water supply and an ability to deal with waste have been critical for urban settlements to flourish.

Water scarcity problems, exacerbated by poor water quality, may limit the volume of water available for specific uses. Degradation often results from human activity – intensive agriculture, resource-heavy industries, and rapid urbanisation – that distorts natural water cycles and processes across the rural-urban spectrum. In cities, for example, the concentration of built-up impermeable areas means that less water infiltrates to groundwater. The base flows of streams are affected and the volume of surface runoff increases. The resulting stormwater flows can convey greater amounts of pollutants, which reduce water quality. Nonpoint source pollution (e.g., agricultural or mining runoff) can seep undetected into aquifers, damaging downstream ecosystems and drinking water sources. The effects of heavy metals are not limited to the degradation of downstream drinking water supply; they can also affect the quality of food intended for urban markets.

The most common water pollutants are microbes, nutrients, heavy metals, and organic chemicals. Eutrophication is the predominant water quality concern in India. It is caused by excess concentrations of nutrients – mainly phosphorus and nitrogen – from agricultural runoff, domestic sewage, industrial effluents, and the atmospheric derivatives of fossil fuel burning and bush fires. Mercury, lead, and other heavy metals from industrial and mining activities, coal-fired power plants and landfills, can accumulate in the tissues of humans and other organisms.

The substances in pharmaceuticals and personal care products – including birth control pills, painkillers, and antibiotics – are showing up in water in increasing concentrations.These emerging pollutants are the next challenge in urban water systems. With advances in science and technology has come knowledge of new contaminants and their impact on human health and the environment. A number of emerging contaminants (e.g., endocrine disrupting chemicals, pharmaceutically active compounds, personal care products and disinfectant resistant microorganisms) have been identified. Their long-term effects on humans and ecosystems are unknown, although some are thought to imitate the actions of natural hormones in various species and cause public and environmental health concerns. These contaminants become more concentrated in low-water conditions. As the knowledge of emerging contaminants and their impacts advances, more stringent water quality standards will be put in place and in turn will increase the pressure on water utilities.

4.5River Restoration

Water quality assessment activities in India performed by many organization including Central Pollution Control Board have provided base line information in respect of water bodies covered under the network locations. Water quality in rivers is deteriorating due to depleting water flow, aggravated by discharge of pollutants from domestic sewage, industrial effluents and run-off from agriculture. Most of the surface water bodies in the country are contaminated to some extent due to organic pollutants and bacteriological contamination. 317 polluted river stretches on 293 rivers and tributaries have been identified (Table 4.2).

The monitoring locations not meeting the water quality criteria have been identified as polluted and the sources of pollution are identified for intervention to contain the discharges. The river action plans are formed on the basis of source identification and enforcement of discharge standards.

Table 4.2: Priority Wise Polluted River Stretches and Towns Along

Priority Class	Polluted River Stretches	No. of Towns
I	48	110
II	21	55
III	78	171
IV	52	116
V	118	207
TOTAL	**317**	**659**

Sewage generation and treatment capacity of the identified cities and towns along the polluted river locations revealed that there is large gap in the system hence treated/untreated and partially treated municipal wastewater is flowing into nearby rivers causing pollution in the downstream reaches. The identified rivers are not polluted in its entire length but the locations or segments are polluted downstream of urban centers i.e. cities or towns, after meeting a polluted tributary, drains or any nearby point source.

Sources of Pollution

Broadly sources of pollution are categorized as point sources and non-point sources. Point sources impacting the water resources in a significant manner whereas non-point sources are contributing only during the monsoon season or the rainy days which are confined to 40 monsoon days in the large part of Indian sub-continent. Thus the control of pollution from point sources is the prime requirement and accordingly required to be prioritized.

Municipal Waste Water

Water pollution from untreated municipal wastewater is an enormous problem in India with grave implications for public health as well as environmental quality. Even the largest cities are struggling to put in place expensive wastewater treatment systems and associated infrastructure. It is implausible that such expensive infrastructure can contribute meaningfully to the water pollution and sanitation challenge in smaller towns and rural areas in the foreseeable future.

Low-cost, decentralized, wetland-based bio-treatment systems have strong potential to dramatically improve the water quality and sanitation problems facing much of India. Scientific research has shown that well designed bio-treatment systems have good performance in terms of removing pollutants from municipal wastewater. Moreover, they are low-cost, quick to deploy, and easy to operate and maintain, making them ideal for India's sanitation context. They can be used extensively in rural areas, small towns, peri-urban areas of large cities, industrial townships or institutional campuses, as well as for certain types of industries such as agro-food/beverage.

In addition to contribution towards improved public health and water quality, this approach has additional potential co-benefits such as employment generation and availability of treated wastewater for irrigation that can increase farm productivity and incomes. However, these potential benefits can only be realized if such bio-treatment systems are deployed widely. Prospects of large scale deployment of bio-treatment systems including potential challenges, sources of finance, manpower, appropriate government interventions and civil society support needs to be considered. These approaches have the potential to contribute significantly to the goal of important government programs such as the Swachh Bharat Mission as well as our commitment to Sustainable Development Goals.

Municipal Wastewater Generation and Treatment

It is estimated that 62,000 million litres per day (MLD) of domestic sewage is generated from urban areas in India which is projected to reach 80,000 MLD by 2030. The installed treatment capacity is about 23,277 MLD from 816 STPs of which only 522 plants are operational, limiting the treatment to 18,883 MLD.

In view of the population increase, demand of freshwater for all the uses will be unmanageable. It is estimated that the projected wastewater from urban centers may cross 120,000 MLD by 2051 and the rural India will also generate not less than 50,000 mld in view of water supply designs for community supplies in rural areas. However, waste water management plans do not address the pace of wastewater generation.

In addition to these limitations, there are issues with regard to regular operation of these STPs and compliance to discharge standards. The new standard for sewage treatment plant (with BOD-10 mg/l, COD-50mg/l, Suspended Solids -10mg/l, T-Nitrogen – 10 mg/, Total Coliform < 230 MPN, pH 6.5 -9.0, NH4-N 5 mg/l, PO4-p 2 mg/l) have been proposed with an objective to encourage use of treated water for non-potable domestic, commercial or industrial use as well as to provide better assimilating capacity to receiving water bodies. Limitations in managing the treatment of domestic wastewater in the country are attributed to:

- Lack of sewerage systems for collection and conveyance of sewage (open storm water drains carry city sewage in many cities)
- Non availability of STPs
- Inappropriate technology and capacity of STPs
- Non-prioritization of wastewater treatment (focus has been on supply of drinking water rather than wastewater treatment)
- No revenue source to meet the management cost of sewage
- Limitation of skilled manpower, technical know-how on operation
- Non-sustainable approach in design of Sewage management projects
- Water not considered as valuable resources and the concept of Reuse, Recycle & Recovery not imbibed in project design
- Energy recovery potential not envisaged (there is a potential to meet up to 50% of the energy requirement through captive generation)

- Multiple agencies are responsible for meeting the objectives
- ULBs are so far immune to enforcement and regulatory provisions
- Lack of awareness on consequences

Industrial Effluents (Wastewater) discharges and Management Aspect

As per an estimate carried by CPCB in the year 2005, about 11000 MLD of wastewater is generated alone from 17 categories of medium and large scale industries. The quantity of industrial discharge has increased many folds over the years in allsectors thus requires comprehensive assessment. Discharge of untreated industrial wastewater through open drains has potential for soil and groundwater contamination. One of the main challenges in control of wastewater pollution from industries is non-compliance to discharge standards; the reasons for such non-compliance may be attributed to:

- Inadequate capacity of ETPs
- Improper selection of treatment technologies
- Poor operation and maintenance of ETP
- Lack of priority or ETP considered as financial liability (Cost centred)
- Failure of regulators to identify the short-comings
- Exploitation of resource limitation of regulators
- Lack of environmental consciousness or self-regulation by industry

Common Effluent Treatment Plant (CETP)

There are large number of highly polluting small scale industries such as tanneries, textile, electroplating, dye & dye intermediates, food processing etc., which exists in clusters in industrial estates. These industries collectively have high pollution potential on receiving environment. Having limited financial resources at their disposal in individual capacity, CETP (Common Effluent Treatment Plants) are a viable option for SSI units for management of cluster origin industrial wastewater.

Various schemes of Government have been facilitating and encouraging CETPs, over past 2 decades. The number of CETPs increased from 88 facilities (with a capacity of 560 MLD) in the year 2005 to 193 facilities with treatment capacity of 1500 MLD. However, achievement of satisfactory performance has been a challenge, including non-compliance to standards due to (i.) discharge of recalcitrant effluent from heterogeneous chemical industrial sources and (ii) non-compliance to inlet water quality by member industries.

There is huge potential for utilization of treated wastewater as resource in agriculture, non-potable urban and Industrial use. Keeping this in view, CPCB has prescribed guidelines for adoption of zero liquid discharges (ZLD)for major water polluting industries.

Legal and Institutional Provision to control Pollution

Government of India has enacted various Acts and assigned functions to Ministries of Water resources, urban development and Environment & Climate Change to achieve sustainable consumptions and usage of water resources. The Water (Prevention and Control of Pollution) Act, 1974 specifies provision for prevention and control of water pollution and maintaining or restoring of wholesomeness of water. The Act also confers the powers and functions to Central and State Pollution Control Boards to achieve the objective.

The Water Act mandates the Boards to plan and execute nationwide programme for prevention, control or abatement of pollution, disseminate information and knowledge by publishing technical documents and lay down standards for regulatory purpose.

Water quality of natural environment (river, lakes and other water bodies) are mandated under the provisions of environmental acts. The Water ((Prevention & Control of Pollution) Act, 1974 has elaborated on the restoration and maintenance of wholesomeness of water. The wholesomeness has been defined for practical purposes by CPCB in the form of designated best uses of water with a set of parameters and their limits. The water quality assessment and its interpretation have highlighted the compliance of water for designated uses and the exceedance of one or more parameter have been defined as polluted. The regulatory provisions under The Water Act, 1974 are enshrined in section 18 for the Central Govt. Water being the state subject, the enforcement is largely confined to the State Govt. Authorities (SPCB/PCC).

The legal and institutional provisions are provided in Water (Prevention and Control of Pollution) Act 1974 wherein standards are developed and enforced for treatment of municipal wastewater by Pollution Control Boards. There are provisions for tightening of standards by State Pollution Control Board for site specific requirements, in view of low flow or no flow in stretches of rivers or streams and for critically polluted areas in view of high concentration of pollution loads in a specific area. The need based directions for zero discharge are prescribed for grossly polluting industrial units however such enforcements are non-implementable in case of municipal bodies. The concept of delinking of sewer to river is gaining momentum in river conservation plans and may bring visible improvement in water quality of recipient's water bodies. There is however a need of making the rivers and streams perennial by introduction of minimum/environmental/ecological flows for maintaining the biodiversity and sustainable ecosystem of aquatic resources through institutional provisions.

Restoration of Polluted River Stretches

Plan for restoration of polluted river stretches can be executed through two fold concepts. One concept may target for enhancement of river flow through interventions on the water sheds/catchment areas for conservation and recharge of rain water for subsequent releases during lean flow period in a year. This concept will work on dilution of pollutants in the rivers and streams to reduce concentration to meet desired level of water quality. Other concept of regulation and enforcement of standards in conjunction with the available flow in rivers /streams and allocation of discharges with stipulated norms.

Plan for Restoration of Water Quality-Promotional and Statutory intervention

Polluted river stretches throughout the country have been identified for restoration of water quality through identification of sources of pollution and interventions through treatment for the municipal as well as industrial effluents.

The river action plans are designed for control of pollution and to restore the water quality of the rivers. The infrastructure development for treatment of sewage always remains short of the waste water generation. The ever growing population and increasing water use in the urban centers has outpaced the plan for creation of infrastructure. The river action plans although have not improve the quality of the water resources however in absence of such plans, the quality of aquatic resources would have been further deteriorated.

Restoration Plan - Promotional Intervention

The restoration plan may have a number of steps and the beginning shall be with the reconnaissance visit including first round of sampling of river/stream/drains and demarcation on the water shed map. The next step shall be identification of sources of pollution and quantification of pollution load vis-a-vis the treatment facilities for municipal wastewater and industrial effluents. The third step shall be towards the treatment technologies, prevailing discharge standards, available flow in the river/stream and review of discharge standards/stream flow. The fourth step will be assessment of water quality trend of river/stream and to work out augmentation of river/stream flow. The fifth and last step is to disseminate the information gathered during the four steps on assessment/ interventions and monitoring of improvement in water quality. The above stated broad concept shall be followed in the development of water quality management plan for polluted rivers and the respective stretches of the rivers.

Restoration Plan - Statutory Intervention

Water quality management through setting up of standards for discharge of municipal wastewater and industrial effluents are enforced through the consent toestablish and consent to operate require a fresh look in view of ambient water quality requirements of aquatic resources. The prevailing standards prescribed in the consent to industrial sector and generaldischarge standards adopted for sewage treatment require change in approach from consumption to disposal to treat,recycle, reuse and discharge to aquatic system if matches with thenorms of water quality ofaquatic resources.

Water Reclamation or recycling is to put use the treated water to non-potable uses. Over 85% of wastewater in Israel is treated for reuse, most of it in agricultural irrigation, making it the leading nation in water recycling. Australia, a water poor nation, uses technologies like ultra-filtration and reverse osmosis to treat grey water and storm water to potable quality. The costs are high, but the reclaimed water is used for drinking (potable) water, non-drinking uses in households, watering golf courses and recreational parks. Industrial uses such as washing and cooling in power stations and factories, agriculture, horticulture, forestry, pasture, flowers, viticulture and sugar cane growing, fire fighting, groundwater recharge, environmental flows and wetlands. Australia finds community attitude and social acceptance to recycled water a challenge, besides its financial cost. However, the benefits of direct potable reuse may include: Lower energy use, lower greenhouse gas emissions, lower capital and operational costs, and a more robust, climate-resilient water supply.

In developing countries like India, the problems associated with wastewater reuse arise from its lack of treatment. The challenge thus is to find such low-cost, low-tech, user friendly methods, which on one hand avoid threatening our substantial wastewater dependent livelihoods and on the other hand protect degradation of our valuable natural resources. The use of constructed wetlands is now being recognized as an efficient technology for wastewater treatment. Compared to the conventional treatment systems, constructed wetlands need lesser material and energy, are easily operated, have no sludge disposal problems and can be maintained by untrained personnel. Further these systems have lower construction, maintenance and operation costs as these are driven by natural energies of sun, wind, soil, microorganisms, plants and animals. Hence, for planned, strategic, safe and sustainable use of wastewaters there seems to be a need for policy decisions and coherent programs encompassing low-cost decentralized waste water treatment technologies, bio-filters, efficient microbial strains, and organic /inorganic amendments, appropriate crops/ cropping systems, cultivation of remunerative non-edible crops and modern sewage water application methods.

Individual Responsibility

The use of water for various household activities generates waste water. The optimum use of water and good practices lead to saving a lot of water. Water conservation has become essential in all regions, even where water seems abundant. That's because our water resources are finite, and they are getting smaller every year. Use simple tips to save more water, both indoors and in your garden and yard.In addition to saving money on your utility bill, water conservation helps prevent water pollution in nearby lakes, rivers, and local watersheds. Conserving water also prevents greenhouse gas emissions associated with treating and distributing water.

Conserving water can also extend the life of septic system by reducing soil saturation and reducing pollution due to leaks. Overloading municipal sewer systems can also cause untreated sewage to flow to lakes and rivers. The smaller the amount of water flowing through these systems, the lower the likelihood of pollution. In some communities, costly sewage system expansion has been avoided by community-wide household water conservation. The most effective way to save water is to upgrade to efficient fixtures. But there are other ways to help reduce the amount of water use at home.Don't Use the Toilet as an waste basket. Every time we flush a cigarette butt, facial tissue, or other small bit of trash, we are wasting litres of water. Put them in the garbage, or better yet, recycle.

To cut down on water waste, put an inch or two of sand or pebbles inside each of two plastic bottles. Fill the bottles with water, screw the lids on, and put them in your toilet tank, safely away from the operating mechanisms. Or, buy an inexpensive tank bank or float booster. This may save couple of litres of water per day. Replace an old toilet with an ultra-low volume flush modelfor savings in water and will cut indoor water use. Alternatively, consider purchasing a dual flush toilet or installing a dual flush converter that turns a standard toilet into a dual flush toilet.

Use Clothes Washer for Only Full Loads and avoid the permanent press cycle, which uses the extra rinse. For partial loads, adjust water levels to match the size of the load.Consider a High Efficiency Washing Machine that pay for itself over its lifetime in water and energy savings. New Energy Star rated washers use less water and energy per load.

Install Water-Saving Showerheads, Shower Timers, and Low-Flow Faucet Aerators for conserving water. Inexpensive water-saving low-flow showerheads or restrictors are easy for the homeowner to install. Long showers can use considerable volume of water every unneeded minute.One way to cut down on water use is to turn off the shower after soaping up, then turn it back on to rinse. A four-minute shower uses approximately 20 litres of water.

Community Responsibility

Water Conservation by Communities may start with developing a plan to educate and involve residents in water conservation efforts. Water system manager should prevent leaking and unwanted wastage of water in gardening, floor washing, car washing. Implement a water-loss management program through universal metering. Consider a reclaimed wastewater distribution system for non-potable uses.

Public health department maintain water supplies to residents should insist on Installation of ultra-low flow toilets and urinals in household and commercial buildings. Retrofit water-saving devices in common utility places. Community must insist on Installation of faucet aerators and low flow shower heads in common services areas and buildings. As the common utility appliances or equipment wear out periodically, society management must replace them with water-saving models.

The policies and programs to encourage water conservation must ensure the utility rate structure encourages water efficiency, or at least does not encourage water waste. The incentive programs (rebates/tax credit) to homeowners and businesses to encourage replacement of plumbing fixtures and appliances with water-efficient models may be offered. Communities must promote water-efficient landscape practices to home owners and businesses, especially those with large, irrigated properties. Practices include use of native plants, landscape innovation to reduce water use, and more efficient irrigation.

The water conservation practices may also be considered while disposal of waste in low income and un-sewered communities. The perception of onsite/decentralized systems are inferior, old-fashioned, less technologically advanced, and not as safe as centralized wastewater treatment systems from both an environmental and public health perspective, many communities have pursued the construction of centralized systems (collection systems and sewage treatment plants).

Centralized wastewater collection and treatment systems, however, are not the most cost-effective or environmentally sound option for all situations (e.g., sewage treatment plants can discharge high point source loadings of pollutants into receiving waters). They are costly to build and operate and are often infeasible or cost prohibitive, especially in areas with low populations and dispersed households. Many communities lack both the revenue to fund these facilities and the expertise to manage the treatment operations. In addition, centralized treatment systems can contribute to unpredicted growth and development that might threaten water quality. As development patterns change and increased development occurs in rural areas and on the urban fringe, many communities are evaluating whether they should invest in centralized sewage treatment plants or continue to rely on on site wastewater treatment systems. The availability of innovative and alternative onsite technologies and accompanying management strategies now provides small communities with a practical, cost-effective alternative to centralized treatment plants.

The water comes out as supernatant from decentralized community managed systems can be utilized in development of grasslands and in agriculture areas in the vicity.Thus the communities be made aware of the options of water use and recycling of grey water which will conserve fresh water use for various purposes.

Summary

The ancient water management systems and resources conservation was helpful in meeting the needs of small communities. The population growth and improving economic situation has increased water demand enormously. The necessity of rainwater harvesting for enrichment of depleted aquifers in overexploited dark zones has been understood and practiced widely throughout the country. The importance of watershed in maintaining ecosystem and harmonization of forestation and grassland development should be visualized in sustaining flow in streams and rivers to deal with extremities of draught and floods and management of water requirements. The importance of recycling, reuse for maintaining requirement of environmental flows in the rivers should be recognized for river restoration and control of pollution.

To Do Activities

- To understand the ancient water management system, visit manmade tanks and step wells in the vicinity
- To understand the watershed and importance of afforestation travel to hill tops to visualize water divide cliffs forming sub watersheds
- Understand aquatic resources, water scarcity and need of rainwater harvesting
- To know the rejuvenated aquifer regions by rainwater harvesting discuss with panchayat officials about the steps being taken by them and resultant outputs in their hinterlands
- Learn methodologies for watershed management and water reclamation by introduction of recycling and reuse of treated wastewater
- To know the impact of floods and damage to communities living along, visit the river reaches in plains of rivers and streams.
- To know flood forecasting and mitigation measures
- Educate individual and community by raising awareness to save water
- Planning and prioritization of river restoration activities by prevention and control of sources of pollution

Self Assessment Questions

1. What were the ancient water management system and how they can be restored?
2. What is watershed and how it is maintain ecosystem and feed water to rivers and streams?
3. How rainwater harvesting to be planned and safeguards in maintain subsurface water quality?
4. How water reclamation be done through recycling and reuse of water and wastewater?
5. How individual and community awareness will help in water conservation?

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Chapter 5 Testing of Water, Waste Water, Soil and Solid Waste

Introduction

The quality of surface or ground water is a function of either or both natural influences and human activities. Without human influences, water quality would be determined by the weathering of bedrock minerals, natural leaching of organic matter from soil and biological processes within the aquatic environment. As a result, water in the natural environment contains many dissolved substances and non-dissolved particulate matter. Dissolved salts and minerals are necessary components of good quality water as they help maintain the health and vitality of the organisms that rely on this ecosystem service.

Water quality is usually determined by analysing samples of water that were collected during monitoring of aquatic resource. The results of water quality monitoring are vital to being able to track both spatial and temporal trends in surface and ground waters.

Typically, water quality is determined by comparing the physical and chemical characteristics of a water sample to water quality guidelines or standards. Drinking water quality guidelines and standards are designed to enable the provision of clean and safe water for human consumption, thereby protecting human health. These are usually determined based on scientifically assessed acceptable levels of toxicity to either humans or aquatic organisms.

Objectives

- To know the importance of water quality and understand impact of environments components
- To know how to collect representative samples, preservation, transportation and associated protocol
- To know the standard operating procedures for analysis of water samples in laboratory
- To know how to interpret analytical reports for logical conclusion
- To know best management laboratory techniques for quality assurance

5.1 Importance of Water Monitoring

The quality of water in various water bodies is rarely constant in time. While there may be some relationship between the rates of change of different variables, others alter independently. The larger the number of samples from which the mean is derived, the narrower will be the limits of the probable difference between the observed and true means. Variations in WQ are caused by changes (increase or decrease) in the concentration of any of the inputs to a water body system. Such changes may be natural or man-made and either cyclic or random. Since it is possible for some changes to occur in combination, the reasons behind variations may sometimes be obscured.

Random variations in the quality of water occur due to unpredictable events. Sudden storms will lead to increased flows followed by polluted runoff and leaching or to the operation of sewer overflows. Rainfall effects may be modified by flood control arrangements. There may be accidental spillages and leakages. Any of these may occur at any time and without warning.

Annual cycles may be the result of regular rainfall patterns, snow melts and seasonal temperature changes, among others. The seasonal growth and decay of vegetation will also give rise to cyclical changes in the composition of the water rates of self purification and nitrification are strongly temperature dependent. There may be daily cycles of natural origin particularly those caused by photosynthesis and affecting dissolved oxygen and pH, industrial, agricultural and domestic activities may cause cyclical changes due to cycles of discharge and abstraction. Hydraulic manipulation of river flow such as by river regulation and dam management for power generation, navigation or other purposes tend to be cyclical but can occur randomly. River flows in India vary widely especially where large scale diversions that are permanent in nature adversely affect water quality.

Water quality variability in a river depends on the hydrological regime, i.e. the water discharge variability, the number of floods per year and their magnitude or the occurrence of low flows. During flood periods, water quality usually shows marked variations due to the different origins of the water: surface runoff, sub-surface runoff (i.e. water circulation within the soil layer), and groundwater discharge. Surface runoff is generally highly turbid and carries large amounts of total suspended solids, including particulate organic carbon. On the one hand, sub-surface runoff leaches dissolved organic carbon and nutrients such as Nitrogen and Phosphorus from soils, whereas ground waters provide most of the elements resulting from rock weathering. On the other hand during low flows a general deterioration of the water quality can be observed due to a higher concentration of pollutants. Thermal pollution of the water quality is caused by the use of water as a coolant by power plants and industrial manufacturers, when returned to the natural environment at a higher temperature.

Water quality monitoring provides an understanding of water-quality conditions in natural streams, rivers, ground water and aquatic systems; how those conditions may vary locally, regionally and nationally; conditions are changing over time; how natural features and human activities affect those conditions; and where are those effects most pronounced.

Main purposes of a water quality monitoring have been the need to verify whether observed parameters are suitable for intended uses. However, over the time monitoring has evolved to enable assessments of the current state of water quantity and quality and its variability in space and time.

Often such assessments are appraisals of the hydrological, morphological, physicochemical, chemical, biological and/or microbiological conditions in relation to reference conditions, human health effects and/or the existing or planned uses of water. Such reference conditions may take into account elevated concentrations of specific determinant parameters due to natural geophysical and geo-chemical processes to support decision-making and operational water management in critical situations.

When pollution events occur, reliable data are needed, which may require early warning systems to signal when critical pollution levels are exceeded or toxic effects occur. In these cases, models can often support decision-making. The impact monitoring determines trends in the quality of the aquatic environment and how the environment is affected by the release of contaminants, by other human activities, and by waste treatment operations.

Background quality monitoring of the aquatic environment is carried out for comparing and assessing the results of impact monitoring; determine treatment options for polluted water; determine ecological flows; evaluate the effectiveness of water management/remedial measures.; and provide the basis of the formulation of science-based environmental policies, and also allow possible for evaluations that determine of whether or not a policy has resulted in the desired effect and been cost effective.

When a water quality monitoring is being planned, water-use managers or similar authorities can reasonably expect that the programme will yield data and information that will be of value for management decision-making. The analysis of water management issues and objectives is the basis for specifying the information needs. These are related to uses (e.g. drinking water, wild life protection, irrigation, recreation) and functions (maintenance of aquatic life) of the watercourse or groundwater body that put requirements on the quality and availability. Other Issues (e.g. flooding, sedimentation, salinisation, pollution) that hinder proper use and functioning of the watercourse or groundwater body; measures taken to address the issues or improve the use or functioning of the watercourse or groundwater body, including environmental aspects.

We should take into account current or envisaged measures, policies and action plans in water management. In specifying human uses and the ecological functioning of water bodies and in identifying pressure factors, issues and targets, the full range of qualitative and quantitative factors in river-basin management should be considered.

The various functions and uses of water bodies - both ecological and human - must be considered. Uses may compete or even conflict, in particular if water is scarce or its quality is deteriorating. A multi-functional approach tries to strike a balance between all desired uses, including ecosystem functioning. This allows the introduction of a hierarchy of uses, providing flexibility for the different levels of water resource management policy development, and for prioritisation in scheduling.

The monitoring and assessment of water quality and quantity require adequate financial resources. Therefore, those responsible for these activities need to demonstrate both the benefits of monitoring for integrated water resources management and the possible costs, in terms of environmental degradation and other impacts, of not monitoring. It is well known that often the prevention of an environmental problem is less costly than its remediation.

While solutions for many environmental problems are expensive and technically challenging, what is often not recognized is that the cost of well-designed monitoring programmes is generally much less than either the cost of policy implementation or the monetary benefits associated with the environmental improvement. This is particularly crucial for countries in which monitoring activities still seem to be insufficiently funded. All basic components of the hydrological cycle should be measured or estimated, taking into account temporal and spatial aspects of hydrological and hydrogeological processes as an important part of any water quality monitoring.

Various types of water quality monitoring programmes can be planned in accordance to objectives, water bodies, pollutants and water uses, as well as any combination thereof. In practice, assessments are limited to trend monitoring; basic survey; operational surveillance; background monitoring; preliminary surveys; emergency surveys; impact surveys; modelling surveys; and early warning surveillance. The background monitoring of surface waters in clean water reaches has usually been developed to help the interpretation of trend monitoring which is conducted on time variations over a long period and the definition of natural, spatial variations.

Models and their related surveys have usually been set up to predict the water quality for management purposes prior to treatment of wastewater, or to test the impact of a new source of pollution, and are thus closely connected to operational surveillance and impact surveys. Early warning surveillance is undertaken for specific uses in the event of any sudden and unpredictable change in water quality, whereas emergency surveys of a catastrophic event should be followed in the medium and long-term by impact surveys.

The groundwater monitoring normally includes the testing for long-term changes in water quality in major aquifers so as to provide a basis for statistical identification of the possible causes of observed conditions and to provide the statistical basis for the identification of trends.

The Water (Prevention and Control of Pollution) Act, 1974 being implemented in India envisages water quality monitoring for following target issues:

- For rational planning of pollution control strategies and their prioritization,
- To assess nature and extent of pollution control needed in different water bodies or their part
- To evaluate effectiveness of pollution control measures already in existence
- To evaluate water quality trend over a period of time
- To assess assimilative capacity of a water body thereby reducing cost on pollution control
- To understand the environmental fate of different pollutants and
- To assess the fitness of water for different uses.

The process of water quality (WQ) monitoring and assessment is a sequence of related activities starting with the definition of objectives and information needs, and ending with the dissemination of the information product for use by communities, scientists and decision- makers to effectively allow the protection and sustainable management of national and transboundary water resources.

The structure of a water quality monitoring (WQM) programme includes the following main elements:

- Objectives
- Preliminary surveys
- Monitoring design
- Field monitoring operations
- Hydrological monitoring (surface water and groundwater)
- Laboratory activities
- Quality assurance procedures
- Data management and product development

These components and their linkages need to be adequately considered during the planning process of a water quality monitoring system, so as to ensure that the implementation of the programme will meet with success and generate the required information products for use by communities, scientists and decision - makers to effectively allow the protection and sustainable management of national and trans boundary water resources. This planning process encompasses mainly three phases. The first phase consists in defining the need for, and establishing the objectives of monitoring (such as in support or management or research and policy), and what WQ issues are to be addressed. With the objectives defined it can then be decided what data are needed and how they will be used.

The second phase comprises the design of the monitoring programme, which should consider and include the planning of a monitoring network with the choice of locations for the sampling operations, supported by preliminary investigations (inventories and surveys) needed before the programme is started, so that issues, problems and risk factors can be clearly identified and evaluated; the selection of chemical, biological and micro-biological variables, i.e. which variables to monitor for different uses (i.e. municipal or industrial supply, irrigation, recreation, cooling, agriculture, drinking water supply, livestock needs etc.), and in relation to different pollution sources.

The subsequent activities are towards the definition of sampling procedures and operations, such as in situ measurements with different devices, manual or automated measurements, for sampling of appropriate media (water, biota, particulate matter), sample pre-treatment and conservation, identification and shipment; the planning of field measurements (frequency).

The other activity is the assessment of resources required for the monitoring programme, e.g. the laboratory facilities, the inventory of field stations and groundwater observation wells, equipment and instruments, vehicles and other transportation means, office and field staff involved in water quality activities, human resources development and training required, internal and external communication needs, and, finally, the estimation of costs of the programme.

The third phase comprises the actual operations (implementation) of the programme with the setting up of a quality assurance system at the strategic/organizational, tactical and operational levels, essential for ensuring the reliability of information obtained by monitoring, covering field and laboratory work, data handling and analysis, as well as the application of water quality standards and indices; and the management of data and development of products, leading to the reporting and dissemination of results and findings.

5.2 Water Sampling Techniques

The monitoring of water quality to provide reliable and usable data involves many distinct activities and can be expensive. Thus, the first step in planning the establishment of such a system should be to define the objectives of monitoring (such as in support or management or research and policy), and what WQ issues are to be addressed. With the objectives defined it can then be decided what data are needed and how they will be used. In accordance with the goals, answers or information that are sought, WQM and assessment can be looked at from different perspectives in terms of basic variables and present status, time trends and spatial differences, uses, pollution impacts and management needs for information for decisions and action.

All this will result in different approaches for the design and implementation of monitoring programmes, to the selection of variables to be measured, to the frequency and location of measurements, to the additional information needed for interpretation and to the way in which information is generated and presented to meet particular information requirements.

When establishing monitoring objectives, the intended uses of the water are particularly important. The environment, aquatic life, drinking-water sources and bathing areas require high quality, while navigation and water for cooling of industrial processes or cold storage have lesser quality requirements. In the case of livestock watering, irrigation, boiler water, and fisheries, each demands a specific level of quality and has its own relative economic importance. To help with the establishment of objectives, the following questions might be addressed:

I. Why is monitoring going to be conducted? Is it for basic information, planning and policy information, management and operational information, regulation and compliance, resource assessment, or other purposes?
II. What information is required on water quality for various uses?
III. Which variables should be measured, at what frequency and in response to which natural or man-made events?
IV. What is practical in terms of the human and financial resources available for monitoring? There is little point in setting unrealistic objectives.
V. Which agency is responsible for the different elements of monitoring?
VI. Who is going to use the monitoring data and what is the intended use of the information?
VII. Will monitoring results support management decisions, ensure compliance with standards, identify priorities for action, provide early warning of future problems or detect gaps in current knowledge?

A list of monitoring objectives that might be used as the basis for design of sampling networks is enumerated as an example.

I. Identification of baseline conditions in the water-course system.
II. Detection of any signs of deterioration in water quality.
III. Identification of any water bodies in the water-course system that do not meet the desired water quality standards.
IV. Identification of any contaminated areas (surface water and/or groundwater).
V. Determination of the extent and effects of specific waste discharges.
VI. Estimation of the pollution load carried by a water-course system and groundwater.
VII. Evaluation of the effectiveness of a water quality management intervention.
VIII. Development of water quality guidelines and/or standards for specific water uses.
IX. Development of regulations covering the quantity and quality of waste discharges.
X. Development of adequate quality assurance/quality control (QA/QC) processes.
XI. Development of a Water pollution Control Programme

With the objectives of the water quality programme defined and the decision on what data are needed and how they will be used, as a next step the sampling locations and frequencies are then chosen with a view to obtaining the required information with minimum effort and cost, while ensuring that the resources are employed to the best advantage.

A monitoring programme commonly covers the water-course system of a catchment area (i.e. a main river and all its tributaries, streams, brooks, ditches, canals, etc., as well as any lakes or ponds that discharge into the river or tributaries), or it can comprise an administrative unit, e.g. State, etc. In some cases groundwater enters the water-course system from an aquifer or a system of aquifers, all or part of which may lie outside the topographic one. Surface and groundwater catchment areas not often coincide.

The level of detail that monitoring can provide depends on the density of the network, the frequency of samplings, the size of the basin and the issues under investigation. For example,when a station at the outlet of a river basin reports water quality changes, often a more detailed monitoring network is needed to reveal the source, causal agent and the pathways of pollutants. The interaction between surface and groundwater's may also be different in the upper and lower parts of the basin. In these cases, information is needed for smaller sub-basins. The different sources of WQ pollution, such as point source (e.g. sewage, industrial leakage to subsurface), or non-point sources (e.g. agricultural runoff/percolation) also need to be considered.

The monitoring and assessment of groundwater quality is often more complicated because of (i) the complex structure and composition of aquifers; (ii) the recharge and abstraction conditions of the aquifer; and (iii) the relatively long time-scales of groundwater movement and residence.
Monitoring networks, the frequency of measurements, the selection of parameters and determinants, as well as assessment methodologies should be adapted to all these conditions. To facilitate this, a conceptual model of the river basin might be developed, so that the whole system is well understood, establishing whether interactions between surface and groundwater exist or not, so that water quantity and quality can be taken into account.

At the planning stage the following alternatives are important to be considered:

- Fixed site network, useful for public information and broad policy issues; should be limited to drinking water sources that require regular monitoring;
- Flexible survey approach, more convenient for regulatory purposes, for determining management options in cases of pollution, and for related investment decision-making;
- Decentralized monitoring alternatives instead of a national network operated by a central agency ; and
- Monitoring of the quality of the aquatic environment should be coupled with the appropriate hydrological monitoring.

When starting a monitoring programme it is better to have a complete record of reliable data concerning water quality at a few sampling stations than to have a lot of data of questionable quality from many sampling stations. When reported data are not credible and reliable, the programme lose credibility, and poor or incorrect decisions may be made with potentially serious and costly consequences.

Selection of Sampling Stations

Processes affecting water quality and their influence should be taken into account when sampling sites are selected. This requires consideration of: (i) the monitoring objective(s); (ii) some knowledge of the geography of the water-course system; (iii) actual and potential water uses; (iv) actual and potential sources of pollution; (v) water control operations; and (vi) local geochemical conditions and type(s) of the water body (ies). In many cases the precise location of a sampling station can be made only after a field investigation.

In the specific case of groundwater monitoring programmes the fundamental requirement is to define in three dimensions the distribution of water quality. This requirement is the same regardless of the specific objectives of the programme. Thus, in all cases the objective is to obtain representative samples which fully reflect the conditions of the groundwater in situ at a specific point, periodically at known times. Having established the objectives of quality assessment, the next step is then to design the sampling network. This is essentially a function of the sampling point type, density and location, sampling method and frequency and choice of parameters

As regards the types of sampling sites, the global environment monitoring network defines the following three types of monitoring stations:
Baseline Stations: Are typically located in headwater lakes, undisturbed upstream river stretches, and in aquifers where no known direct diffuse or point-sources of pollutants are likely to be found. They are used to establish the natural water quality conditions; to provide a basis for comparison with stations having significant direct human impact (i.e., trend and global river flux stations); to determine, through trend analysis, the influence of long-range transport of contaminants and of climatic changes.

Trend Stations:Are typically located in major river basins, lakes or aquifers. They are used to follow long-term changes in water quality related to a variety of pollution sources and land uses; to provide a basis for the identification of causes or influences on measured conditions or identified trends. Since trend stations are intended to represent human impacts on water quality, the number of trend stations is relatively higher than the other categories of stations, in order to cover the variety of water quality issues facing various basins. Ideally, each country should cover all major human influences on water quality. Most of the stations are located in basins with a range of pollution-inducing activities. However, some stations are located in basins with single, dominant activities. Some trend stations may also serve as river flux stations.

Flux Stations: Are located at the mouth of rivers as they exit to the coastal environment. They are used to determine integrated annual fluxes of critical pollutants from river basins to oceans or regional seas, thereby contributing to geochemical cycles. For calculation of chemical fluxes, it is essential that water flow measurements be obtained at the location of the river flux stations.

Finally, in large programmes involving several parties, institutional issues are very important. Sampling sites may exist operated by different entities that might not be co-operating. Such issues should preferably be solved in the early stages in order to streamline the national monitoring and enable best possible data-sharing.

Preliminary Surveys
Preliminary investigations such as inventories and surveys are needed before any monitoring

programme is started, so that issues, problems and risk factors can be clearly identified and evaluated, with the overall aim to allow the establishment of monitoring systems as effectively as possible. These are short-term, limited activities to determine the water quality variability, specific issues in lakes, river basins and groundwater, the type of monitoring media and pollutants to be considered, and the technical and financial feasibility of a complete monitoring programme. Inventories and in-depth surveys provide: (i) relevant background information with respect to the uses of water; (ii) the possible presence of pollutants not previously monitored; (iii) toxicological factors; (iv) the natural background concentrations of components in groundwater; and (v) the spatial and temporal variability of pollutant distributions. Finally, national surveys together with land-use maps can provide a rapid overview of possible pressures in the basin. In this context, it is useful to consider homogeneous areas where these preliminary investigations are to be undertaken.

Inventories: These should bring together all the available data, even where data is scattered around different agencies or institutions. This can involve the registering of historical data, licenses, etc. in administrative databases, as well as a general screening and interpretation of all the relevant information. For inventories of pollution sources, this will involve examining information at their source such as figures concerning production processes and the usage of raw materials, as well as the investigation of suspect incidents through additional questioning.

Water quality surveys provide a preliminary insight into the functioning of the aquatic ecosystem, the geochemical characteristics of groundwater and the occurrence of pollution and toxicity in water. The ecological status of a river, lake and estuary can be assessed by investigating the qualitative and quantitative structures of the biotic components of ecosystems. Chemical screening of surface water, sediment and effluents at hot spots and key locations can be performed with the supporting analyses. Any specific target compounds that inventories suggest might occur can also be analysed and toxic effects in surface water, sediments and effluents can also be investigated at such locations.

Preliminary surveys also help to refine the logistical aspects of monitoring. For example, access to sampling stations is tested and can indicate whether refinements are necessary to the site selection (a certain site may be found impractical for a variety of reasons, e.g. transport difficulties). Similarly, operational approaches may be tested such as on-site testing techniques or sample preservation and transport methods, can be evaluated. Sample volume requirements and preservation methods can then also be refined.As a final result of the inventory, a listing of sampling sites should be prepared and sampling stations or wells selected during the design of the monitoring programme.

During the design phase of a water quality programme it is essential that full documentation be compiled. This should initially cover the description of a monitoring area comprising, as a minimum: (i) the definition of the extent of the area where water conditions are going to be monitored; (ii) a summary of the environmental conditions and processes (including human activities) that may affect WQ; (iii) the availability of meteorological and hydrological information; (iv) a description of the existing water bodies; and (v) a summary of actual and potential uses of water. Subsequently, the initial steps of the planning process should then be recorded, starting with the monitoring objectives through the choosing of sampling locations.

The parameters which characterize water quality comprise physical properties, redox conditions, inorganic and organic chemicals and biological components (both microbiological and macrobiotic) which can indicate the ecological health of the aquatic environment. The parameters selected for evaluation at a station or observation well will be determined largely by the objectives of the monitoring programme.

Water bodies can be fully characterized by the three major components: hydrodynamics, physico-chemistry, and biology. A complete assessment of water quality needs therefore to be based on appropriate monitoring of these components. The selection of variables for any water quality assessment programme should be indicative of functions and issues in river basins. The selection must therefore consider known characteristics of the water resource and of the polluting sources.
Classification of water quality variables

The water quality variables may be listed, grouped and classified in different ways. As an example, a number of broad categories under which determinant parameters may be grouped as follows.

- Basic determinant parameters, e.g. water temperature, pH, conductivity, dissolved oxygen and discharge, used for a general characterization of water quality.
- Suspended particulate matter, e.g. suspended solids, turbidity and organic matter (Total Organic Carbon - TOC), Biochemical Oxygen Demand - BOD and Chemical Oxygen Demand - COD).
- Indicators of pollution with oxygen consuming substances e.g. dissolved oxygen, BOD, COD and ammonium.
- Indicators of pollution with nutrients and eutrophication effects, e.g. nitrogen and phosphorus, and various biological effect variables, e.g. chlorophyll and Secchi-disc transparency.
- Indicators of acidification, e.g. pH, alkalinity, conductivity, sulphate, nitrate, aluminium, phytoplankton and diatom sampling.
- Specific major ions, e.g. chloride, sulphate, sodium, potassium, calcium and magnesium. These are essential factors in determining the suitability of water for most uses, such as public water supply, livestock watering and crop irrigation.
- Specific minor ions, e.g. arsenic, fluoride; the presence of these ions above certain concentration is toxic to human health.
- Metals, e.g. cadmium, mercury, copper and zinc.
- Organic micro-pollutants, such as pesticides and the numerous chemical substances used in industrial processes, products and households.
- Indicators of radioactivity, e.g. total alpha and beta activity, 137Cs, 90Sr.
- Microbiological indicator organisms e.g. total coliforms, fecal coliforms and fecal streptococci bacteria.
- Biological indicators of the ecological quality, e.g. phytoplankton, zooplankton, zoobenthos, fish and macrophytes.

River basin management and water pollution control have relied for a long time on summary determinant parameters, such as BOD and COD, indicators widely used to assess the amount of organic oxygen-consuming pollution in rivers. For human consumption and public water supply, a set of microbiological indicator organisms (eg. faecal coliform bacteria) have been identified and are now commonly applied to determine the hygienic suitability of water for drinking.

Typically, drinking water quality is assessed by comparing water samples to drinking water quality guidelines or standards. Many countries set such guidelines based on the WHO ones and may modify or tailor them to their domestic context.

Selection of variables

The variables to be measured as part of any given sampling programme should reflect consideration of the uses to which the water is put as well as any known or anticipated impacts on the water quality. In addition, the selection of variables to be included in a water quality assessment should be related to the objectives of the programme. Assessments can be divided broadly into two categories, use- and impact-orientated, as is described below. However, they can also be based on the widely-accepted Drivers-Pressures-State-Impact-Responses framework to guide state and trend assessments of surface and groundwater ecosystems.

There may be need for those responsible for assessments to decide which monitoring activities may have the highest priority. By using risk assessment techniques (and recording how these were applied), this could be done using the concept of “expected damage” – that is, determining what goes wrong when there is insufficient information because of lack of monitoring, or what losses occur when less than optimal decisions are made as a result.

Selection of variables in relation to water use: Use-orientated assessment tests whether water quality is satisfactory for specific purposes, such as drinking water supply, industrial use or irrigation. Many water uses have specific requirements with respect to physical and chemical variables or contaminants. In cases, therefore, the required quality of water has been defined by guidelines, standards or maximum allowable concentrations.These consist of recommended (as in the case of guidelines) or mandatory (as in the case of standards) concentrations of selected variables which should not be exceeded for the prescribed water use. Existing guidelines and standards define the minimum set of variables for inclusion in assessment programmes. Other variables can also be monitored, if necessary, according to special conditions related to the intended use. Acceptable WQ is also related to water availability. When water is scarce, a lower level of quality may have to be accepted and the variables measured can be kept to a minimum.

Selection of variables in relation to pollutant sources: Water quality assessment often examines the effects of specific activities on water quality. Typically, such assessment is undertaken in relation to effluent discharges, urban or land runoff or accidental pollution incidents. The selection of variables is governed by knowledge of the pollution sources and the expected impacts on the receiving water body. It is also desirable to know the quality of the water prior to anthropogenic inputs. This can be obtained, for example, by monitoring upstream in a river or prior to the development of a proposed waste disposal facility. When this cannot be done, background WQ from an adjacent, uncontaminated, water body in the same catchment can be used.

Most of the variables can be measured by various methods and techniques, depending on the resources available, time constraints (how quickly the results are needed) and the accuracy of the results required.

Selection of variables for early warning systems: The appropriate indicative variables to be monitored for early warnings will vary, and should be selected on the basis of the past history of pollution emergencies (frequently occurring local risk substances); issues specific to the river basin (e.g. dissolved oxygen, pH); and any additional need to detect specific micro pollutants, such as heavy metals, harmful organic compounds or pesticides, using advanced technologies

Variables should also be selected for early-warning systems according to the availability of equipment for in situ measurements and other cost-benefit considerations, due to the high investment, operating and maintenance costs for automatic measuring devices. Acute toxic effects may also be recognisable with the help of biological systems examining species from different trophic levels and with various functions.

Any potentially hazardous pollutants that frequently occur in a river basin in concentrations that may jeopardise water uses should be targeted by early-warning systems. Simple indicative parameters such as dissolved oxygen, pH or oil substances can routinely be measured by automatic in situ sensors. If specific problematic micro pollutants such as pesticides need to be detected, more advanced analytical systems can be used, although investment, operating and maintenance costs are high. Toxicological effects in organisms at various trophic levels can be measured with automated biological early-warning systems.

Early warnings provide enough time for emergency measures to be taken. The locations of early-warning water quality monitoring sites, including their observational infrastructure (stations), should therefore be determined with regard to the response time (the interval between the moment of sampling and the issue of an alarm) and the time any contaminant plume in a river will take to flow from the warning station to any site downstream where the water is used, such as a water supply intake. The diffusion of contaminants may be crucially affected by high river discharges. Sampling points should also be carefully located to ensure that the presence of all the relevant pollutants will be observed.

The frequency of measurements should be determined by the expected size of contaminant plumes so that no significant pollution is missed. Plumes will inevitably disperse to some extent between their discharge source and the sampling location, according to the characteristics of the river. Furthermore, sampling frequencies should allow sufficient time for action to be taken in the event of an emergency. Additional and intensified sampling is recommended after any first indication of accidental pollution. One example of a river basin alarm systems is a Rhine Alarm system.

Regarding contamination plumes in groundwater, observations wells should be monitored at specific locations to verify whether the plume is not reaching some potential receptors like deeper aquifers, rivers or surrounding groundwater system.

Selection of Water Quality Monitoring Methods and Techniques

There are a variety of monitoring methods and different levels of technology (from low cost to very expensive instruments) and techniques available and being developed to address the quality of water resources around the globe. There is no simple, single method which can be applied across the board, in every aquatic situation. The challenge for water managers is in the efficient use of a mixture of technologies specifically to address each particular situation.

Methods for field monitoring

Traditionally, water sampling operations include in situ measurements, sampling of appropriate media (water, biota, suspended solids), sample pre-treatment and conservation, identification and shipment. The various alternative methods that may be chosen are elaborated as follows.

Methods for field monitoring are in situ measurements with different devices,manual or automated measurements, continuous or snap-shot monitoring, water sampling including -grab sampling,depth integrated sampling, time proportional composite sampling and space composite sampling.Protocols to ensure the comparability of results and to prevent sample contamination be established for all monitoring methods. Methods of measuring are determined by a number of factors, the type of material being monitored - ground- or surface water, bottom or suspended sediment; groundwater well sampling, the type of sample - grab, composite or integrated; the quality parameter being analysed; the amount of sample; whether the sample is analysed on the spot or sent back to a laboratory.

Traditional water sampling for laboratory chemical and biological analysis provides accurate results if performed with care and sufficient quality assurance procedures are used. They are in many cases also the only acceptable method when high precision is required. Laboratory analyses may however be expensive and time consuming.

5.3 Water Analysis Parameters and Methodology

On-site testing

Some water quality parameters must be analysed in the field. On-site monitoring instruments and field test kits are available that permit analyses of a wide range of variables. This makes it possible to run a monitoring programme without the need for a fixed laboratory, but raises certain problems of analytical quality control.

Temporary laboratories

If a monitoring programme is expected to be of short duration, it may be expedient to set up a temporary laboratory. Sufficient space, water and electricity supplies are essential, but equipment and supplies can be brought in and then removed after the monitoring programme is completed.

Mobile laboratories

It is possible to set up a laboratory in a suitable motor vehicle, e.g. truck or van, boat or even an airplane. In effect, this is a variant of on-site testing, but may provide better facilities than field kits.

Temperature

Temperature Should be measured in situ, using a thermometer. Some meters designed to measure oxygen or conductivity can also measure temperature. As temperature has an influence on so many other aquatic variables and processes, it is important always to include it in a sampling regime, and to take and record it at the time of collecting water samples. For a detailed understanding of biological and chemical processes in water bodies it is often necessary to take a series of temperature measurements throughout the depth of the water, particularly during periods of temperature stratification in lakes and reservoirs. There are also gauges for measuring water temperature in monitoring wells.

pH

pH is a measure of the acidity or alkalinity of a solution. Neutral solutions have a pH of 7, acid solutions a pH of less than 7, and alkaline solutions a pH greater than 7. The pH should be determined in the field, immediately after sample collection. There are many portable pH meters on the market today; the investigator should select the one that suits his needs best.

Conductivity

Conductivity (specific conductance) is a numerical expression of water's ability to conduct an electric current. Conductivity depends on the concentration of ions in solution. In situ measurements are preferable. Conductivity is temperature dependent. If the conductivity measurement is not automatically temperature corrected, then the temperature at the time of measurement should also be recorded. There are various conductivity meters available which may also have temperature and salinity determining capabilities.

Alkalinity

Alkalinity Is measured commonly by titration, using either a burette or the drop count technique. A sample is titrated with an acid solution, which neutralizes the alkaline species present. The endpoint is determined by observing a colour change or by titrating to a pH value of 4.5, using a pH electrode as an indicator. The volume of titrant required to change the colour to reach the endpoint is then used to calculate total alkalinity. Both methods have limitations. Sample colour or turbidity affects the operator's ability to detect the colour change. Use of a burette or dropper is tedious and time-consuming. There are total alkalinity test kits which simplify routine alkalinity measurement, ideal for field use.

Dissolved Oxygen

Dissolved oxygen (DO) should be measured in situ or in the field, as concentrations may show a large change in a short time if the sample is not adequately preserved. Even when the sample is preserved, as in a Winkler analysis, it is advisable to run the titrations within 3 to 6 h from the time the sample was taken. Dissolved oxygen concentrations may be determined directly with a DO meter, optode or by a chemical method such as Winkler analysis or the Hach method. The method chosen will depend on a number of factors including the accuracy and precision required, convenience, equipment and personnel available and expected interferences. For very precise measurements the potentiometric method should be considered.The samples for oxygen determinations are always taken as vertical series starting from the uppermost layer in the epilimnion (usually one meter) and finishing in the hypolimnion at a depth that is one meter above the bottom sediment.

Turbidity and Transparency

This is an optical measure of suspended sediment such as clay, silt, organic matter, plankton and microscopic organisms in a water sample. Whenever possible, turbidity should be measured in-field, since some of the particulate matter will settle or adhere to the container wall during transportation. Furthermore, changes in the pH of the sample may cause the precipitation of carbonates and humic acids, affecting the turbidity of the sample. Turbidity can be measured with turbidity meters that measure light scattering by the suspended particles.Although optical devices are available for measuring the intensity of solar radiation at depth in the water column, the very simple procedure of determining transparency with a Secchi disk still retains its value. The method is to observe the depth at which a 30 cm-diameter disk, painted white or with black and white quadrants, disappears from view as it is lowered in the water column. The actual procedure is to record the point of disappearance as the disk is lowered, allow it to drop a little farther, and then determine the point of re-emergence as the disk is raised. The mean of the two readings is taken as the Secchi disk transparency.

Colour

The colour and the turbidity of water indicate the depth to which light is transmitted. This, in turn, controls the amount of primary productivity that is possible by controlling the rate of photosynthesis of the algae present. The visible colour of water is the result of the different wavelengths not absorbed by the water itself or the result of dissolved and particulate substances present. It is possible to measure both true and apparent colour in water. Minerals such as ferric hydroxide and organic substances such as humic acids give true colour to water. True colour can only be measured in a sample after filtration or centrifugation. Apparent colour is caused by coloured particulates and the refraction and reflection of light on suspended particulates. Polluted water may, therefore, have quite a strong apparent colour.

Taste and Odour

Water odour is usually the result of labile, volatile organic compounds and may be produced by phytoplankton and aquatic plants or decaying organic matter. Industrial and human wastes can also create odours, either directly or as a result of stimulating biological activity. Organic compounds, inorganic chemicals, oil and gas can all impart odour to water, although an odour does not automatically indicate the presence of harmful substances. Regarding groundwater, hydrogen sulfide,(H2S), has a strong odour which can easily be recognised by the human sense of smell.

Residue and Total Suspended Solids

The term "residue" applies to the substances remaining after evaporation of a water sample and its subsequent drying in an oven at a given temperature. It is approximately equivalent to the total content of dissolved and suspended matter in the water since half of the bicarbonate (the dominant anion in most waters) is transformed into CO2 during this process. The term "solids" is widely used for the majority of compounds which are present in natural waters and remain in a solid state after evaporation (some organic compounds will remain in a liquid state after the water has evaporated). Total suspended solids (TSS) and total dissolved solids (TDS) correspond to non-filterable and filterable residue, respectively.

Total Suspended Solids

Suspended particles affect water clarity and light penetration, temperature, the dissolved constituents of surface water, the absorption of toxic substances such as organics and heavy metals, and the composition, distribution and rate of sedimentation of matter. Waters high in suspended solids may be aesthetically unsatisfactory for recreational activities. Solids' analyses are important in the control of biological and physical wastewater treatment processes and for assessing compliance with guidelines imposed by regulatory agencies for wastewater effluents.Total suspended solids (TSS) is a measure of the material collected on a glass fibre filter and dried to a constant weight at 103 to 105^{0}C. If the suspended matter clogs the filter and prolongs filtration, the difference between the total solids content (also dried at 103 - 105^{0}C) and the total dissolved solids (filtrate dried to constant weight at 180^{0}C) may be used to estimate the total suspended solids. TSS can also be determined using optical instruments (backscattering of light).

Chlorophyll

Chlorophyll fluoresces red when excited by blue light and this property can be used to measure chlorophyll levels and indicate algal biomass. Direct, and continuous, measurement of chlorophyll fluorescence can be made with a fluorometer which can be used in situ by pumping water through it or, for some specially designed instruments, by lowering it into the water. Chlorophyll can also be determined in situ by optical spectral instruments using the reflectance spectra and naturally from water samples in a laboratory.

Carbon

The principle of all methods for the determination of total carbon (TC) in water is oxidation of the carbon to carbon dioxide (CO_2). Oxidation may be carried out by combustion, chemical reaction by the wet method using appropriate oxidizing agents, UV irradiation or any other appropriate procedure. The carbon dioxide formed may be determined directly or indirectly following reduction to another component (methane, for example).Various analytical methods have been suggested, some of which are IR spectrometry and flame ionisation following methanisation. A water sample may contain variable amounts of dissolved and particulate organic carbon, organic carbon originating from more or less volatile substances, and dissolved mineral carbon (carbonates, carbon dioxide) and particulate carbon (active charcoal). The different matrices of the specimens that result from the presence of these forms of carbon in variable proportions must be taken into consideration before the analysis, because they largely determine what apparatus and procedure to select. Total fulvic and humic acid content can be determined photometrically and their separate determination can be made with spectrophotometric methods.

Nutrients

Measurement of nutrients (phosphates, nitrates) is a significant and widespread requirement that is mostly met currently by water sampling or the deployment of expensive wet chemical water analysers; however, there are rapid developments in less expensive methods as well. Remote spectral sensing can be used to obtain information about large-scale distributions of nutrients in surface water, but direct measurement methods are required for measurements on smaller scales (e.g. in creeks, rivers, wastewater, outfalls, etc.), for quality assurance and evaluation of the remote sensing data, and for more accurate measurements. Optical spectral sensing techniques have been developed recently that provide reagent-free measurement of nutrients using UV absorption spectrophotometry.

There are in-situ nutrient analysers available for high-frequency time-series determination of nutrient concentrations in marine and fresh waters. Versions are available for the measurement of nitrate, phosphate, silicate and ammonia. Some analysers may be deployed unattended for periods of 1 - 3 months, although much longer deployments have been achieved.

Organic Matter

Organic matter, measured by Dissolved Oxygen, Biochemical Oxygen Demand (BOD) and ammonium, constitute key indicators of the oxygen content of water bodies. Concentrations of these determinant parameters normally increase as a result of organic pollution caused by discharges from waste water treatment plants, industrial effluents and agricultural runoff. Severe organic pollution may lead to rapid de-oxygenation of river water, a high concentration of ammonia and the disappearance of fish and aquatic invertebrates. The most important sources of organic waste load are: household waste water; industries such as paper industries or food processing industries; and occasionally silage effluents and slurry from agriculture. Increased industrial and agricultural production, coupled with a greater percentage of the population being connected to sewerage systems, initially resulted in increases in the discharge of organic waste into surface water in most developed countries. Over the years the biological treatment of waste water has increased, and organic discharges have consequently decreased.

Measurement of TOC (total organic carbon) or DOC (dissolved organic carbon) is a much more rapid means of determining the organic content of water and wastewater than is the measurement of biochemical oxygen demand (BOD). If the relative concentrations of organic compounds in the samples do not change greatly, empirical relationships can be established between TOC and BOD or COD to permit speedy and convenient estimations of the latter. Measurement of TOC can be used to monitor processes for the treatment or removal of organic contaminants without undue dependence on the oxidation states, and is valid at low concentrations.

Humus is formed by the chemical and biochemical decomposition of vegetative residues and from the synthetic activity of micro-organisms. Humus enters water bodies from the soil and from peat bogs, or it can be formed directly within water bodies as a result of biochemical transformations. It is operationally separated into fulvic and humic acid fractions, each being an aggregate of many organic compounds of different masses. Natural organic compounds are not usually toxic, but exert major controlling effects on the hydrochemical and biochemical processes in a water body. Some natural organic compounds significantly affect the quality of water for certain uses, especially those which depend on organoleptic properties (taste and smell). During chlorination for drinking water disinfection, humic and fulvic acids act as precursor substances in the formation of tribalomethanes such as chloroform. In addition, substances included in aquatic humus determine the speciation of heavy metals and some other pollutants because of their high complexing ability. As a result, humic substances affect the toxicity and mobility of metal complexes. Therefore, measurement of the concentrations of these substances can be important for determining anthropogenic impacts on water bodies.

Major ions

The salinity of lake waters depends primarily on the quality of the bedrock, the soil of the watershed, where the lake is situated and where its water source is. There are great differences in salinity between different geological areas. Fresh waters contain alkali and alkaline earth bicarbonate and carbonate, sulphate, chloride in dilutions and largely un-dissociated silicic acids. In smaller quantities there are a great number of different elements (such as important nutrients phosphorus and nitrogen, as well as aluminium, iron, manganese, copper, zinc, etc.), which can be measured everywhere in the globe. The presence of salt can restrict abstraction of water for drinking water. If water abstraction is excessive, intruding salt water can contaminate the groundwater.

The most common elements which have been monitored from inland surface waters are sodium, potassium, calcium, magnesium, chloride and sulphur. Sodium (Na) in water exists principally as the cat ion $Na+$. Potassium (K) does not exist in nature as a free element, it forms salts as chloride, bromide, sulphate, nitrate and aluminium silicates. Potassium is an essential element for plant growth. Calcium (Ca) is the fifth most abundant element in rocks and soils on the earth. In surface waters calcium is one of the most abundant cat ions because of the weathering of rocks and soils. It is largely as the Ca^{2+} ion but complexes can also occur. Magnesium (Mg) is the eighth most abundant element on the earth. In water it exists largely as Mg^{2+} ion. It also forms complexes. Chloride (Cl) does not occur free in nature. The chloride ion is the principal ion in sea water. The chloride ion is widely distributed in the environment as salts with sodium, potassium and calcium. Sulphur (S) is the ninth most abundant element on the earth. Sulphur compounds are widely distributed in minerals and rocks. In water, sulphates occur mainly as free anion SO_4^{2-}, and form ion pairs with Ca^{2+}, Mg^{2+}, Na^+, Fe^{2+}, Fe^{3+} and Mn^{2+}.

Sulphide formation in surface waters is principally through anaerobic, bacterial decay of organic substances in bottom sediments and stratified lakes and reservoirs. Traces of sulphide ion occur in unpolluted bottom sediments from the decay of vegetation, but the presence of high concentrations often indicates the occurrence of sewage or industrial wastes. Under aerobic conditions, the sulphide ion converts rapidly to sulphur and sulphate ions. When appreciable concentrations of sulphide occur, toxicity and the strong odour of the sulphide ion make the water unsuitable for drinking water supplies and other uses.

In connection with drinking water supply many times the variable water hardness is used. Water hardness expresses the sum of all the metallic cations, except for alkali metals. The principal ions responsible for water hardness are calcium and magnesium.

Silica

Silica is widespread and always present in surface and groundwaters. It exists in water in dissolved, suspended and colloidal states. Dissolved forms are represented mostly by silicic acid, products of its dissociation and association, and organo-silicon compounds.Reactive silicon (principally silicic acid but usually recorded as dissolved silica (SiO_2) or sometimes as silicate (H_4SiO_4) mainly arises from chemical weathering of siliceous minerals. Silica may be discharged into water bodies with wastewaters from industries using siliceous compounds in their processes such as potteries, glass works and abrasive manufacture.

Fluroide

Measurement of fluoride content is especially important when a water body is used for drinking water supply. At high concentrations fluoride is toxic to humans and animals and can cause bone diseases. However, a slight increase in natural concentrations can help prevent dental caries although, at higher concentrations (above 1.5-2.0 mg l^{-1}), mottling of teeth can occur (WHO, 1984). Where fluoride is known to occur or can be anticipated, it is an essential variable in surveys where community water supplies are being planned but for long-term monitoring it is less important.

Boron

Boron Is a natural component of freshwaters (groundwater and surface water) arising from the weathering of rocks, soil leaching, volcanic action and other natural processes. Industries and municipal wastewaters also contribute boron to surface waters. In addition, agricultural runoff may contain boron, particularly in areas where it is used to improve crop yields or as a pesticide. Boric acid, which does not readily dissociate, is the predominant species in freshwaters.

Toxic Metals

The low concentrations of metals in natural waters require determination by instrumental methods. Photometric methods, sometimes in combination with extraction, are the oldest and most inexpensive techniques (see various methods handbooks).However, as these have high detection limits, they can only be used for analysis of comparatively polluted waters. Atomic absorption methods are the most widely used for detection of lower levels of metals.ICP-MS (Inductively coupled plasma - mass spectrometry) or ICP-OES (Inductively coupled plasma - Optical Emission Spectroscopy) are techniques that are a highly sensitive and capable of the determination of a range of metals and several non-metals.

Atomic Absorption Spectrophotometry (AAS)

Atomic Absorption SpectrophotometryIs commonly used in many analytical laboratories for determination of trace elements in water samples and in acid digests of sediment or biological tissues. Atomic absorption spectrophotometry is based on the principle that metallic elements in the ground state will absorb light of the same wavelength which they emit when excited. When radiation from a given excited element is passed through a flame containing ground state atoms of that element, the intensity of the transmitted radiation will decrease in proportion to the amount of ground state elements in the flame. The lamps used to furnish the light beam are called hollow cathode lamps and are made of, or lined with the element of interest and filled with an inert gas, generally neon or argon. When subjected to a current, these lamps emit the spectrum of the desired element together with that of the filler gas. The metal atoms to be quantified are placed in the beam of light radiation by aspirating the sample into a flame. The element of interest in the sample is not excited by the influence of the flame, but merely dissociated from its chemical bonds and placed in an unexcited, un-ionized "ground" state. The element is then capable of absorbing radiation from the light source. The amount of radiation absorbed in the flame is proportional to the concentration of the element present. While the simplest analysis procedure is direct aspiration of a liquid sample into the atomizer-burner assembly, there may be limitations of delectability or interferences that make further sample processing necessary to increase concentration or isolate the element of interest from interfering species.

Gas Chromatography

Gas Chromatography Is a highly sophisticated analytical procedure. It should be used only by analysts experienced in the techniques required and competent to evaluate and interpret the data. In gas chromatography (GC) a carrier phase (a carrier gas) and a stationary phase (column packing or capillary column coating) are used to separate individual compounds. The carrier gas is nitrogen, argon- methane, helium or hydrogen. For packed columns, the stationary phase is a liquid that has been coated on an inert granular solid (the column packing) that is held in a length of borosilicate glass tubing. The column is installed in an oven with the inlet attached to a heated injector block and the outlet attached to a detector. Precise and constant temperature control of the injector block, oven and detector is maintained. Stationary phase material and concentration, column length and diameter, oven temperature, carrier gas flow and detector type (e.g. flame ionization detection for PAHs, electron capture detection for phenolics, organochlorinated insecticides and PCBs, thermionic specific detection for nitrogen-containing compounds or organophosphates, mass selective detection, etc.) are the controlled variables.When the sample solution is introduced into the column the organic compounds are vaporized and moved through the column by the carrier gas. They travel through the column at different rates depending on differences in partition coefficients between the mobile and stationary phases.

Flame Photometry

This makes possible the determination of trace amounts of lithium, potassium, sodium and strontium, although other methods of analysis for lithium and strontium are preferred.The sample, after dilution if necessary, is sprayed into a butane- air or propane- air flame. The alkali metals absorb energy from the flame and become raised to an excited energy state in their atomic form. As these individual atoms "cool" they fall back into their original unexcited or ground state and re-emit their absorbed energy by radiation of specific wavelengths, some of which are within the visible region of the electromagnetic spectrum.This discrete emission is isolated by an optical filter and, for low concentrations, is proportional to the number of atoms returning to the ground state. This, in turn, is proportional to the number of atoms excited and, hence, to the concentration of the element in the solution.The minimum detection level for both potassium and sodium is approximately 100 µg l- 1. The upper limit is approximately 10.0 mg l- 1, but this may be extended by diluting the samples.

Quality Assurance Procedures

Quality Assurance (QA) is a management method that is defined as 'all those planned and systematic actions needed to provide adequate confidence that a product, service or result will satisfy given requirements for quality and be fit for use'. It is defined as 'the sum total of the activities aimed at achieving that required standard'.Any monitoring programme or assessment must aim to produce information that is accurate, reliable, comparable, and adequate for the intended purpose. This means that a clear idea of the type and specifications of the information sought must be known before the project starts, i.e. there must be a data quality objective. These objectives are qualitative and quantitative specifications that are used to design the system that will limit the uncertainty to an acceptable level within the constraints allowed. They are often set by the end users of the data (usually those funding the project) in conjunction with the technical experts concerned. It is essential to stress that the trend is to strengthen laboratory quality assurance in a step-by-step approach: from simple internal quality control measures to laboratory accreditation, and finally to the application of international standards such as ISO/IEC 17025 covering general requirements for the competence of calibration and testing laboratories. Components of Quality Assurance are often grouped under three levels viz. strategic or organizational level (dealing with the quality policy, objectives and management and usually produced as the Quality Manual); tactical or functional level (dealing with general practices such as training, facilities, operation of QA); and operational level (dealing with the Standard Operating Procedures (SOPs) worksheets and other aspects of day to day operations).

5.4 Microbiological Analysis

There is a strong need for detection of pathogens, onsite and in effectively real time, to avoid the costs and delays associated with water sampling and lab analysis. There is considerable interest in the development of toxicity sensing to overcome the problems associated with identification of individual target species from a large number of possibilities.There are rapid screening technologies, from which results may be obtained within hours, and there is an obvious push towards desktop and portable systems. They can detect e.g. the normal intestinal bacterium Escherichia coli as an "indicator" organism and total coliform bacteria for a wide variety of water testing applications and in addition the following bioagents may also be detected: clostridium botulinum neurotoxin, staphylococcal enterotoxins (A and B), bacillus anthracis, yersinia pestis, and also cholera toxin subunits and tetanus toxin.Methods for detection of the presence of faecal material have been developed which are based on the presence of “indicator” organisms, such as E coli. Such methods are cheap and simple to perform and some have been developed into field kits, particularly for use in developing countries.

However, enumeration of bacteria normally occurring in high numbers in faeces of humans and homoeothermic animals has been very successfully used for more than a century for the detection of faecal contamination. This strategy has been of immense importance in protecting humans against infectious diseases transmitted via water and causing easily extensive epidemics if drinking water is contaminated but also due to contaminated water supplies, in water used for irrigation and in recreational waters.Methods for detection of the presence of faecal material have been developed which are based on the presence of “indicator” organisms, such as E coli. Such methods are cheap and simple to perform and some have been developed into field kits, particularly for use in developing countries.

Characteristics of Indicator Organisms

Total Coliforms: Coliforms are a large group of Gram-negative, rod-shaped bacteria that share several characteristics. The group includes thermo tolerant coliforms and bacteria of faecal origin, as well as some bacteria that may be isolated from environmental sources. Thus the presence of total coliforms may or may not indicate faecal contamination. In extreme cases, a high count for the total coliform group may be associated with a low, or even zero, count for thermo tolerant coliforms. Such a result might be caused by entry of soil or organic matter into the water or by conditions suitable for the growth of other types of coliform. In the laboratory total coliforms are grown in or on a medium containing lactose, at a temperature of 35 or 37 °C. They are provisionally identified by the production of acid and gas from the fermentation of lactose.

Thermo tolerant (faecal) Coliforms: Coliform organisms which grow at 44 or 44.5 C and ferment lactose to produce acid and gas are known as thermo tolerant (faecal) coliforms. In practice, some organisms with these characteristics may not be of faecal origin and the term “thermo tolerant coliform” is, therefore, more correct and is becoming more commonly used. More than 95 per cent of thermo tolerant coliforms isolated from water are the gut organism Escherichia coli, the presence of which is definitive proof of faecal contamination.In the laboratory thermo tolerant, coliforms are grown on media containing lactose, at a temperature of 44 or 44.5 °C. They are provisionally identified by the production of acid and gas from the fermentation of lactose. Nutrient-rich environments may encourage the growth or persistence of some species of thermo tolerant coliform other than E. coli. This possibility should be considered when, for example, an unusually high result is obtained from water that was thought to be relatively clean. In such a case, the advice of a microbiology laboratory should be sought for the determination of the more specific indicator, E. coli.

The presence of faecal streptococci is evidence of faecal contamination. Faecal streptococci tend to persist longer in the environment than thermo tolerant or total coliforms and are highly resistant to drying. It is, therefore, possible to isolate faecal streptococci from water that contains few or no thermo tolerant coliforms as, for example, when the source of contamination is distant in either time or space from the sampling point. Faecal streptococci grow in or on a medium containing sodium azide, at a temperature of 37-44 °C. They are usually detected by the reduction of a dye (generally a tetrazolium-containing compound) or the hydrolysis of aesculin. Routine methods may give “false positives” and additional confirmatory tests may be required.

Heterotrophic Plate Count: The heterotrophic plate count includes all of the micro-organisms that are capable of growing in or on a nutrient-rich solid agar medium. Two incubation temperatures and times are used: 37 °C for 24 hours to encourage the growth of bacteria of mammalian origin, and 22 °C for 72 hours to enumerate bacteria that are derived principally from environmental sources. The main value of colony counts lies in comparing the results of repeated samples from the same source. If levels increase substantially from normal values, there may be cause for concern.

Multiple Fermentation Tube Technique:This method is used for the analysis of drinking-water. In fact, this is the only procedure that can be used if water samples are very turbid. This is the most fundamental method of conducting bacteriological analyses.Separate analyses are usually conducted on five portions of each of three serial dilutions of a water sample. Individual portions are used to inoculate tubes of culture medium five aliquots of water from each of three consecutive 10-fold dilutions; for example, five aliquots of the sample itself, five of a 1/10 dilution of the sample and five of a 1/100 dilution. Aliquots may be 1-ml volumes, each added to 10 ml of single strength culture medium, or 10-ml volumes, each added to 10 ml of double-strength medium. These are incubated at a standard temperature for a standard period of time.The presence of coliforms is indicated by turbidity in the culture medium, by a pH change and/or by the presence of gas.MPN index is determined by comparing the pattern of positive results (the number of tubes showing growth at each dilution) with statistical tables. The tabulated value is reported as MPN per 100 ml of sample. To help to reduce the cost a smaller number of tubes is incubated at each dilution, for example three instead of five. Or, one tube with 50 ml of sample and five tubes with 10 ml of sample are inoculated and incubated.

Culture Media and Buffered Dilution Water: Each part of the test requires a different type of medium. Dehydrated powder, packaged in pre-weighed amounts suitable for making one batch of medium, to be dissolved in an appropriate volume of distilled water, dispensed to culture tubes and sterilised before use. Ampoules of ready-to-use media are the most convenient form but are the most expensive and have the shortest shelf-life. Media should be stored in a cool, dark, dry place. Large bottles containing dehydrated media must be tightly resealed after use to prevent spoilage. Stock solution of buffered dilution water is prepared by dissolving 34.0 g of potassium dihydrogen phosphate, KH2PO4, in 500 ml of distilled water. The pH is checked and, if necessary, adjusted to 7.2 by the addition of small quantities of 1 mol l-1 NaOH solution. Distilled water is added to bring the final volume to 1 litre. The buffered water is stored in a tightly stoppered bottle in the refrigerator. 1.25 ml of stock solution is added to 1 litre of distilled water, mixed well and dispensed into dilution bottles in quantities that will provide, after sterilisation, 9 or 90 ml. The bottles are loosely capped, placed in the autoclave, and sterilised for 20 minutes at 121 °C. After the bottles have been removed from the autoclave, the caps should be tightened and the bottles stored in a clean place until needed. When enumerating coliforms, lauryl tryptose (lactose) broth is used in the first (isolation or presumptive) part. In the second (confirmation) part, brilliant green lactose bile (BGLB) broth is used to confirm total coliforms.

Membrane Filter Technique: This technique is used for larger number of samples. Portable testing kits are also available for field testing. It gives a direct count of total coliforms and faecal coliforms present in a given sample of water. A measured volume of water is filtered, under vacuum, through a cellulose acetate membrane of uniform pore diameter, usually 0.45 µm. Bacteria are retained on the surface of the membrane which is placed on a suitable selective medium in a sterile container and incubated at an appropriate temperature. If coliforms and/or faecal coliforms are present in the water sample, characteristic colonies form that can be counted directly. Membrane filtration and colony count techniques assume that each bacterium, clump of bacteria, or particle with bacteria attached, will give rise to a single visible colony. Each of these clumps or particles is, therefore, a colony forming unit (cfu) and the results are expressed as colony forming units per unit volume. In the case of thermo tolerant coliform bacteria the result should be reported as thermo tolerant coliforms cfu per 100 ml.

5.5 Soil Testing and Toxicity Characteristic Leaching Procedure (TCLP)

Soil needs to be tested for fertility, to determine available concentrations of plant nutrients. Also, it is test for pollution, geotechnical, geo chemical and ecological investigations. For testing soil, 10- 20 sample points are chosen for every 40 acres. Sampling spots can be chosen in a network, z-scheme, diagonally or along tilling lines. Sampling is done by digging a pit. The soil is vertically cut along the pit wall to a depth where roots are present.0-30 cm for field crops, 30-60 cm for permanent crops. Determine the soil unit (or plot). Make a traverse over the soil unit (or plot). Clean the site (with spade) from where soil sample is to be collected. Insert the spade into soil. Standing on the opposite side, again insert the spade into soil. A lump of soil is removed. A pit of 'V' shape is formed. Its depth should be 0-6" or 0-9" or 0-12" (i.e., Depth of tillage). Take out the soil-slice (like a bread slice) of ½ inch thick from both the exposed surface of the pit from top to bottom. This slice is also termed furrow-slice. Usually a composite sample is collected by combining soil from several locations. Up to 1 kg of soil is sent for testing. The composition of soil is affect by depth of the soil sample and timing. Soil chemistry changes over time as biological and chemical processes breakdown or combine compounds. Laboratories test soil for major nutrients- N, P, K, secondary nutrients- S, Ca, Mg, micro-nutrients- Fe, Mn, Cu, Zn, Bo, Mb, Cl. Soil pH is an important quality to test. Common soil contaminants include Petroleum products, industrial solvents, pesticides, salts and plant fertilizers. Also, heavy metals like Arsenic, Barium, Cadmium, Copper, Mercury, Lead and Zinc. Lead is particularly dangerous. Geo technical tests include shear strength, compressive strength, consolidation, permeability, foundation load, soil index, standard penetration test (SPT), Dynamic Cone Penetration (DCP)and moisture/density.

Soil Testing Parameters Include physical (texture, structure, permeability, porosity, water holding capacity, etc.), Chemical (pH, Salinity (EC)- we measure with pH, Cation exchange capacity, etc.) and Microbial (soil resporation, enzyme activities, etc.) Soil sampling for industrial pollutants is done in accordance with ISO norms. Samples are collects from 0-20 cm surface and 20-40 cm sub-surface. The samples are crushed, mixed, dried, grinded, sieved. For pH, Total nitrogen and total organic carbon, a fraction of less than 2 mm was used. An aqueous solution of 1:2.5 is made. After mixing and settling of particulate matter (after 30 min), the pH and EC are checked. Total Nitrogen content is studied by Kjeldahl method.

Toxicity Characteristic Leaching Procedure (TCLP)

The TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid, and multiphasic wastes. If a total analysis of the waste demonstrates that individual analytes are not present in the waste, or that they are present but at such low concentrations that the appropriate regulatory levels could not possibly be exceeded, the TCLP need not be run. If an analysis of any one of the liquid fractions of the TCLP extract indicates that a regulated compound is present at such high concentrations that, even after accounting for dilution from the other fractions of the extract, the concentration would be above the regulatory level for that compound, then the waste is hazardous and it is not necessary to analyze the remaining fractions of the extract. If an analysis of extract obtained using a bottle extractor shows that the concentration of any regulated volatile analyte exceeds the regulatory level for that compound, then the waste is hazardous and extraction using the ZHE is not necessary. However, extract from a bottle extractor cannot be used to demonstrate that the concentration of volatile compounds is below the regulatory level.

For liquid wastes (i.e., those containing less than 0.5% dry solid material), the waste, after filtration through a 0.6 to 0.8 µm glass fiber filter, is defined as the TCLP extract. For wastes containing greater than or equal to 0.5% solids, the liquid, if any, is separated from the solid phase and stored for later analysis; the particle size of the solid phase is reduced, if necessary. The solid phase is extracted with an amount of extraction fluid equal to 20 times the weight of the solid phase. The extraction fluid employed is a function of the alkalinity of the solid phase of the waste. A special extractor vessel is used when testing for volatile analytes. Following extraction, the liquid extract is separated from the solid phase by filtration through a 0.6 to 0.8 µm glass fiber filter. If compatible (i.e., multiple phases will not form on combination), the initial liquid phase of the waste is added to the liquid extract, and these are analyzed together. If incompatible, the liquids are analyzed separately and the results are mathematically combined to yield a volume-weighted average concentration.

TCCLP finds out the amount of EPA-listed contaminants are present and likely to be absorbed into soil and groundwater. It indicates the possible public health or environmental health hazards exist in the sludge being tested. Here, a soil sample extraction method is employed for chemical analysis. A collection of four leaching tests are conducted, that follow the tiered approach of leach testing. Each test is designed to vary a critical release-controlling parameter (pH, liquid-to-solid ratio, leaching time) to provide leaching data over a broad range of test conditions.

Leaching characterization under LEAF (Leaching Environmental Assessment Framework) consists of testing using one or more of the following four methods:

Method 1313: pH Dependence: - Liquid-Solid Partitioning (LSP) as a Function of Eluate pH Using a Parallel Batch Extraction Procedure.

Method 1314: Percolation Column: - Liquid-Solid Partitioning (LSP) as a Function of Liquid-to-Solid Ratio Using an Up-Flow Percolation Column Procedure

Method 1315: Mass Transfer Rates: - Mass Transfer Rates in Monolithic and Compacted Granular Materials Using a Semi-dynamic Tank Leaching Procedure

Method 1316: Batch L/S: - Liquid-Solid Partitioning (LSP) as a Function of Liquid-to-Solid Ratio Using a Parallel Batch Extraction Procedure

SPLP analysis by EPA 1312 is designed to mimic the leaching of contaminants exposed to normal weathering in situ by acid rain. TCLP extraction is performed by subjecting the material tested to a simulated landfill leachate. Acetic acid is chosen as the extraction fluid as it is the major component of typical municipal landfill leachate. The pH is maintained at 4.93. This sample/ acetic acid mixture is subjected to 18+ - 2 hours of rotary extraction. The resulting liquid is analysed for 39 contaminants from the EPA's TCLP final Rule, including 8 metals, 11 organic VOCs, 12 semi-volatile organic compounds, 6 pesticides and 2 herbicides. The TCLP test must only be done for those wastes which are destined for a landfill. Otherwise, wrong interpretation is likely. For materials not destined for landfills, leaching is possible due to acid rain. Hence, such materials are subjected to SPLP. Here, instead of acetic acid, the test is done with nitric acid and sulphuric acid to simulate acid rain.The TCLP test method has essentially 6 steps.

STEP 1: Separate the liquid and solid portions of the waste (as needed): Liquids (containing less than 0.5% dry solid material) are filtered through glass fiber to create a TCLP extract. Wastes (containing 0.5% or greater dry matter) are separated and stored for later analysis.

STEP 2: Crush the solid portion of the waste: Using a standard 9.5 mm sieve, we filter solid material and prepare it for extraction by cutting, crushing or grinding to a particle size of 1 cm or less.

STEP 3: Extract the solid material: Place the crushed solid portion in a system that simulates the conditions of a landfill by filtering a large quantity of water through it. The solid material is then extracted for at least 18 hours with a slightly acidic fluid equal to 20 times its weight. The materials are placed in a tumbler to simulate the leaching action of water seeping through waste in the landfill.

STEP 4: Final Separation: Collect the leachate from the system. The liquid waste is then separated from the solid waste through a fiber glass filter. The solid material is discarded and the liquid components are then assessed.

STEP 5: Recombine the separated liquid portion of the waste (if any) with the collected leachate. The initial liquid components may be added or may be analyzed separately, depending on compatibility.

STEP 6: Analyze the leachate for constituents of concern. Atomic spectrometry technologies such as atomic absorption spectrometry (AA), inductively coupled plasma optical emission spectrometry (ICP-OES), and inductively coupled plasma mass spectrometry (ICP-MS), are often used because they provide the sensitivity various global regulations require.

The TCLP test is an expensive and time-consuming procedure. It's important to know that there are three scenarios where TCLP is not required.If a total analysis of the waste demonstrates that the individual contaminants are not present in the waste, or present in levels that could not possibly exceed the regulatory threshold, then the TCLPis not required. For wastes that are 100% physically solid, the maximum theoretical leachate concentration is 1/20 of the total concentration in the waste.If this value is below the regulatory threshold, the TCLP need not be run.If the waste is 99.5% or more liquid, then the waste itself is the extract, and can analyze it directly without performing the TCLP.

Here are three examples of when it is necessary to run a TCLP. For example, the regulatory level for the toxicity characteristic for lead (D008) is 5 ppm

1. If a wastewater solution contains 5 ppm or more dissolved lead, then it would be a D008 waste. A lower concentration would not be D008.
2. If a semisolid sludge contains 5 ppm or more total lead, then it would be a D008 waste. A lower concentration would not be D008.
3. If a solid brick or dry ash contains less than 100 ppm dissolved lead, then the extract could

not possibly have more than 5 ppm lead, and the solid could not be a D008.

4. If a solid brick or dry ash contains 100 ppm (20 times 5 ppm) or more elemental lead, then it is possible that the extract produced by the TCLP could have 5 ppm or more elemental lead, therefore the TCLP or an equivalent procedure must be performed. The extraction of sample involve agitation apparatus that must be capable of rotating the extraction vessel in an end-over-end fashion at 30 + 2 rpm. Suitable. The Zero-Headspace Extraction Vessel is used only when the waste is being tested for the mobility of volatile analytes that allows for liquid/solid separation within the device, and effectively precludes headspace. This type of vessel allows for initial liquid/solid separation, extraction, and final extract filtration without opening the vessel. The vessels shall have an internal volume of 500-600 mL, and be equipped to accommodate a 90-110 mm filter.

When the waste is being evaluated using the nonvolatile extraction, a jar with sufficient capacity to hold the sample and the extraction fluid is needed. Headspace is allowed in this vessel. The extraction bottles may be constructed from various materials (such as borosilicate glass bottles), depending on the analytes to be analyzed and the nature of the waste. Plastic bottles, other than polytetrafluoroethylene, shall not be used if organics are to be investigated.

Summary

The environmental monitoring of water quality to assess the level of contamination and source identification is first step for planning of interventions. The appropriate procedures are required to be followed for generating credible data. Various water quality parameters are required to be tested for fulfilling the objective of understanding of water quality and to demarcate the measure for mitigation. The testing of water, waste water, soil and leachate are largely dependent on the sampling, preservation, transportation and laboratory analysis following quality assurance and quality control protocols. There is another important part of these whole exercise is to interpret data for deriving logical conclusion. Thus to plan the environmental monitoring requires through knowledge of various components so that the output results are comprehensive in scientific arena. It would be prudent for the business managers to implement scientific approaches based on the course material for management of environmental parameters holistically.

To Do Activities

- To begin with environmental monitoring of water, prepare a field visit check list
- To know the objective of monitoring and procedures of site selection
- To identify mixing zones, representative depth and sampling for parameters concerned.
- To understand the importance of sample preservation, transportation to laboratory in a given time frame as per protocol
- To know the quality assurance and quality control in field and laboratory analysis
- To understand the importance of reference materials
- To prepare a report covering all the aspects from planning stage to interpretation of analytical results for drawing inferences.

Self Assessment Questions

1. To know the requirement of testing of various environmental parameters

2. To know what are the methods of site selection, sampling, preservatives, shelf life of collected sample and method of analysis's
3. To know what are the environmental standards
4. To understand the writing of report and interpretation of analysis results

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Block 3

Waste Management Banks

Swachhta Action Plan

Mahatma Gandhi National Council of Rural Education

Department of Higher Education

Ministry of Human Resource Development, Government of India

Hyderabad - 500004

सत्यमेव जयते

Where there is Rural Wellbeing there is Universal Prosperity

Contents

Chapter 1 Waste Banks

Introduction

The concept of waste Bank is explained in this block. Moreover, importance and need of waste banks are explained in detail. Waste banks are an organised sector which include control of generation, storage collection, transfer and transport, processing and disposal of solid waste. The challenges of waste Bank organisation such as lack of trained personnel, financial assistance and knowledge are illustrated. Lastly, advantages of waste Bank is enlisted.

Objective

To study the concept, importance, need and advantages of waste banks

1.1. Concept of Waste Bank

Waste bins located in main room collects wastes of each room, following this, the wastes are collected and transported to temporary storage site through hired workers of private companies. For composting wastes collected from several areas of the municipality, communal composting facilities are used by the municipal workers. Based on the survey reported by, most of the people almost 81% do not usually sort wastes at home. Sufficient incentives for sorting waste or need to be provided, waste collectors should be trained for mechanism for treatment of sorting waste. Advantages of sorting should be explained to all dwellers. Care should be taken for that their waste transporter will not mix the sorted waste at the local waste transport station.

1.2. Importance and need of waste banks

There are two main components to be noted in waste banks, namely, an economic cost-benefit estimate and ecological cost-benefit estimate. The former one considers the financial costs and benefits analysis from economic point of view, and the second section considers the benefits of reduction in greenhouse gas emission.

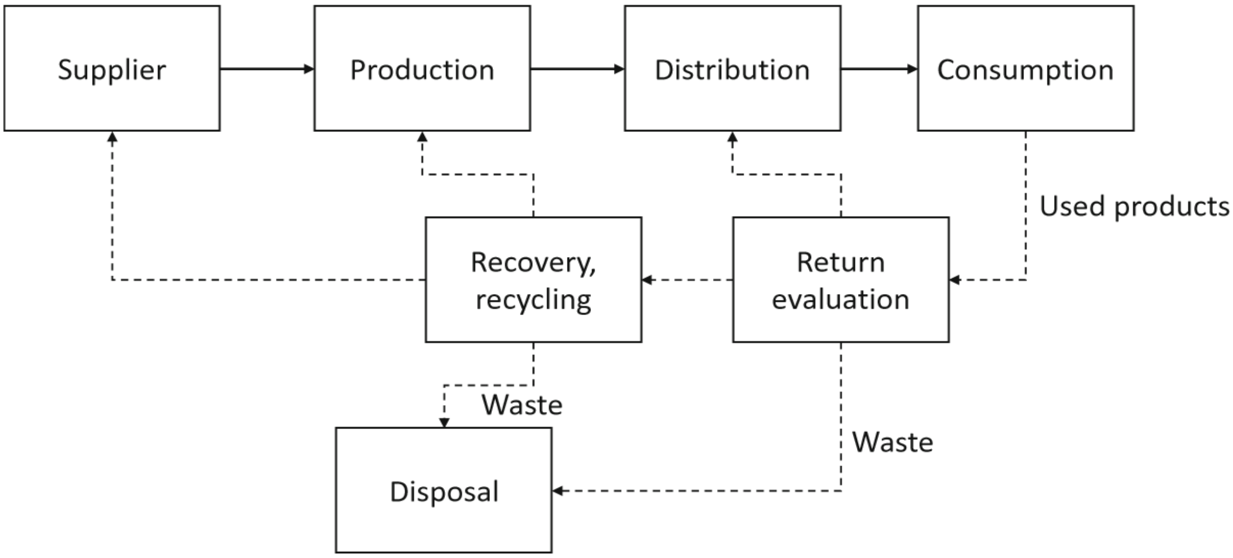


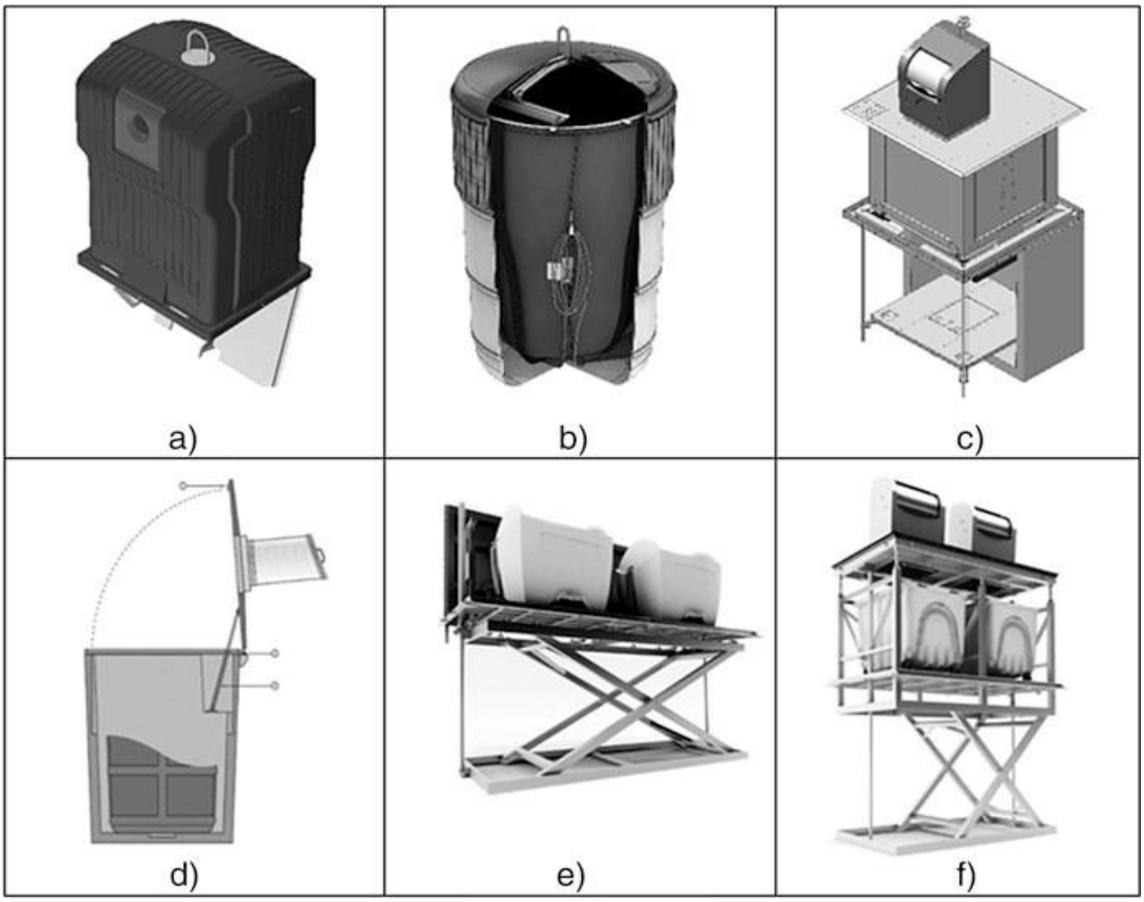
Figure1.1 A generic form of forward/reverse logistics.

1.3. Waste Banks- an Organised Sector

Zero waste target can be achieved through waste banks. Firstly, educating construction and Healthcare institutions, developing treatment and recycling infrastructure and establishing drop off points for large scale trash collection are the initial process of the waste Banks organisation establishment. Subsequently, the process involved treatment of municipal solid waste, separation of waste, treatment of bio-waste through decentralized composting units and reversing/ observing separated dry material by the firm. Following this, waste is treated either by centralised composting facilities or landfill, and the residues will be collected and treated against payment. Next, it is Government's responsibility to check that all Industries have their waste management plants. As the result, recycled product will appear as raw material on the market. Then, recycling industrial sector will be established in every City to achieve zero waste. The biowaste producers may have their own waste management plant which includes feeding animals and composting. Fines will be imposed on the individuals who do not separate household wastes. So that, municipal waste collectors may afford little time for characterizing waste according to the nature. With the help of research Institutes, technologies will be developed to ensure that no more wastes tipped at the landfill.

(a) (b)

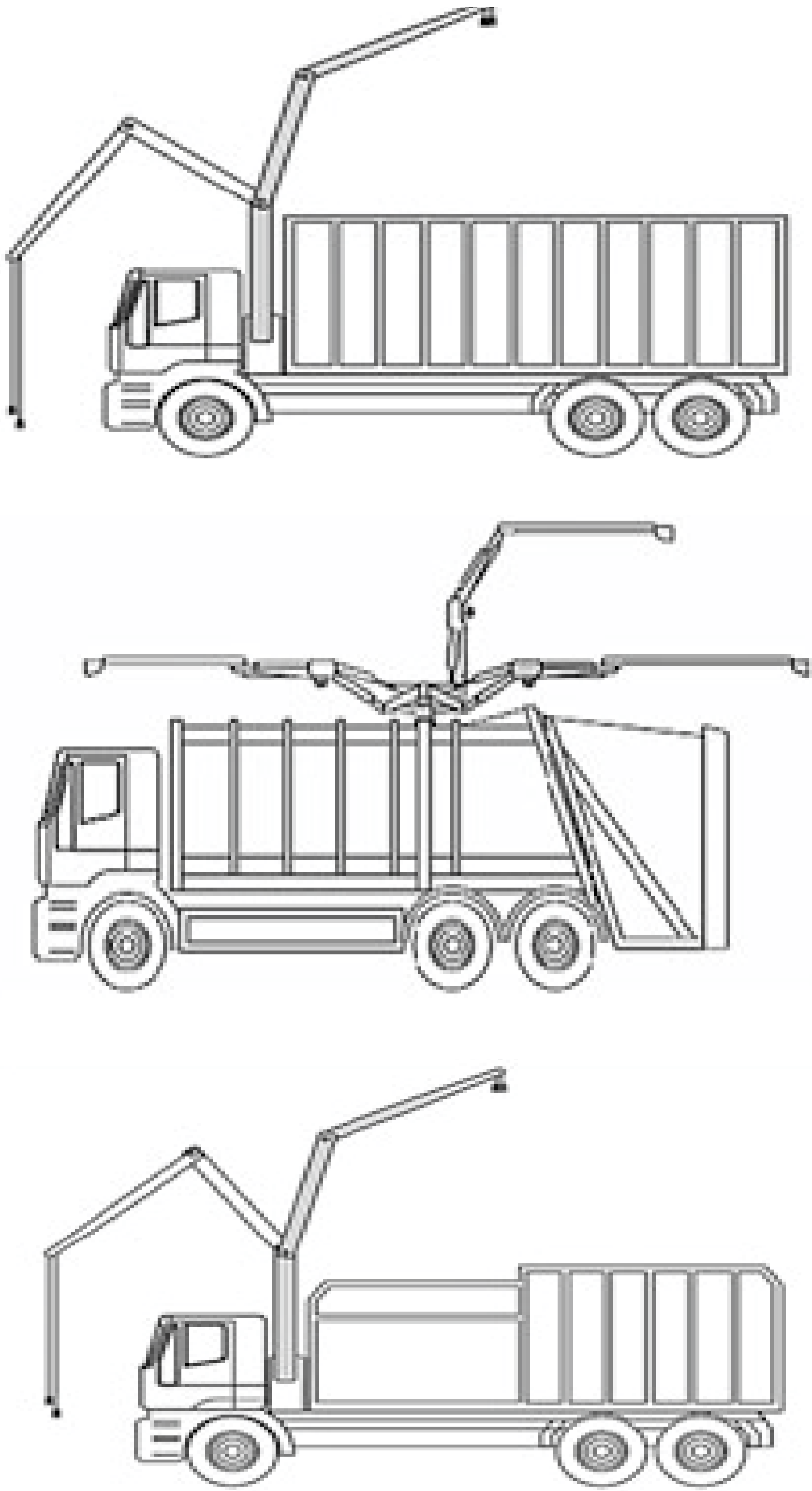
(c)



(d) Containers

Figure 1.2Waste collection

(b)



(c)-(e)Types of vehicles

Figure 1.3 Waste transport

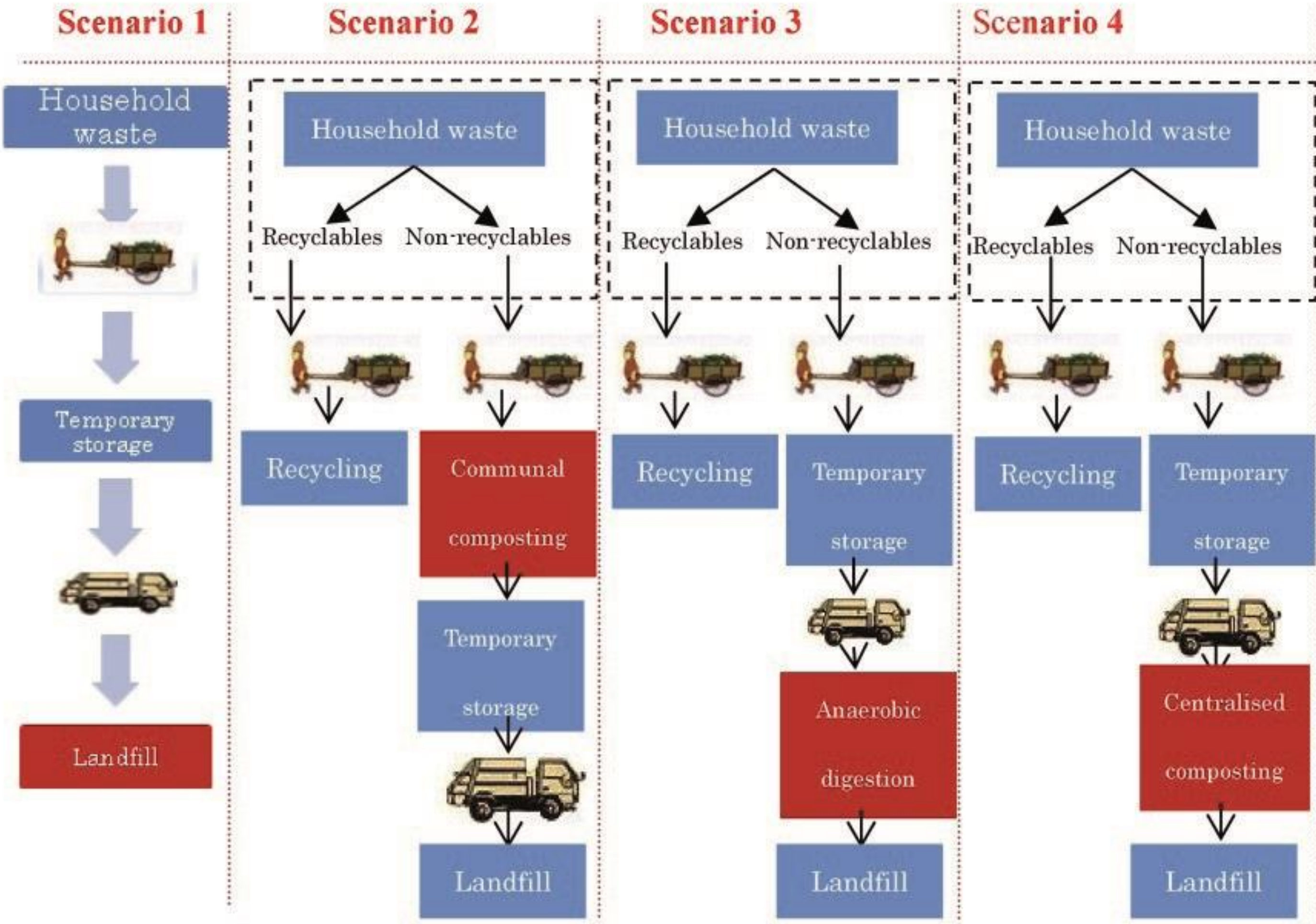


Figure 1.4 System boundaries and scenarios for waste management

Table 1.1 Characterization of 'biowaste' and 'inorganic waste'.

Waste category	Sub categories	Type of waste	Composting and recycling
Food scraps (kitchen waste)	N/A	Biowaste	CO
Garden waste	N/A	Biowaste	CO
Paper & cardboard	Newspapers	Inorganic	RE
	Magazine	Inorganic	RE
	Other paper	Inorganic	NRE
	Card packaging	Inorganic	NRE
	Other card	Inorganic	NRE
Wood	N/A	Inorganic	NCO
Textile	N/A	Inorganic	NRE
Disposable diapers	N/A	Inorganic	NRE
Rubber & leather	N/A	Inorganic	NRE
Plastic	Refuse sacks	Inorganic	RE
	Other plastic film	Inorganic	NRE
	Clear plastic beverage bottles	Inorganic	RE
	Other plastic bottles	Inorganic	RE
	Food packaging	Inorganic	RE
	Other dense plastic	Inorganic	NRE
Metal	Steel beverage cans	Inorganic	RE
	Steel food cans	Inorganic	RE
	Batteries	Inorganic	NRE
	Other steel cans	Inorganic	RE
	Other ferrous metal	Inorganic	RE
	Aluminum beverage cans	Inorganic	RE
	Aluminum foil	Inorganic	RE
	Other non-ferrous metal	Inorganic	RE
Glass (pottery & ceramics)	Brown glass bottles	Inorganic	RE
	Green glass bottles	Inorganic	RE
	Clear glass bottles	Inorganic	RE
	Clear glass jars	Inorganic	RE
	Other glass	Inorganic	NRE
Other (ash, dirt, dust, soil, ewaste	N/A	Inorganic	NRE

CO: compostable. NCO: non-compostable. RE: recyclable. NRE: non-recyclable

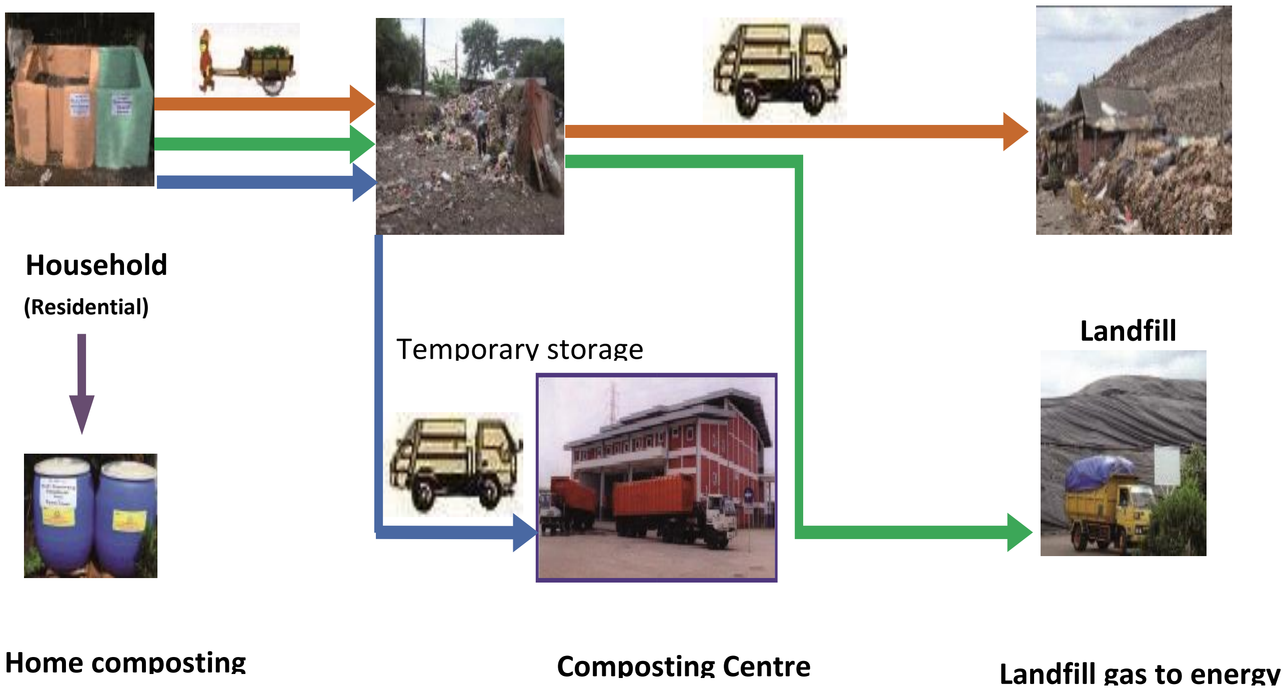


Figure 1.5.Flow chart of the household solid waste management system in Jakarta

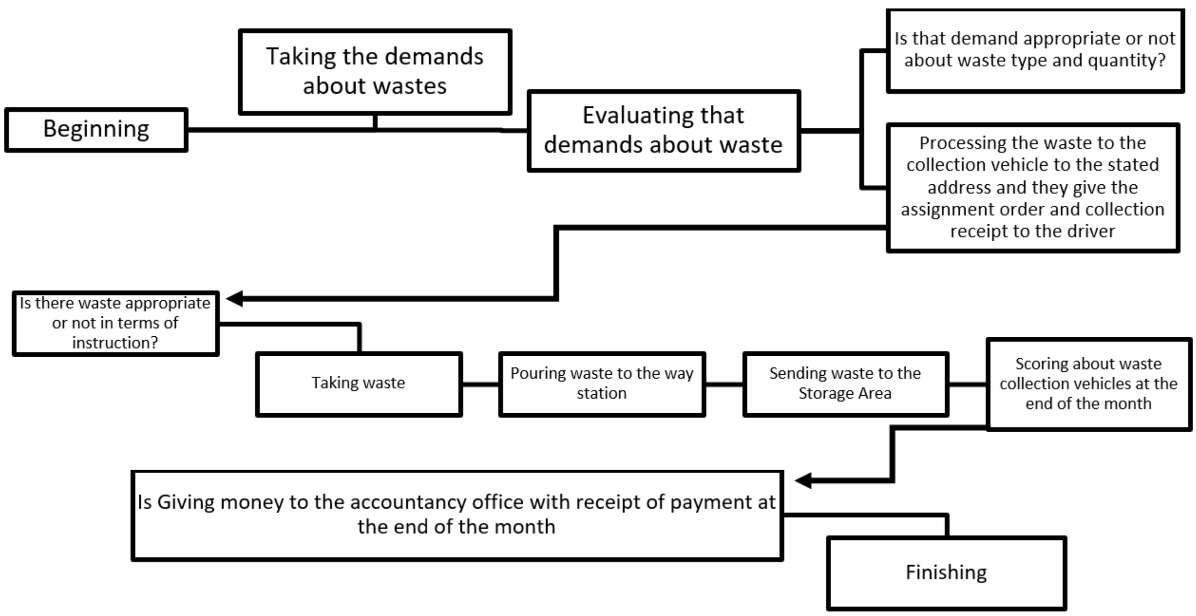


Figure 1.6 Waste banks – An organised sector

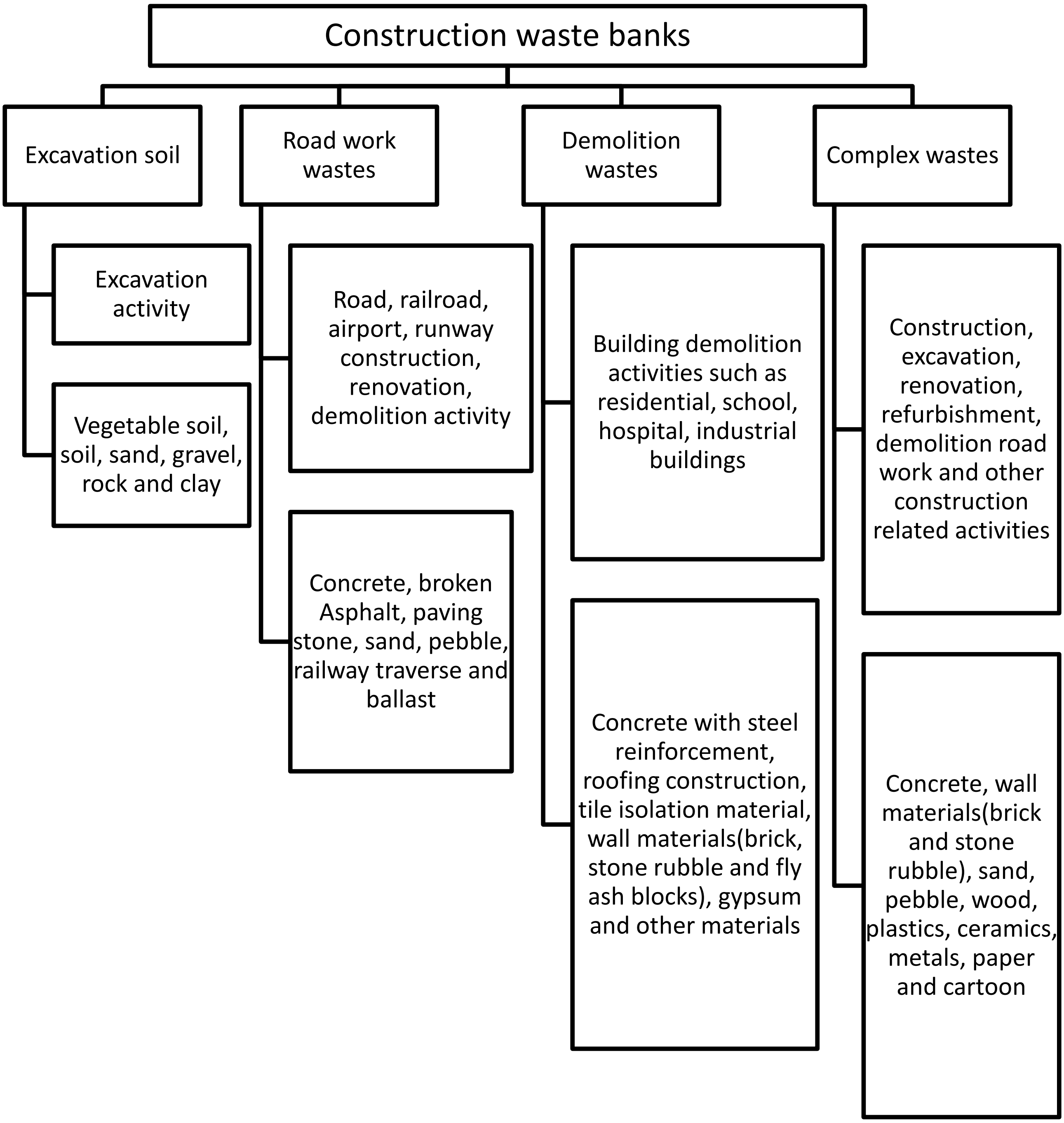


Figure 1.7Construction waste banks framework

1.4. Waste Circulation through Banks

Three primary sources of organic waste exist: i) agricultural and forestry activities, ii) urban activity, and iii) industrial activity [1]. Wastes originating from agricultural and forestry activities include livestock slurry, manure, crop remains, and waste from pruning and from the maintenance of woodlands. Industries generate organic wastes, which include the sub products of the agri-food industry (e.g., bagasse, coffee dregs, remains from slaughterhouses, sub products of the fruit and legume industries, and milk serum), wool and skin remains, and cellulose sludge. Such organic waste is increasingly considered not only an environmental problem but also a potential resource whose recovery could lead to important economic benefits. This paradigm shift is powered partly by legislation and partly by market forces.

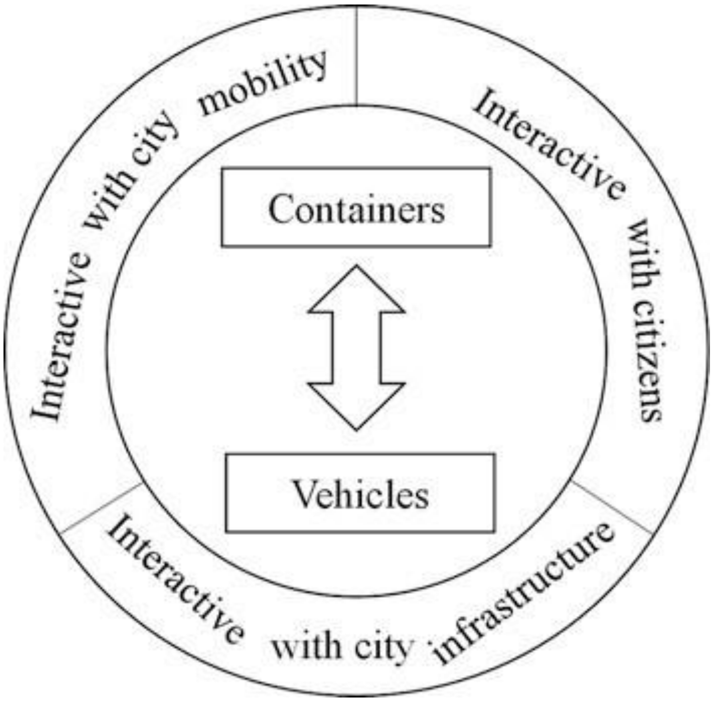


Figure 1.8 Waste collection system diagram

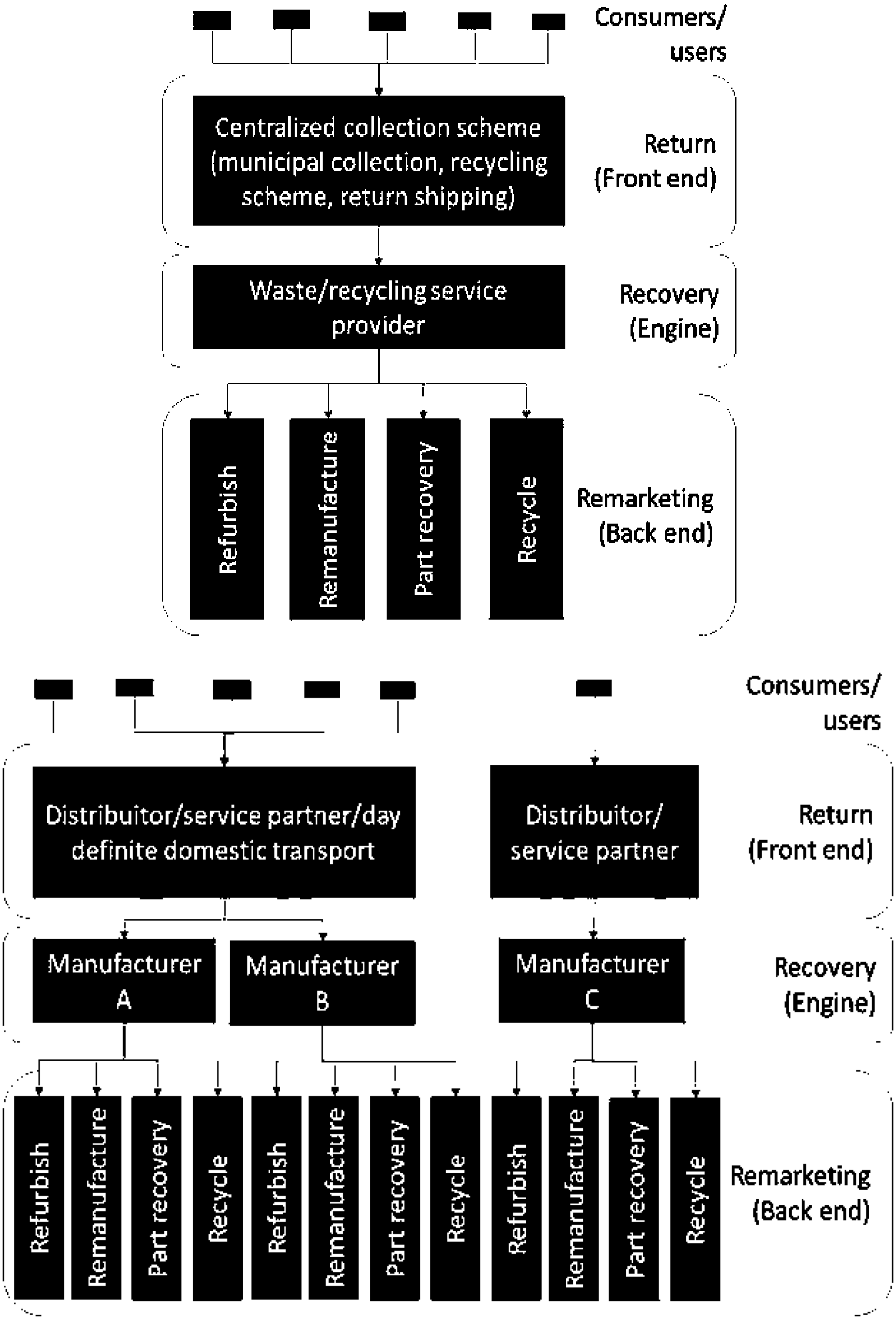


Figure 1.9 Recovery service provider

1.5. Advantages of Waste Bank

The addition of such wastes to the soil has several advantages, especially the improvement of the chemical and physical properties of the soil. These wastes (adequately composted) will increase the humus content and, as a consequence, the water retention capacity of the soil. The wastes also improve the soil structure, which is fundamental for root penetration and appropriate drainage and aeration. In addition, organic waste is an important source of nutrients, and its addition to the soils closes the mineral cycle. In agricultural areas, where soils are not limited by the organic matter content, as can be the case in Gallize, organic waste can help to ameliorate other adverse effects, such as acidity. Several studies indicate that these organic materials, if added to acidic soils, can be effective as acid neutralisers; this effect is associated with an increase in fodder crop yield.

From a biological viewpoint, fertilisation with organic waste also induces an increase in microbial activity, which in turn improves nutrient availability for plants. Similarly, the addition of organic waste reduces the amount of chemical fertiliser needed, thus leading to savings in energy and raw materials, with a concomitant reduction in the greenhouse effect. includes the addition of organic waste among the management practices related to carbon sequestration. have observed that organic agriculture systems (no synthetic fertilisers) produce less greenhouse gas than traditional systems. Solid waste related diseases are parasitic infection, bronchitis, skin diseases, bronchopneumonia, dysentery, bronchial asthma and allergy conditions, all other respiratory diseases, typhoid, influenza and trachoma.

1. Recycling minimizes pollution (Web link: Conserve energy future)

All forms of pollution in the modern world emanate from industrial waste. Recycling of these industrial wastes such as plastics, cans, and chemicals go a long way towards considerably cutting back on levels of pollution because these waste products are reused rather than just being thrown away recklessly.

2. Protects the environment

The great benefit of recycling waste material is that it plays a big part in protecting Mother Nature in the most balanced way. While many trees are felled every day, recycled paper manufactured from specific trees is continually utilized to reduce deforestation. This classical example demonstrates that other natural resources can be recycled and made useful this way to conserve the environment.

3. **Recycling minimizes global warming**

It is perfectly true that recycling minimizes global warming and its grave impacts. During waste disposal, huge amounts of waste are combusted that lead to emission of vast greenhouse gases such as carbon dioxide, sulfur, and nitrogen, which contribute to climate change and global warming.

Recycling process involves minimal combustion and waste is transformed into reusable materials with zero or minimal harmful impact on the environment. The whole process of processing and manufacturing products from waste materials emits few greenhouse gases because the very waste recycling industries burn little fossil fuels.

4. **Conserves natural resources**

If the process of recycling used and old materials was not there, it means new products will be manufactured by extraction of fresh raw materials underneath the earth through the process of mining and extraction. Recycling is a surefire way of conserving existing raw materials and protecting them for future use. Taking steps to conserve natural resources like minerals, water and wood ensures sustainable and optimal use.

5. Recycling cuts down amount of waste in landfill sites

Recycling old and used materials into reusable products enormously reduces the possibility of choking of landfill sites. This is beneficial because it helps minimize land and water pollution since landfills contribute mightily to environmental degradation.

6. Recycling ensures sustainable use of resources

Recycling guarantees that existing resources will be used sensibly and sustainably. The recycling process alleviates the possibility of discriminate use of raw materials when they are obtainable in huge supply. Governments these days have stepped in to encourage recycling from lower levels, for instance, schools, small-sized organizations and also at global levels. This means that manufacturing industries can leave existing natural resources for exploitation by our children in the future without affecting current production.

7. **Recycling contributes to creation of jobs**

To add to the benefits it brings to the environment; recycling opens up job opportunities. Recycling means many recycling plants will be set up, thus, leading to a long chain of collection and delivery. All these activities are performed by humans, so this will trigger an explosion of opportunities.

8. Reduces energy consumption

A lot of energy is used to process raw materials in the course of manufacture. Recycling plays a big role in reducing energy consumption, which is vital for large-scale production, for instance, mining and refining. Recycling also renders the whole process of production less expensive, which is a great victory for manufacturers.

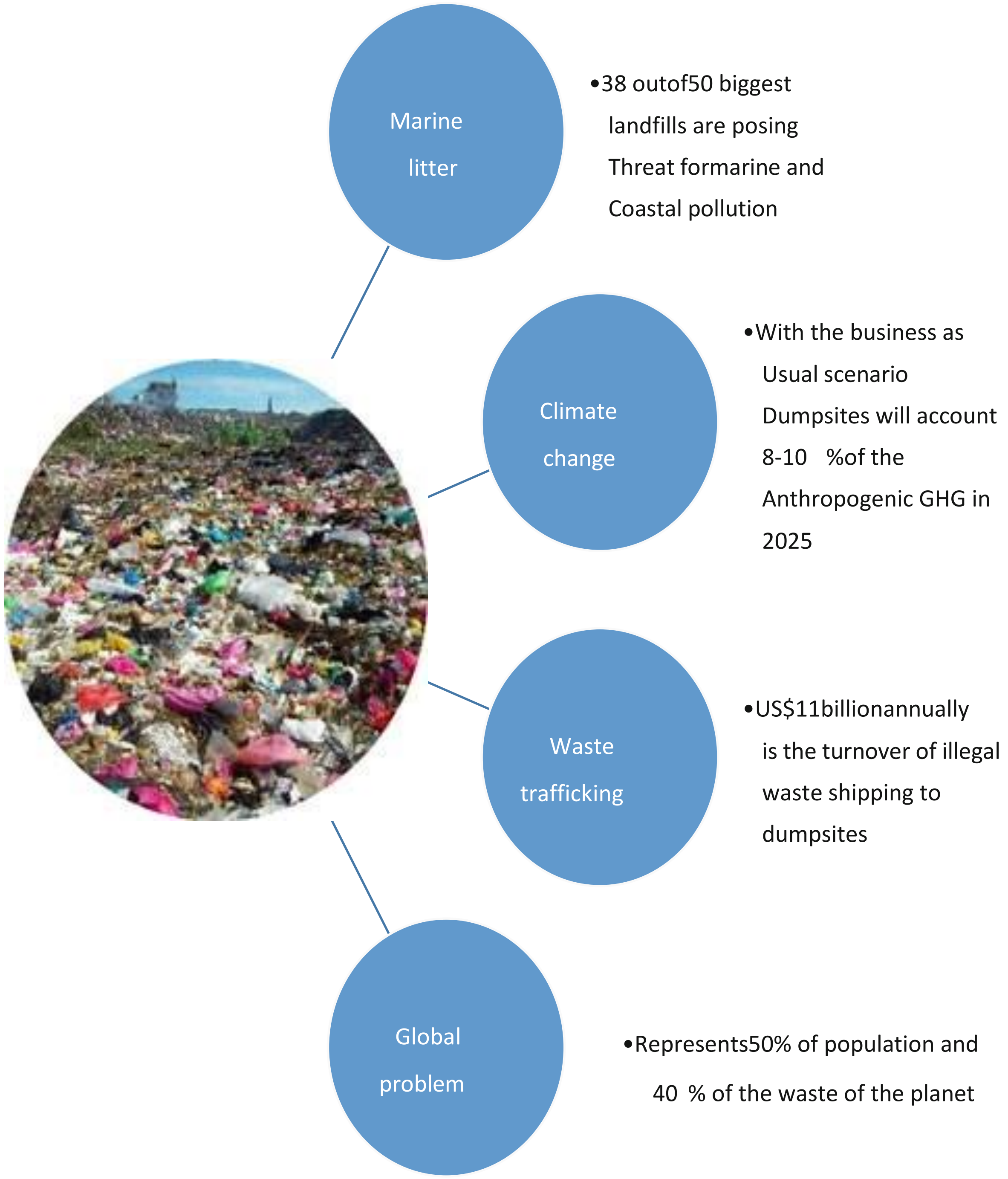


Figure 1.10 Dumpsite as a global challenge

Summary

Fist block reported concept, importance and need of waste banks. Through waste collection methods and reusing strategies, waste problem can be managed, and also local economy is improved. The waste banks are organized sector to achieve zero waste cities. Management of food waste, agro-industrial waste, e-waste and plastic lethal waste are discussed. Advantages of waste banks are explained in this chapter.

Activity

- Draft the concept of waste bank (2 Pages)
- Prepare caselets on effective utilization of waste banks to achieve zero waste cities (2 Pages)
- Draft the frame work of waste banks – an organized sector (2 Pages)
- Report advantages of waste banks though national and international caselets (2 Pages)

Review questions

1. Explain
   (a) Concept of waste bank
   (b) Importance of waste bank
   (c) Need of waste bank
   (d) Waste circulation though banks
2. Why waste banks are named as organized sector?
3. What are all the advantages of waste bank?

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Chapter 2 Reuse / Recycle methods

Introduction

This block reports waste deposition and distribution methods which include identification and linking with needy humans - beggars, old age home, orphanages. Perhaps, food wastesare supplied to animal shelters, gaushalas and piggeries. Also, it explains the collection and re-utilization of E-waste and plastic Lethal waste by Linking the users with authorized specific dealers. Further, compost and sell of biodegradable waste is reported.Moreover, process of recycle, reuse and reduce, namely,'3R'sare detailed.

Objective

To identify the beneficiaries for waste disposal through reuse, reduce and recycle process

2.1. Waste deposition and distribution

Waste deposition and distribution activities include collection transportation and separation according to the nature of the waste. The waste collection services are provided by the municipality. A typical model for waste collection method followed by North East Institute of Science and Technology (NEIST), a constituent laboratory of Council of Scientific and Industrial Research (CSIR), is shown in the Figure2.1. When compared to collection of unsegregated waste from curbside and sorting into recyclables and reusable waste, curbside segregation is the most common and convenient method in waste management. In Figure 2.1, general waste, paper, glass and plastic wastes are separated in curbside by providing four types of dustbins.

The materials recovery facility (MRF) is retrieval of the hazardous material from a waste plant. This was first established officially in Philippines with sanctioned project from World Bank in 2001. Mainly, the municipal waste item was screened though different level and some automated and manual level of material recovery farming are done and the hazardous item got recovered and can be utilised for reuse. Firstly, it was limited access to success and later on while developing the mechanized activity, it becomes a necessary part of hazard waste management. Mainly, in recovery of materials or MRF, the items of different levels are classified into different categories. As the organic and inorganic wastes are treated separately so this is a useful tool to handy information over the waste management. MRF mainly undergoes some plan, structure and procedure of operation as well as the factors for success and sustained process. The MRF undergoes with some sorting of waste materials and processed further. The various steps that take place in waste stream sorting are as follows:

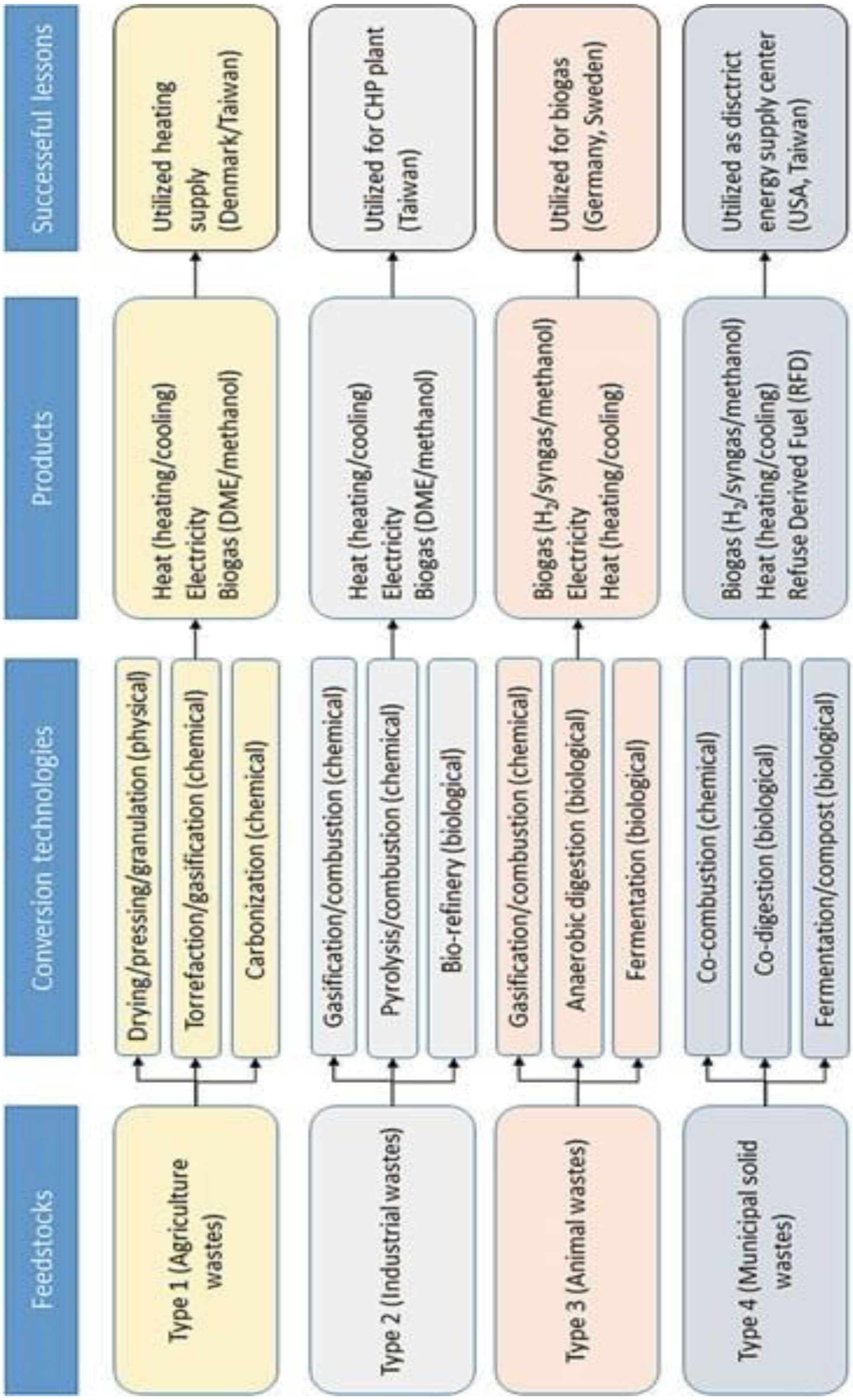


Figure 2.1Technology tree for waste management techniques

(a) At the source/household level that recovers of household reusable items

(b) At the municipal bin that process of different category

(c) At the centralized sorting facility with manual and automated machines

(d) At waste processing site (pre-sorting and post-sorting)

(e) At the landfill site

This will totally sort the solid waste material into some category and easily the item recovery can be done. After this recovery facility, a portion of the solid management part can easily be disposed for no further use and can be treated in disposal plant.

(a) General waste collection

(b) Glass waste

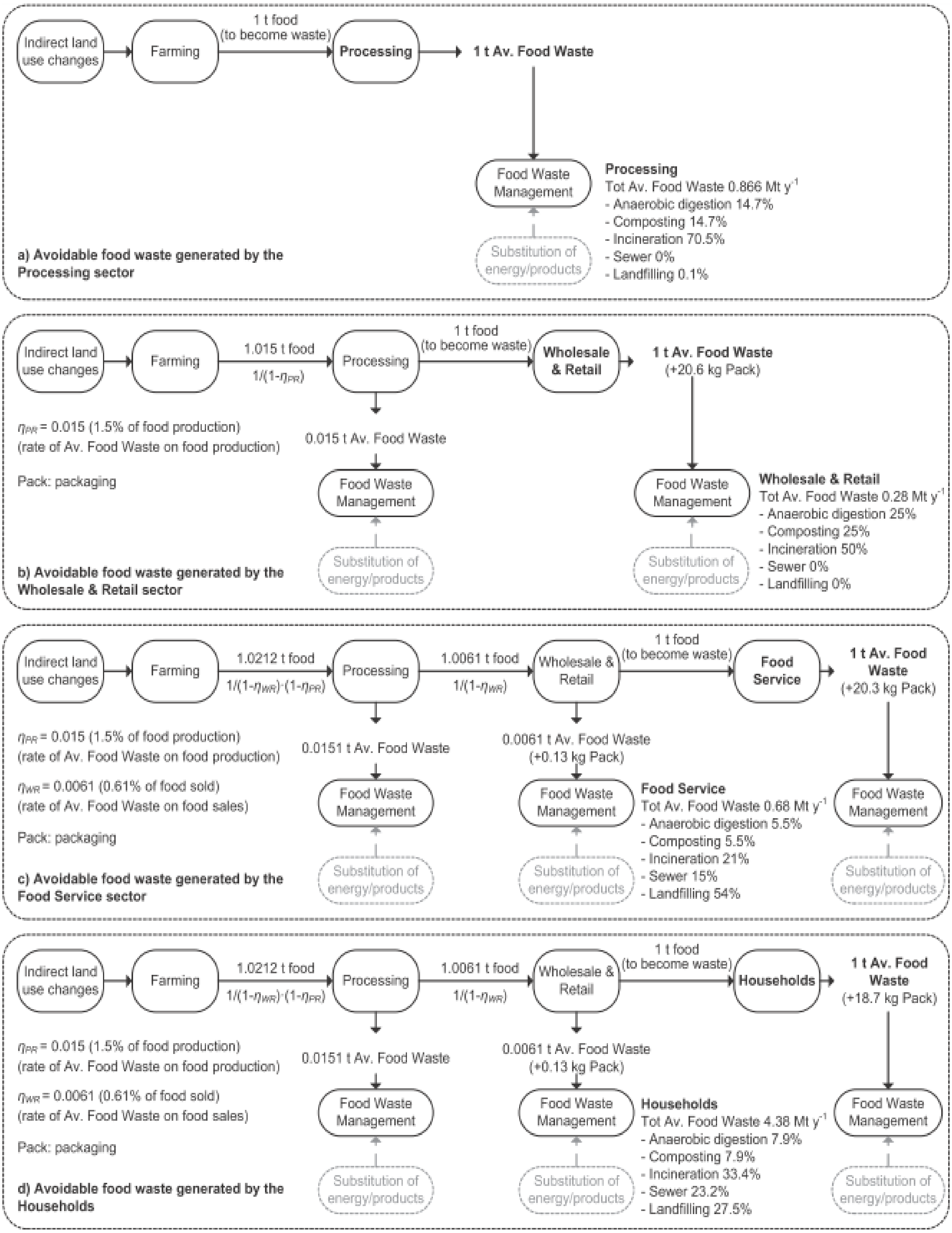
(c) Paper and plastic waste collection

(d) Waste composition categories.

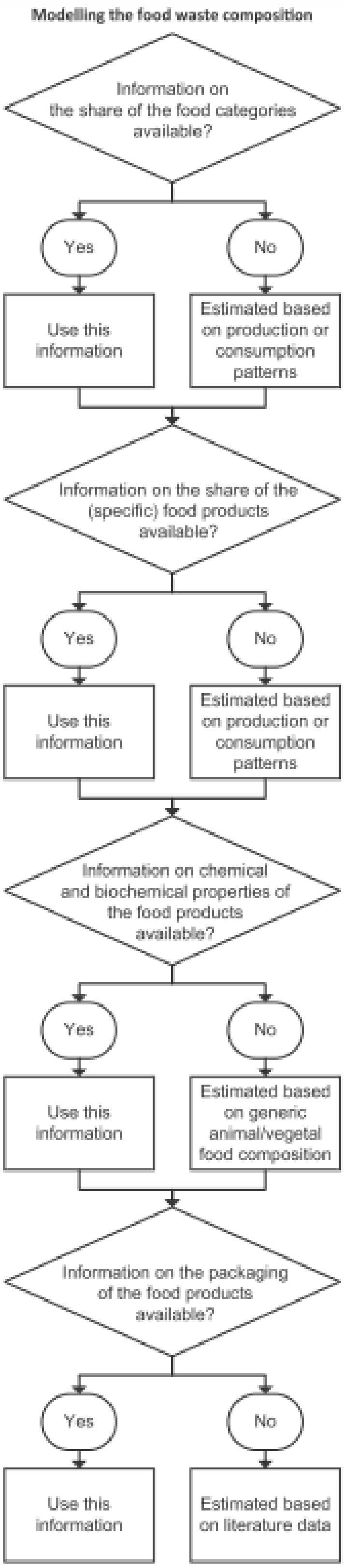
Figure 2.2 Waste management at CSIR-NEIST

2.2. Food waste, E-waste and plastic lethal waste

Food waste is food that is discarded or wasted uneaten. The food is wasted in all stages of the food chain. Sustainable production and consumption approach and tackle food surplus waste are the solutions suggested by researchers. The framework explains food waste management is shown in figure2.2.As shown in framework (Figure 2.2), food waste can be supplied to animal shelters, goshalasand piggeries. Other possible ways of production and disposal of food waste are Consumer marketing, landfills and greenhouse gases, animal feed, distribution to needy people/organisation like old age homes, orphanages and beggars, composting, anaerobic digestion, commercialization food waste, agricultural food waste, cockroach feeding.



(a) Food waste management



(b) Framework approach to model the food waste

(c) Sorting of dry waste

(d) Classical plastic bag method of waste collection

(e) Sorted dry waste ready for recycle

Figure 2.3Collection and Sorting of different type of wastes

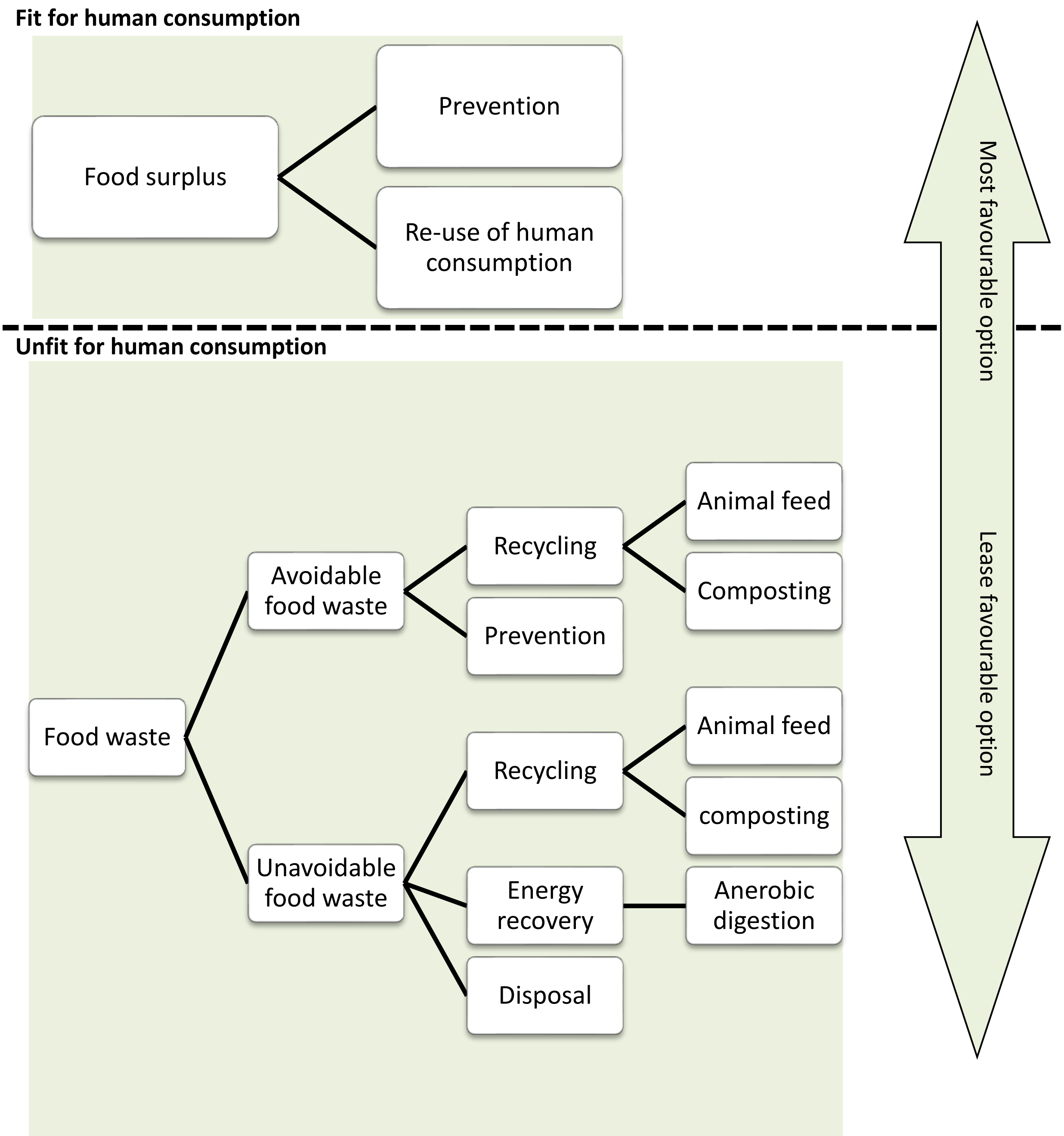


Figure 2.4Surplus food and waste framework*(Papargyropoulou E et al. 2014)*

2.3. Reutilization of E-Waste and Plastic Lethal Waste

Electronic waste keeps growing around the world. Reportedly, 1.3 million metric tons of e-waste are sorted in landfills in the United States in 2005. Reuse and recycling services are the best solutions suggested for end-of-life electronics. It can be achieved deposition through e-market. By offering discounts for return on deposit, the firm can refurbish or resell to transfer the deposit after recycling. Therefore, the end-of-life of electronics are deferred until true life.

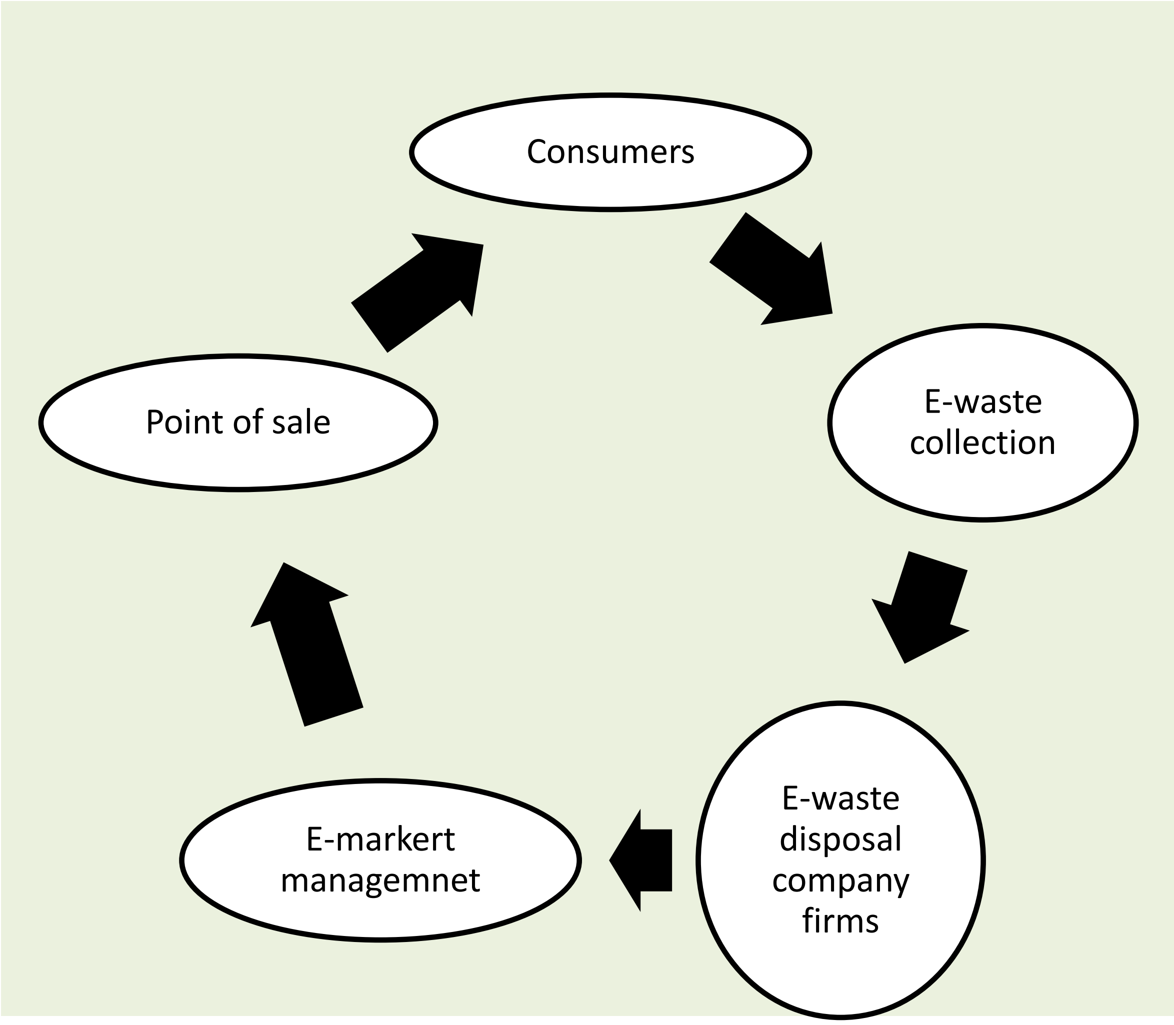


Figure 2.5 E-Market for returned deposit system*(Kahhat et al. 2008)*

The plastic bags are inexpensive to produce, easy to carry and store. In United States, out of 1 trillion waste produced, only 13 percent were recycled, and the remaining were disposed of in landfills. The framework of plastic waste management is shown in Figure 2.4.

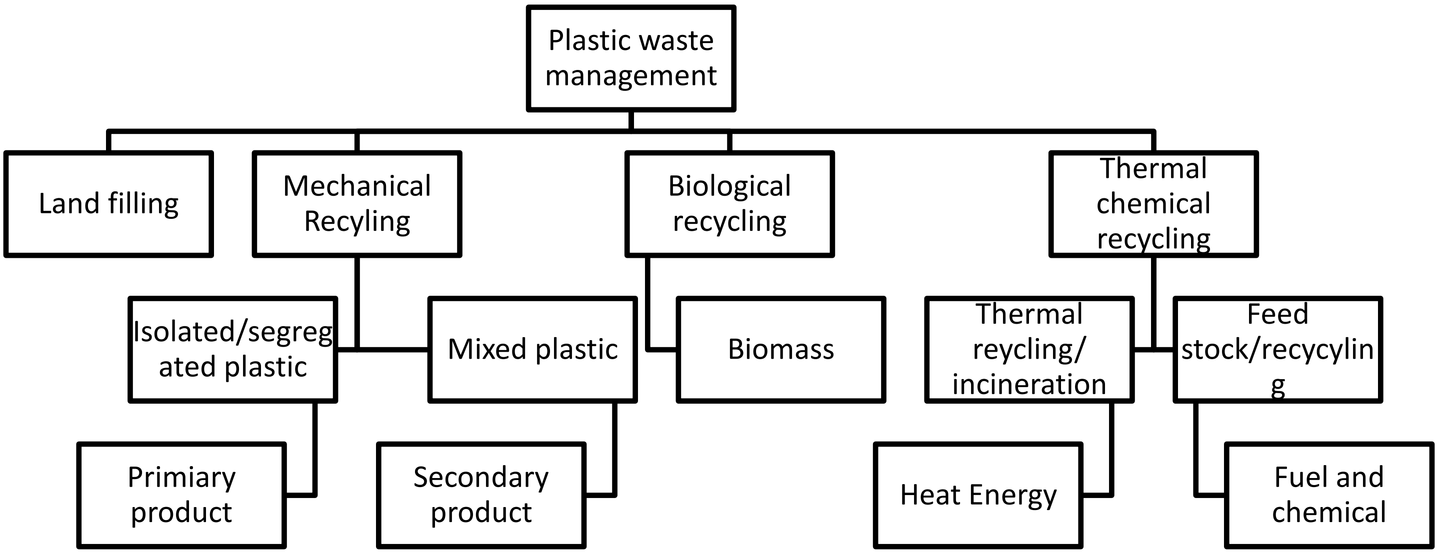


Figure 2.6 Plastic waste management*(Panda et al. 2010)*

2.4. Biodegradable Waste

In domestic waste collection, biodegradable wastes are separated, where organic matter in the waste is broken down into simple organic molecules by composting. The sources of biodegradable waste can be found in municipal solid waste, food waste, paper waste and biodegradable plastics. Usually, the biodegradable waste is separated from the mainstream of waste byKerb-side collection or by sorting method. Kerb-side collection is nothing but removing biodegradable household waste from the collection units of metropolitan cities, urban and suburban areas.

Figure 2.7 Sorting of biowastes

2.5. Importance of Reuse and Recycling

The planet Earth has a limit of natural resources. No resources in infinite. The main strategy to simplify all this allometric balance is to "Reduce, Reuse and Recycle" – referred to as the three 'R's of change. This simple strategy can be applied to the all extend of planet in terms of reduce the waste material and can help the natural balance. To change and reduce of all use, we need to dramatically decrease the pay of pressure that we throw on these natural resources. For instance, an agency reported that that use of 1-ton industrial paper could save an equivalent to 17 trees and 7000 gallons of water (U.S. Environmental Protection Agency).

Reuse: Various resourceful use of any item will help to not throw an item instead we can think about how to manage it and innovate some ideas to reuse it. Like some day-to-day items we can make from our old items and this will not only develop our reuse mentality but also widens our ethnic style in fashioned manner. We can reuse old clothes as bags instead of using plastic ones. Using writing skills on both sides of paper will save at least half of previous use. Our 'no need' may be of someone's need, so by donating old items to poor and needy, can develop the process behind use of used items.

Figure 2.8 Paper recycling box in an office

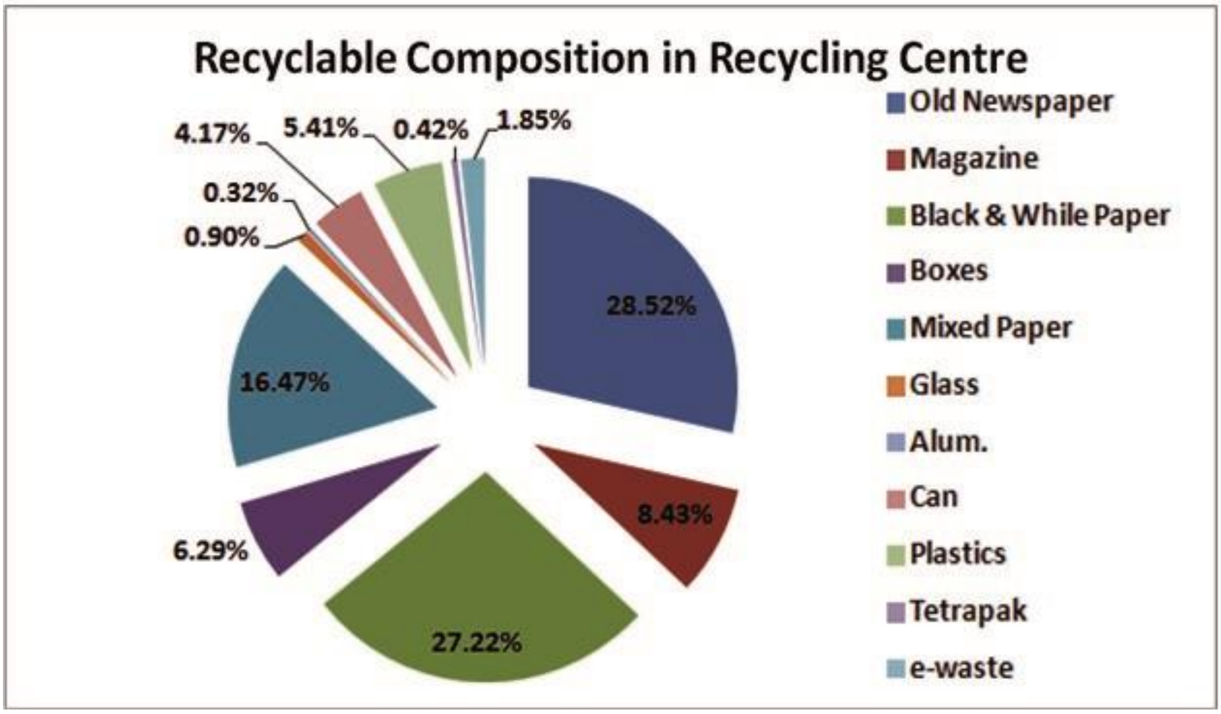


Figure 2.9. Recyclable items composition at the Recycling Centre

Recycle: Most advanced and modern waste management procedure is recycling of used item. This technique will not only change the potential of used item to reuse it but also pays no pressure on natural resources for new regeneration. International Standard Organization (ISO) standards some item with their marking in various platform for recycling such as ISO 15270:2008 used for plastic waste material, ISO 14001:2004 used for the management manipulate in environmental recycling. Energy usage and raw material expenditure is the main saves through the recycling of a product. Recycling not only reduces the raw item but also decreases the pollution in land, water & air in terms of newly management waste disposal issue. The green is clean, so to be green, clean all over the pollutions and need to reuse & recycle for any waste materials.

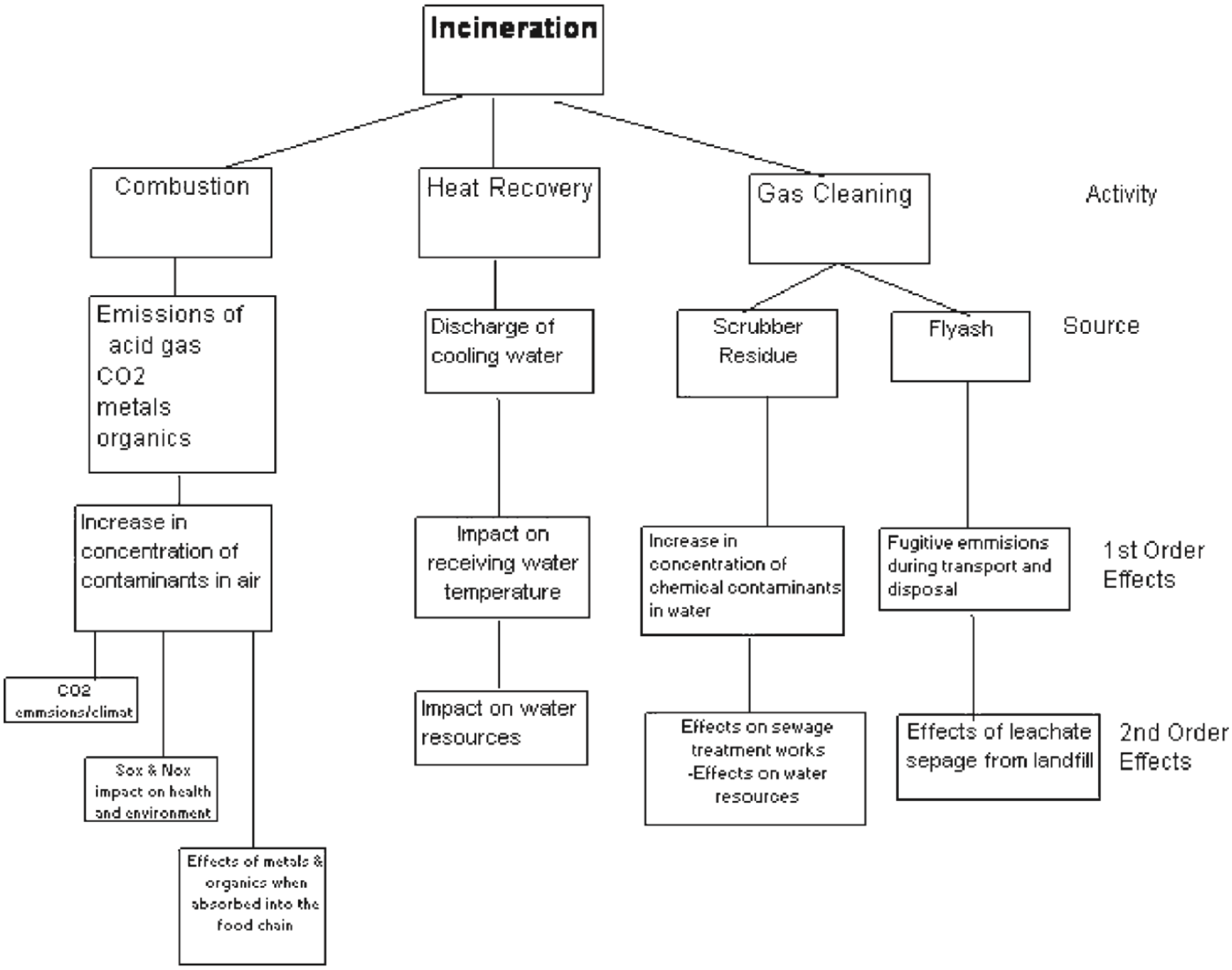


Figure 2.10Impacts and effects of incineration on the environment.

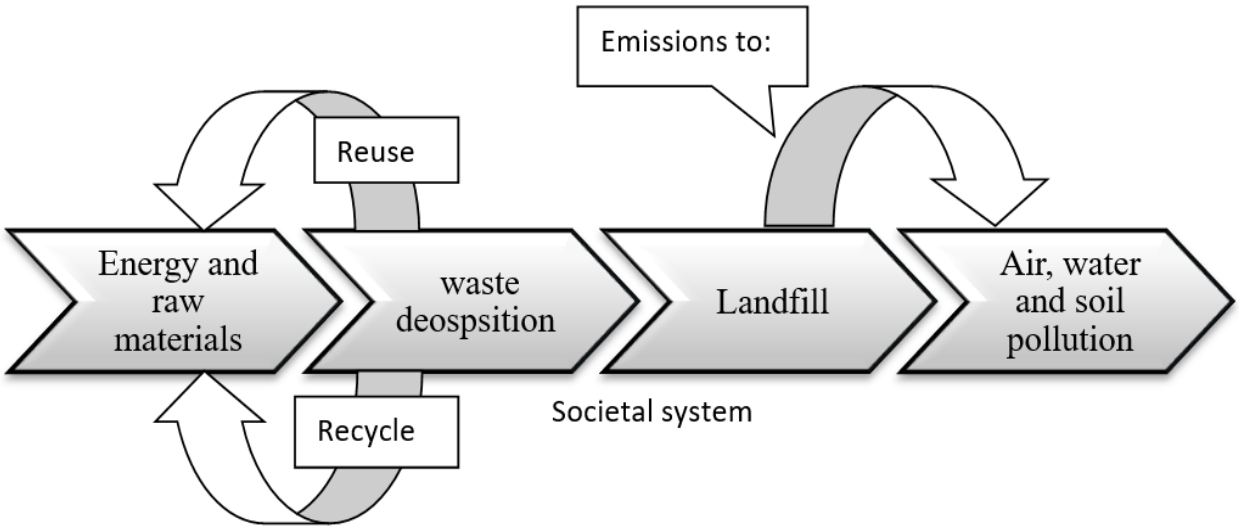


Figure 2.11Waste management(Al-Salem et al. 2009)

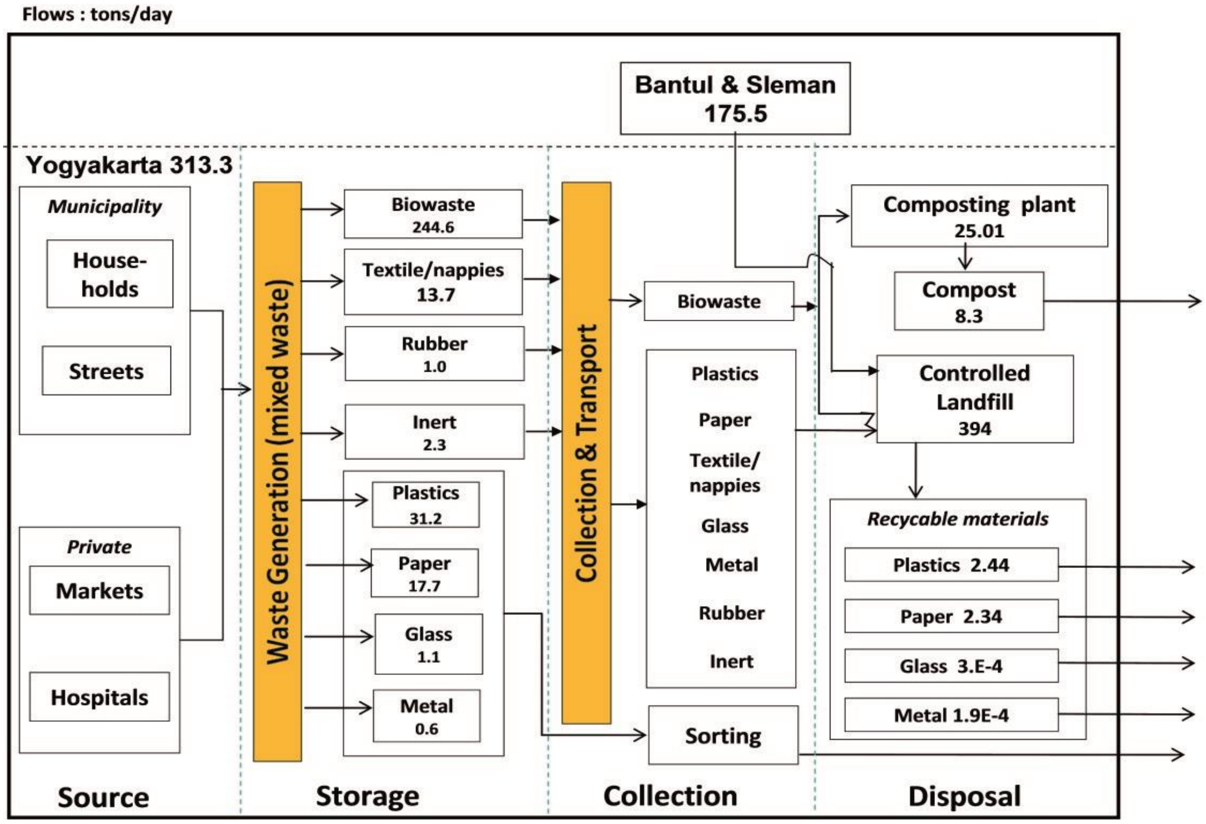


Figure 2.12Waste stream in boundary system

Summary

As can be seen from the above waste collection methods and reusing strategies, waste problem can be managed, and also local economy is improved. Management of food waste, agro-industrial waste, e-waste and plastic lethal waste are discussed. Method of collection, process and recycling with the support of firms are detailed in this block.

Activity

- Prepare caselets for food waste management (2 Pages)
- Prepare caselets for biodegradable waste management (2 Pages)
- Report possible ways of collection and separation of biodegradable waste (2 Pages)
- Prepare caselets for e-waste and plastic lethal waste management followed by developed and developing countries(2 Pages)

Review questions

- Draw flowchart of following
    - Food waste management
    - Biodegradable waste management
    - Plastic waste management
- E-waste management
- State the importance of 3Rs such as reuse, recycle and reduce?
- What is mean by return on deposit in e-waste management?

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Chapter 3 Simple Daily Waste Banks

Introduction

This block reports types of waste Bank include clothes, books, e-waste, scrap metals, household items and furniture. Also, it illustrates trash in cash concept true resale, reuse and recycle. Moreover, local economic development and impact of waste Bank to local economy are detailed with caselets. Importance of drop off and buybacks centers in zero waste cities is explained.This study will enhance the management strategies and how waste is increasing from households to the global level is discussed.

Objective

To study the types of waste banks influencing local economic development.

3.1 Types of Waste Banks

Cloths, books, e-waste, scrap metals, household items, clinical and furniture: Mainly clothing items are waste giant and this is more issuable products. “Let waste not, no more want not.” This old heritage spoken dialogue is a fix in the cloths waste only, so we have to fix the culture of “throwaway” and have to make our innovative mind to recreate any new items like bag, mat, cloth mat used for outer need. Every household should keep this mind to re-innovate old one clothes to new one redesigned material and if possible, have to recycle and reuse them by giving them to any needy one instead of throwing away.

Table 3.1 Categories of Infectious Wastes

Waste Category	Examples
Isolation wastes	Wastes generated by hospitalized patients who are isolated to protect others from communicable diseases
Cultures and stocks of infectious agents	Specimens from medical and pathology agents and associated biologicals laboratories Cultures and stocks of infectious agents from clinical, research, and industrial laboratories; disposable culture dishes and devices used to transfer, inoculate, and mix cultures Waste from production of biologicals Discarded live and attenuated vaccines
Human blood and blood products	Waste blood, serum, plasma, and blood products
Pathological waste	Tissues, organs, body parts, blood, and body fluids removed during surgery, autopsy, and biopsy
Contaminated sharps[b]	Contaminated hypodermic needles, syringes, scalpel blades, Pasteur pipettes, and broken glass
Contaminated animal carcasses, body parts, and bedding[c]	Contaminated animal carcasses, body parts, or bedding of animals that were intentionally exposed to pathogens

Table 3.2Miscellaneous Contaminated Wastes

Miscellaneous Contaminated Wastes	Examples
Wastes from surgery and autopsy	Soiled dressings, sponges, drapes, lavage tubes, drainage sets, underpads, and surgical gloves
Miscellaneous laboratory wastes	Specimen containers, slides and cover slips, disposable gloves, lab coats, and aprons
Dialysis unit wastes	Tubing, filters, disposable sheets, towels, gloves, aprons, and lab coats
Contaminated equipment	Equipment used in patient care, medical laboratories, research, and in the production and testing of certain pharmaceuticals

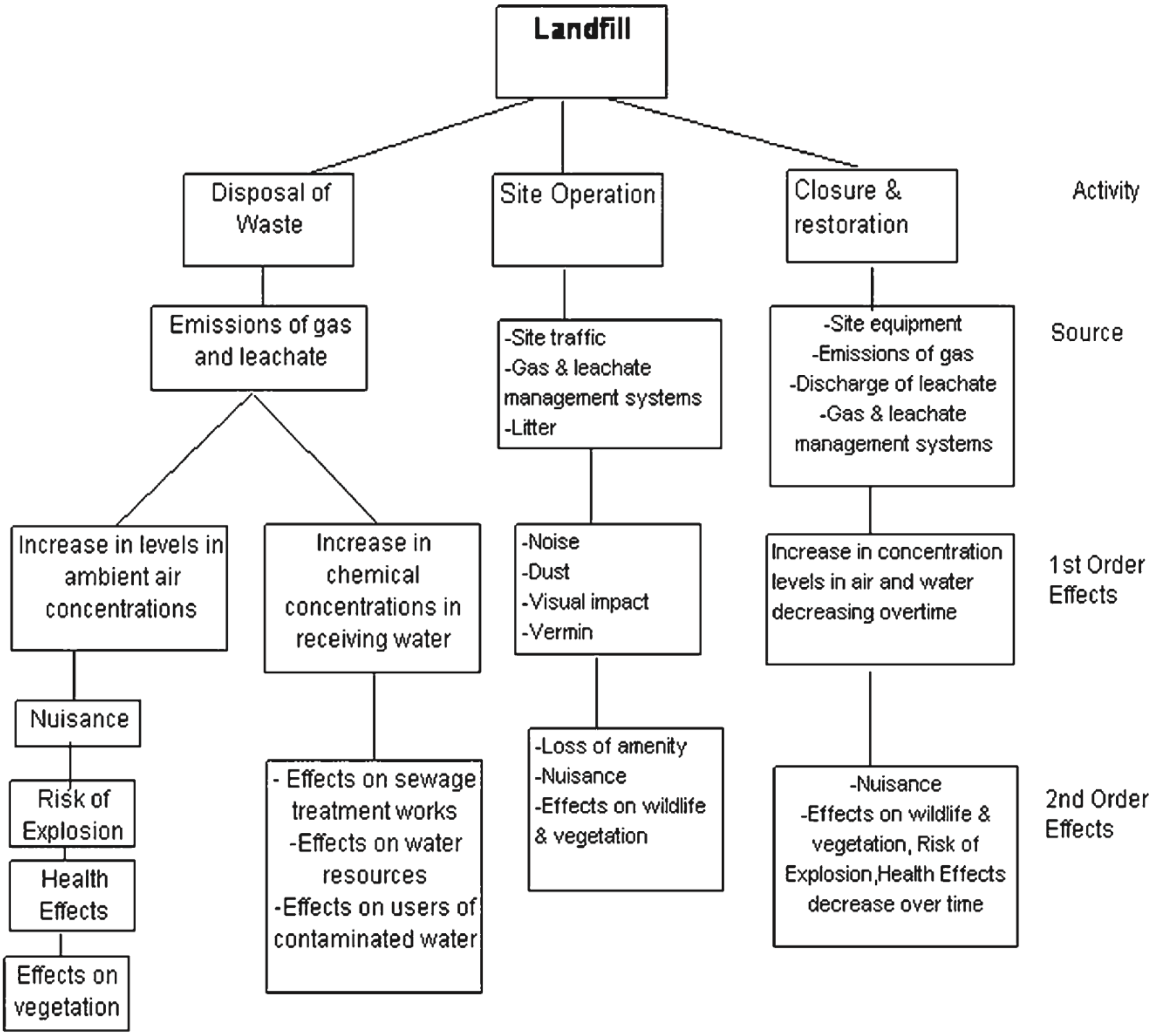


Figure 3.1Impacts and effects of landfill on the environment.

Electronic Sources of Waste: Mainly, e-wastes include DVD and CD players also CD's, Television, Computational items like printer and its materials, UPS and wired item, also vacuum cleaner and its utilities, electrical stuff like other electronic appliances are which are of no use after the damaging. These e wastes can be recycled, and these can be sent to the wirehouse for re-usable item recovery. Some are also called as e-scrap materials or e-waste materials which include TV and another electronic chipped item that contains harmful things like mercury, lead etc. can be directly given to the manufacturing company for re-instalment by checking and choking their parts.

- Refrigeration equipment – that requires specialist treatment under the Ozone Depleting Substances regulations

- Other large household appliances – that have a metal-rich content and can be easily reprocessed together
- Equipment containing CRTs – due to health and safety concerns relating to broken monitor glass this grouping must be handled separately
- Linear and compact fluorescent tubes – to prevent contamination and to enable easier recycling
- All other WEEE – those where there are no known technical reasons or EH&S concerns which prevent this mixed grouping of WEEE from being reprocessed together

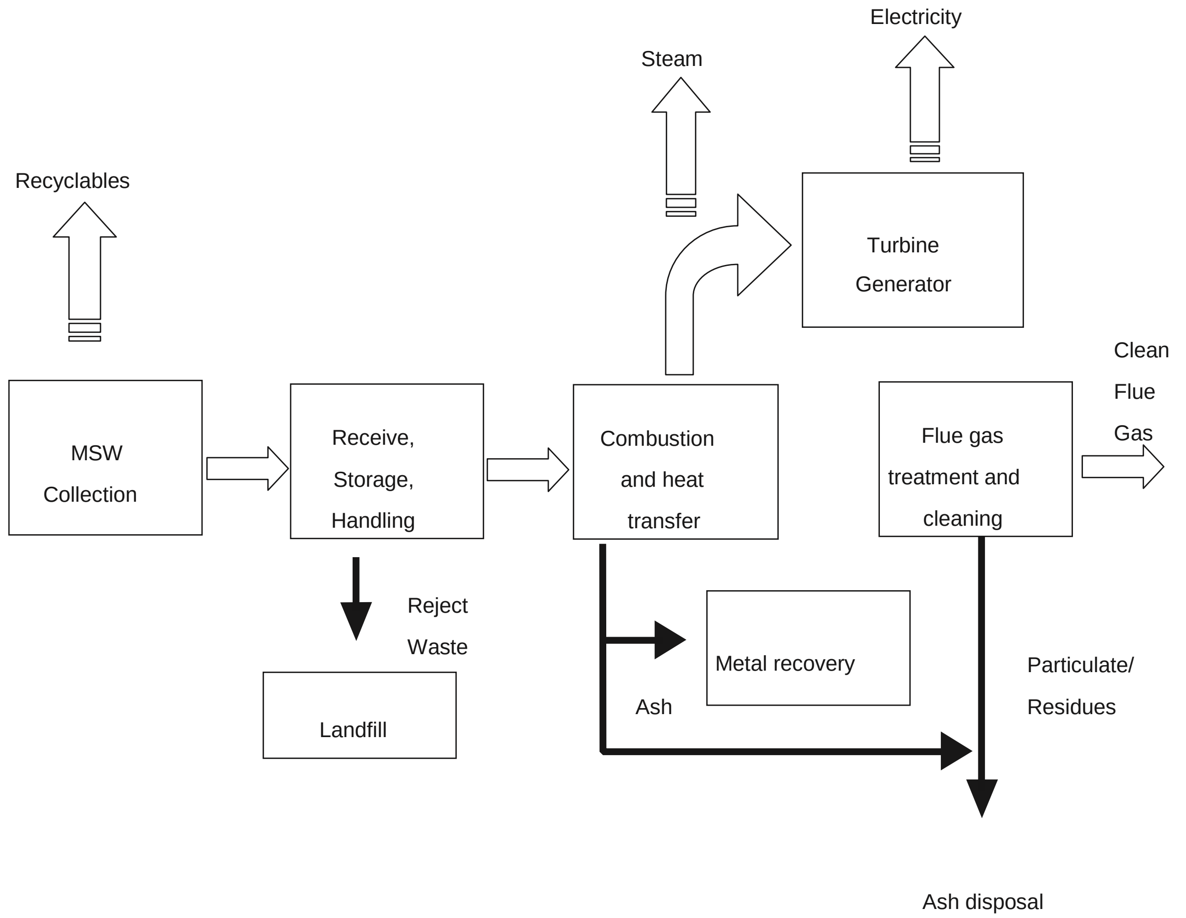


Figure 3.2Block diagram of a mass-burn incinerator.

Household sources of wastes: Mainly, including the garbage from different household items like vegetable waste, marketing waste, school waste, office related waste, cloths, much materialistic waste like plastic bottle, plastic Tiffin, cans, food waste etc. All this have to be sort in terms of various item baskets sorting facility like different organic and inorganic materials sort. Everyday an average of 20 million tonnes household waste products are being treated all over globe and nearly this is one-third of the total production of household waste.

Wastes from Construction or Demolition: A huge amount of plastic and packages from different sources used for construction and demolition were found in waste field. These are mainly package boxes, concrete debris, wooden waste, plastic material etc. All these are yielded in some particular places where waste products like these are in fielded in some residential area and this called the demolition waste.

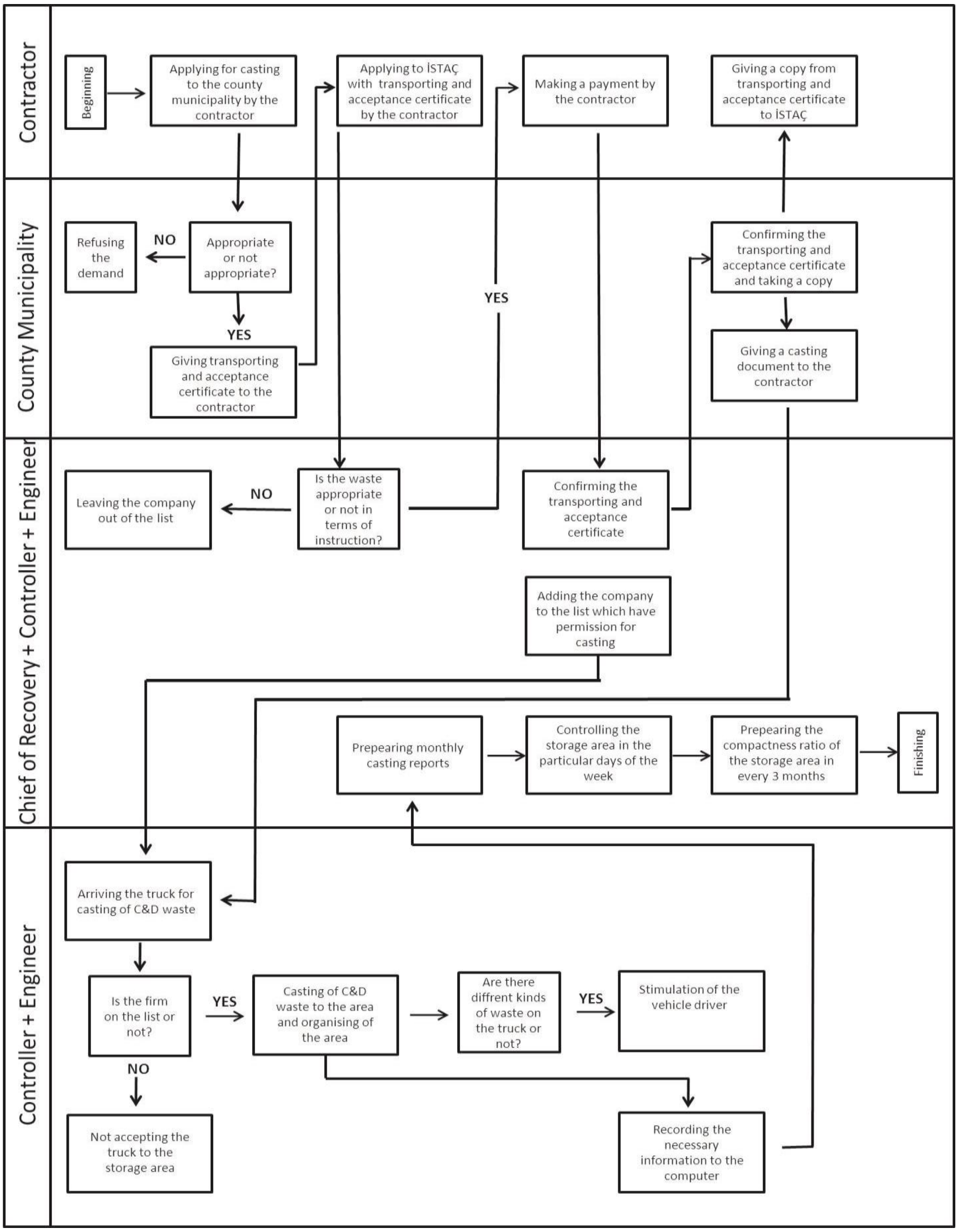


Figure 3.3. Construction and demolition waste handling process

Figure 3.4. Salvaged Building Materials Outlet

Figure 3.5. Salvaged Building Materials Outlet

Figure 3.6Demolition Waste Recycle Facility

Trash in cash by resale, recycle and reuse

The great effort in this planet that can save our natural resources and cleaning up method is by recycling. We can easily recycle our products from issues and can generate clean and green Earth. Some recycled items like plastic, bottle made up of glass, paper products and metallic materials could be trashed in terms of cash and tax deduction as per new govt. policy (UK, USA, Thailand, and China). By making some cash it is very attracting skills for the recycle criteria. This will not make anyone a quick rich but it will be enough well in terms to waste some materials and being the boss of this planet. This may be a hobby to earn some money by trashing the waste products and converting into the pocket cash. This is may be a green business for the clean earth.

Figure 3.7Five compartment for different categories of waste collection

Making some cash through recycling the waste material will help to build the pocket money on a minimal level but also it gives the recycling level to a new and exciting interest. Some items like copper, gold and silver are of valuable items and these are often found in different materialistic item, if we go for recycling materials and hardly if these are found, then 'cash after trash' will be a healthy one. These will also reduce the pressure from metal mining and opens the recycled potential for any item.

In such a case like, reusable items will also save our money by not buying they and this could be unfamiliar at all but a working process to 'cash after trash' movement. This will be second scenery for how we could save this planet for not availing any more resources further and we will store it for our future.

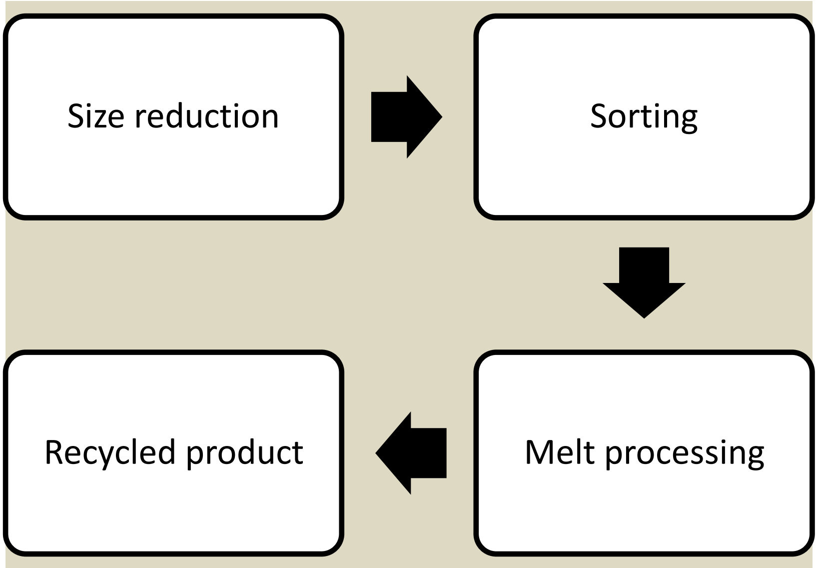


Figure 3.8 Schematic representation of recycled product development on E-waste

3.2 Local Economic Development

A public factor is that by recycling material will help nature by reducing the weight of waste in it. Everything comes under the fact that using plastic bottle to any plastic packing will benefit us in for short time only, but its bad impact will last for long times. To decompose such a material will be a burden for us in near future and developing such item will compromise the economic growth. By manufacturing many and many such items need many raw materials. This will be losing our planetary resources. But if we go by recycling material and eager to produce materials from the material, then this will not only save our resources but also produce millions of jobs in recycle industry. Also, this will save new material cost from growing it like a zero ground to an industrial level. This will benefit by reducing the cost of the raw material and also to need to recycle gives a hard and pre-defined item structure in for the laboratory issue. Largely, main issue is the manufacturer can save up to 85% of the raw material cost by recycling a material other than seeking a new material from it.

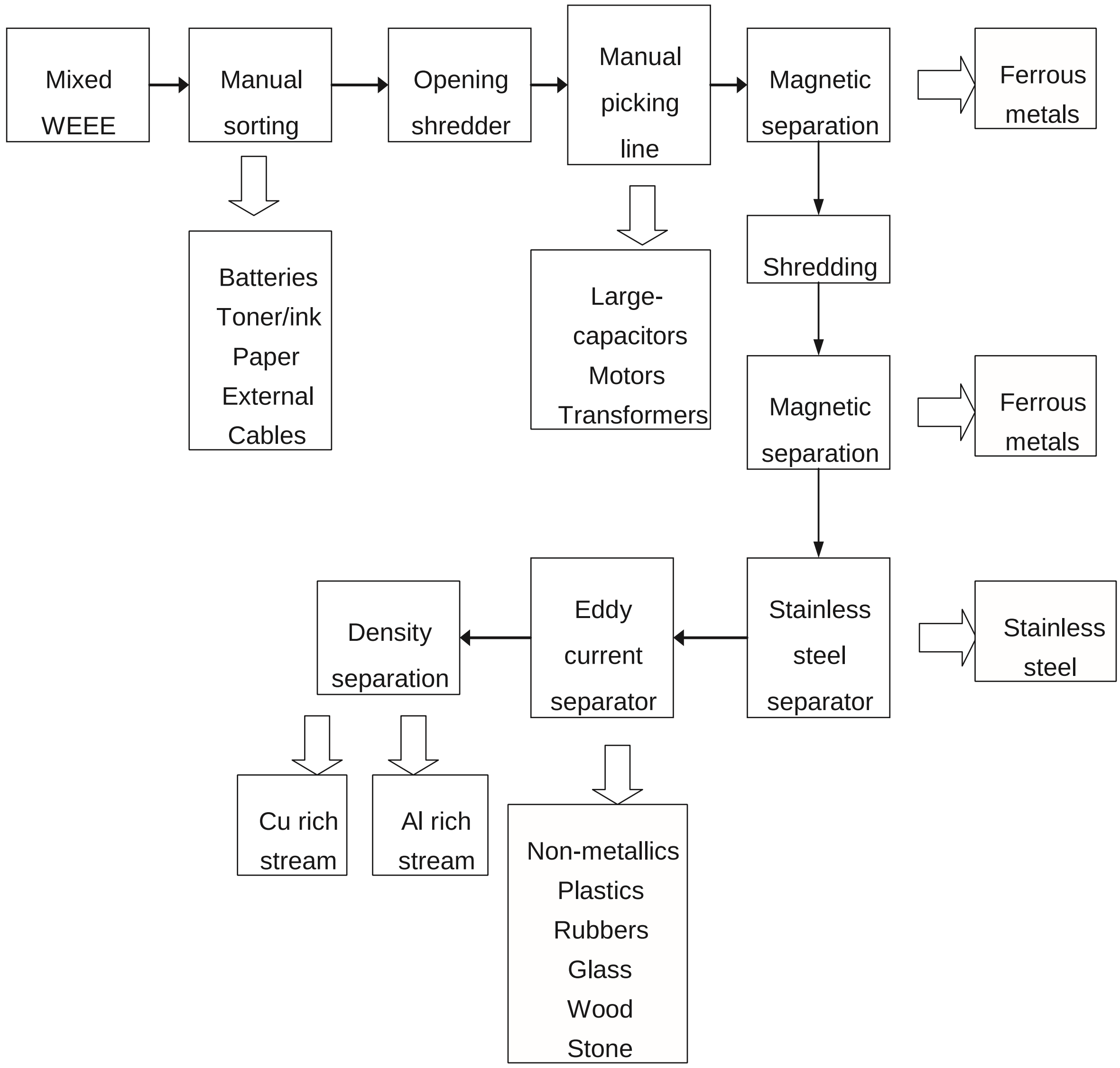


Figure 3.9Simplified process flow for a mixed Waste Electrical and Electronic Equipment (WEEE) metal recovery plant.

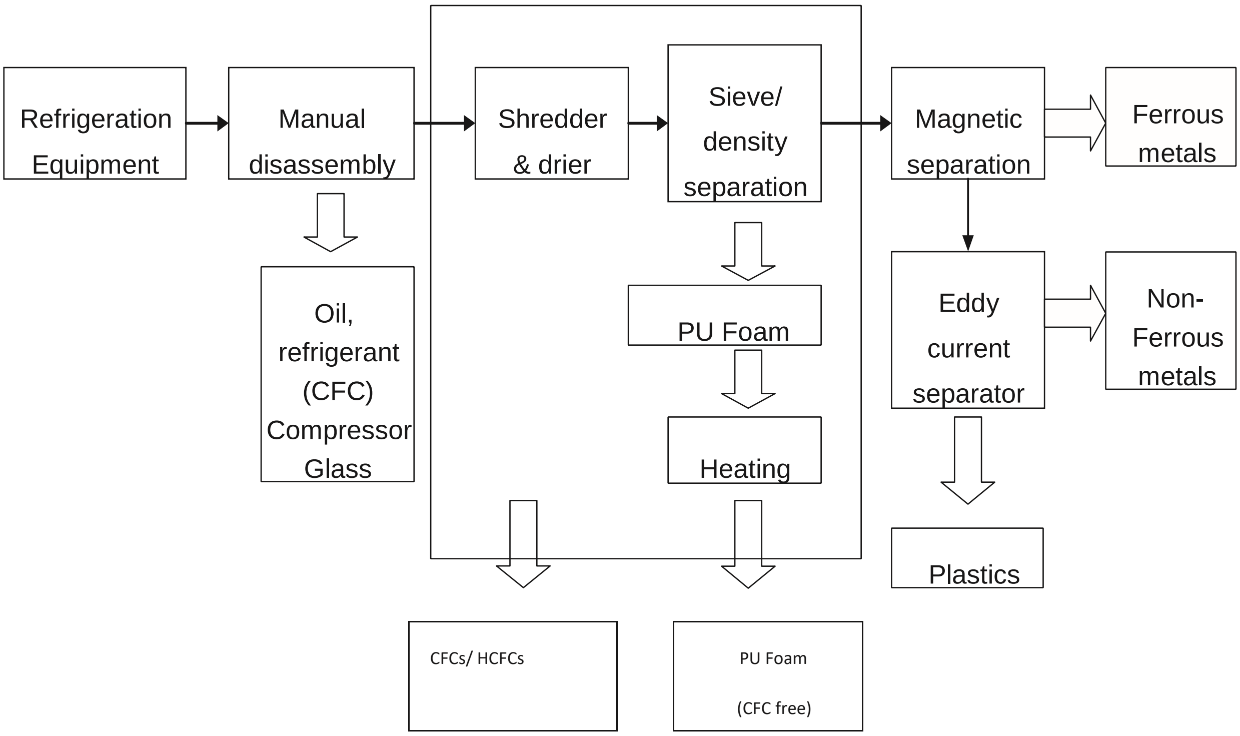


Figure 3.10Simplified process flow for refrigeration equipment.

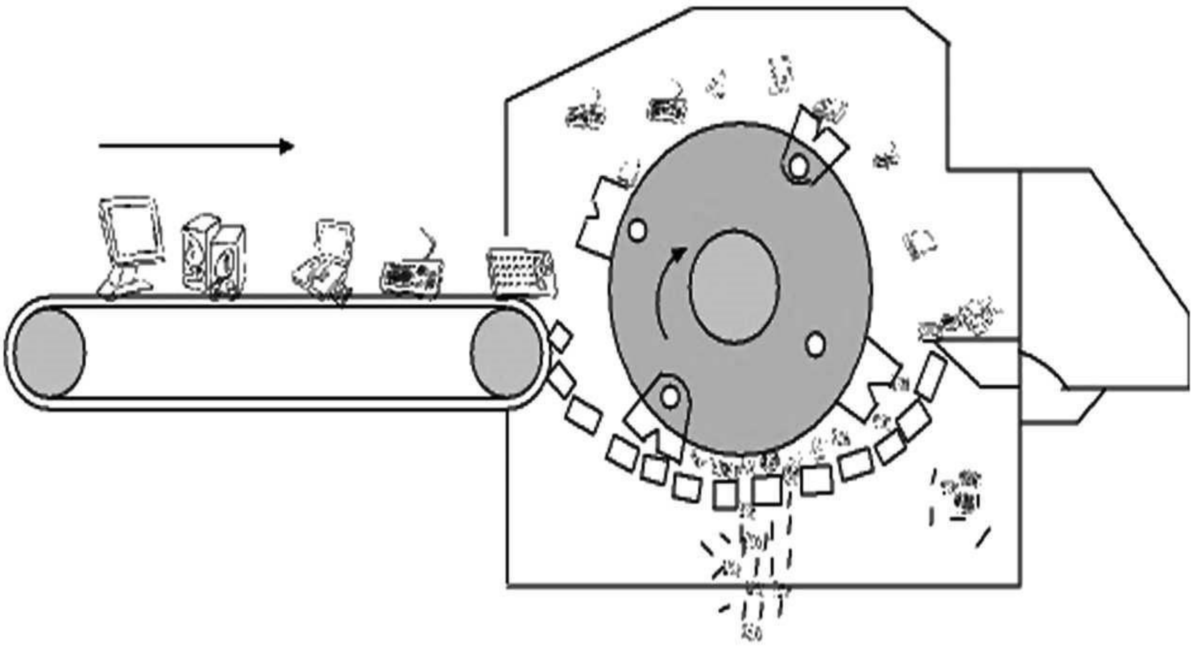


Figure 3.11Hammer mill

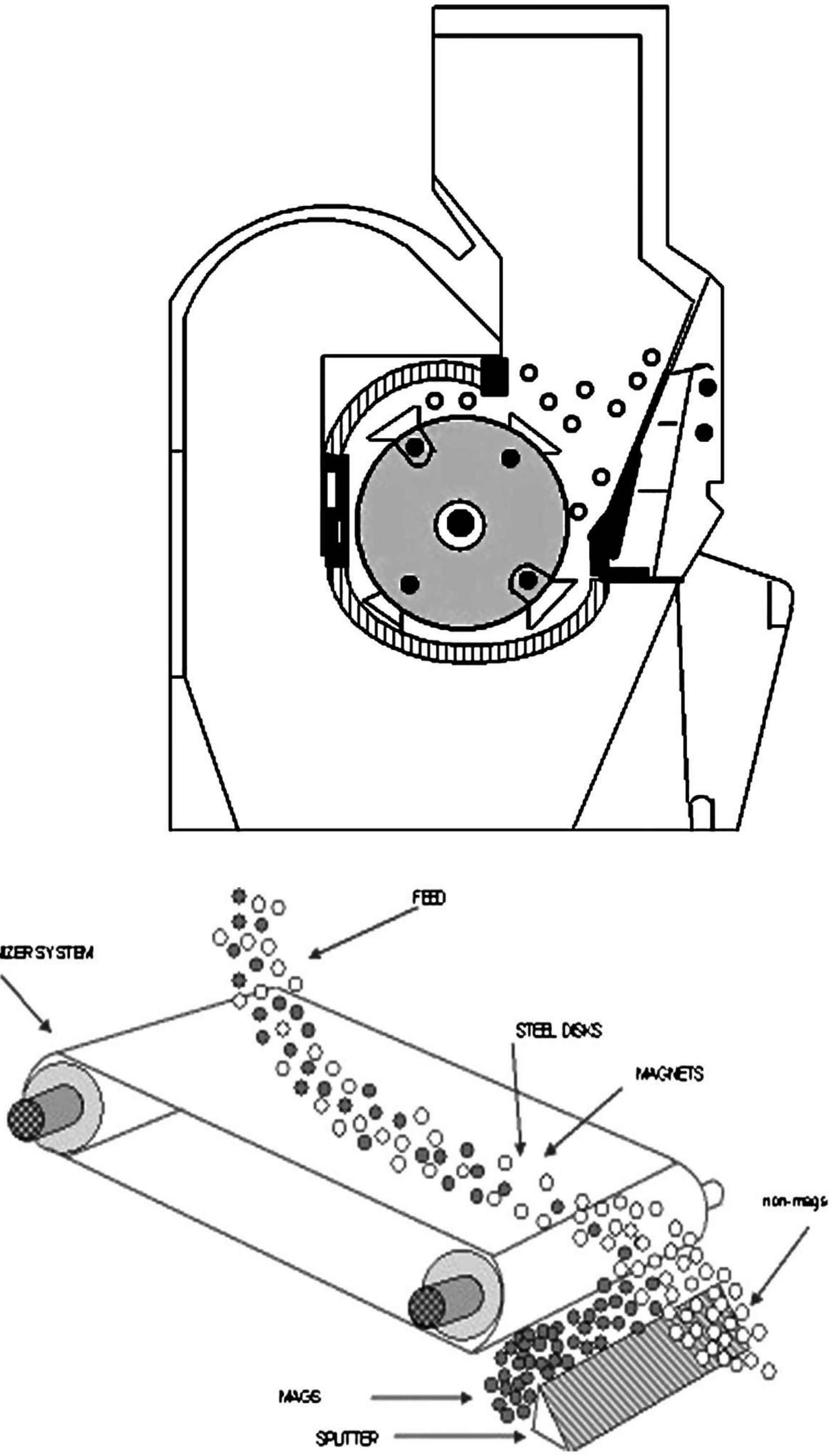


Figure 3.12Crusher and Magnetic separator

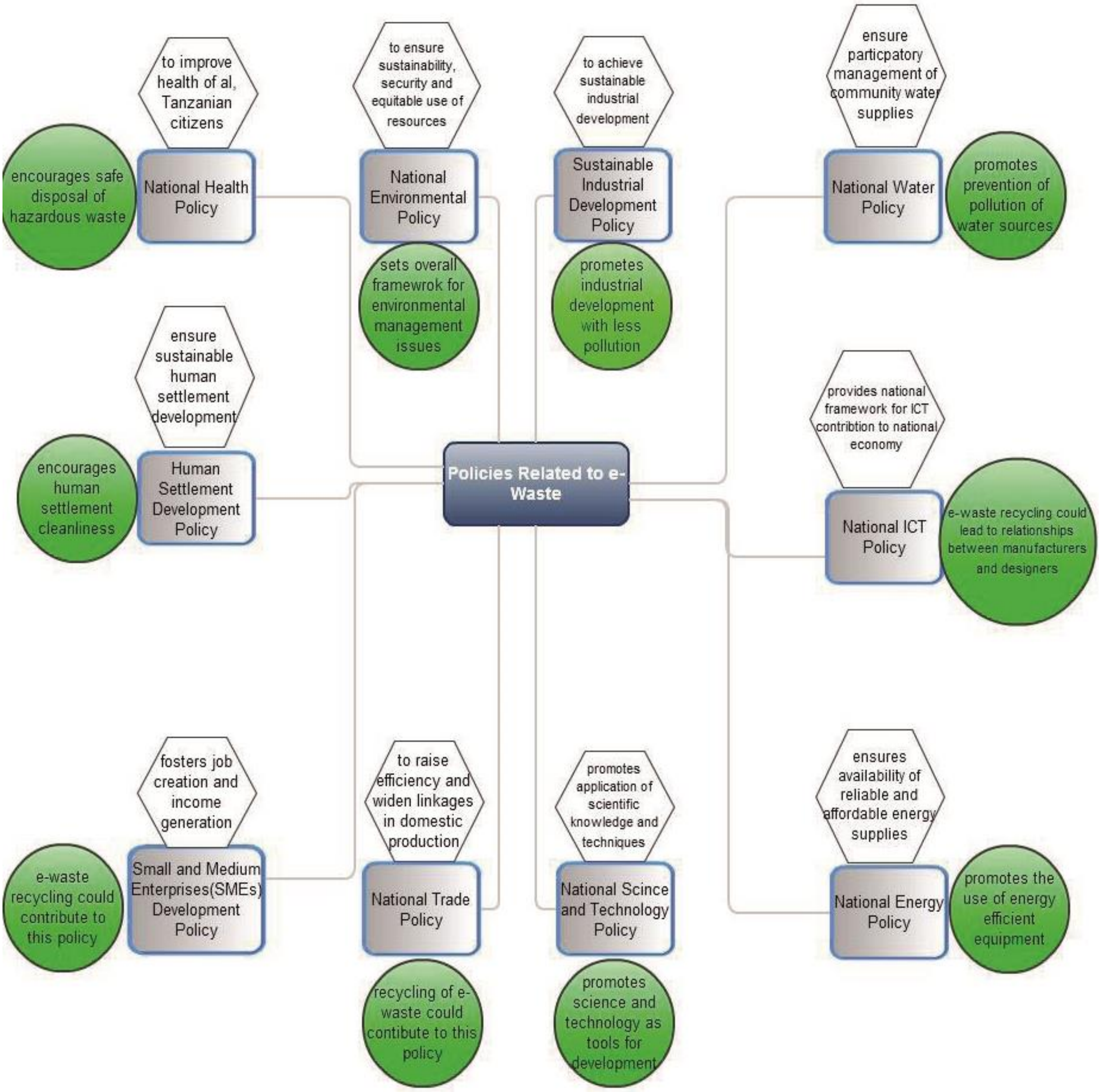


Figure 3.13. An Overview of Policies related to e-Waste Management in Tanzania: The Policy, Objective and Relevancy.

Table 3.3 Current and future technology summary.

		Current technologies		Future technologies	
Process stage	Process	Technique	Comment	Technique	Comment
Disassembly	Manual	Pre-sorted waste then physically checked			
	Impaction	Mechanical dismantling under force with chains			
	Shredding/ Fragmenting	Various shredding devices – similar to above			
	Automated	QZ machine	Combination of devices above and sepn methods below	Imaging and recognition Robotics Enhanced fastenings RF tagging	
Size reduction	Crushing	Hammer mill Granulation		Cryogenics	Used in combination with other size-reduction methods
Separation	Size	Screeners/classifiers			
	Magnetic	Low-intensity drum High-intensity magnetic field			

Recycle helps in the industrial extraction and raw material detection process. Also, it gives job security to a new level of people who can easily depend on collecting household wastes for the recycle factory. Refining is another need in this development and provides obtaining material and collects the parts whatever can be used to newly generated items. Also helps in the field lowering the cost price and saves the expenses from collecting raw one.

Reusing a recycled item also cost-effective in different fields where some estimating value like 10,000tons of waste material can create hardly 6 types of job for refining and extraction and up to 6 times this would be possible. A role of ranging from different material stores to be depicted and have to shorten the loss of the natural resources in this material and management. Surely this will develop a huge economic growth at the local level by creating jobs and different level of reefing unit also for clean and green planet.

3.4 Impact of Waste Bank to Local Economy – Caselets

One case study in Nigeria, Enugu State revealed that due to non-availability of sustainable management and efficient methods, solid waste management is in child condition in Nigeria. No practices by locality, no process of development and no need of unused sustained deform the management of wastes in Nigeria capital. The background behind the locality and economic condition also matter the management in sustainable development of waste field.

These objectives were addressed primarily using a structured questionnaire administered to a cross-section of people in three selected local government areas (Enugu East, North and South LGAs respectively). This case study in Nigeria performed by Dr.Agbaeze E. K ;Dr. I. O. Onwuka and Agbo, C. C in 2014 (*Impact of Sustainable Solid Waste Management on Economic Development – Lessons from Enugu State Nigeria, 2014*) and they prepared some questionnaire and augmented specified report depend upon field study and perspective of the local people. They found that there is no space available in Nigeria to prepare a waste damping industry like repair and reusable manner. In Nigeria, there is no provision of segregation of waste material in damping station. Because technology less and resources less country like Nigeria can effort such a need in advance and they can use the landfills for the slummy damping and trends to be very slum. Local manner in this way also being a non-specified objective as these are not under any certain rules for waste aggregation and waste sedimentation. Also, such a country has no economic purpose for using recycling and reduction of waste material for some materials like polythene, plastic bags, metallic cane etc will not be cost effective after being they are recycled and reused.

This case study demanded that to disintegrate the current situation on Nigeria, a huge and explosive number of public campaigns is needed to embark the people upon the cause of waste management and so have to develop the economic condition by this need. In country like Nigeria if people choose to reuse a material then it also is cost effective for them that they don't need to buy a new one instead an old item can be re-innovated for some new need in own demand. The figure (Fig-1) following is the best hierarchy to denote the need of waste management in such a low poverty country and to overcome the economic condition for the best in situation.

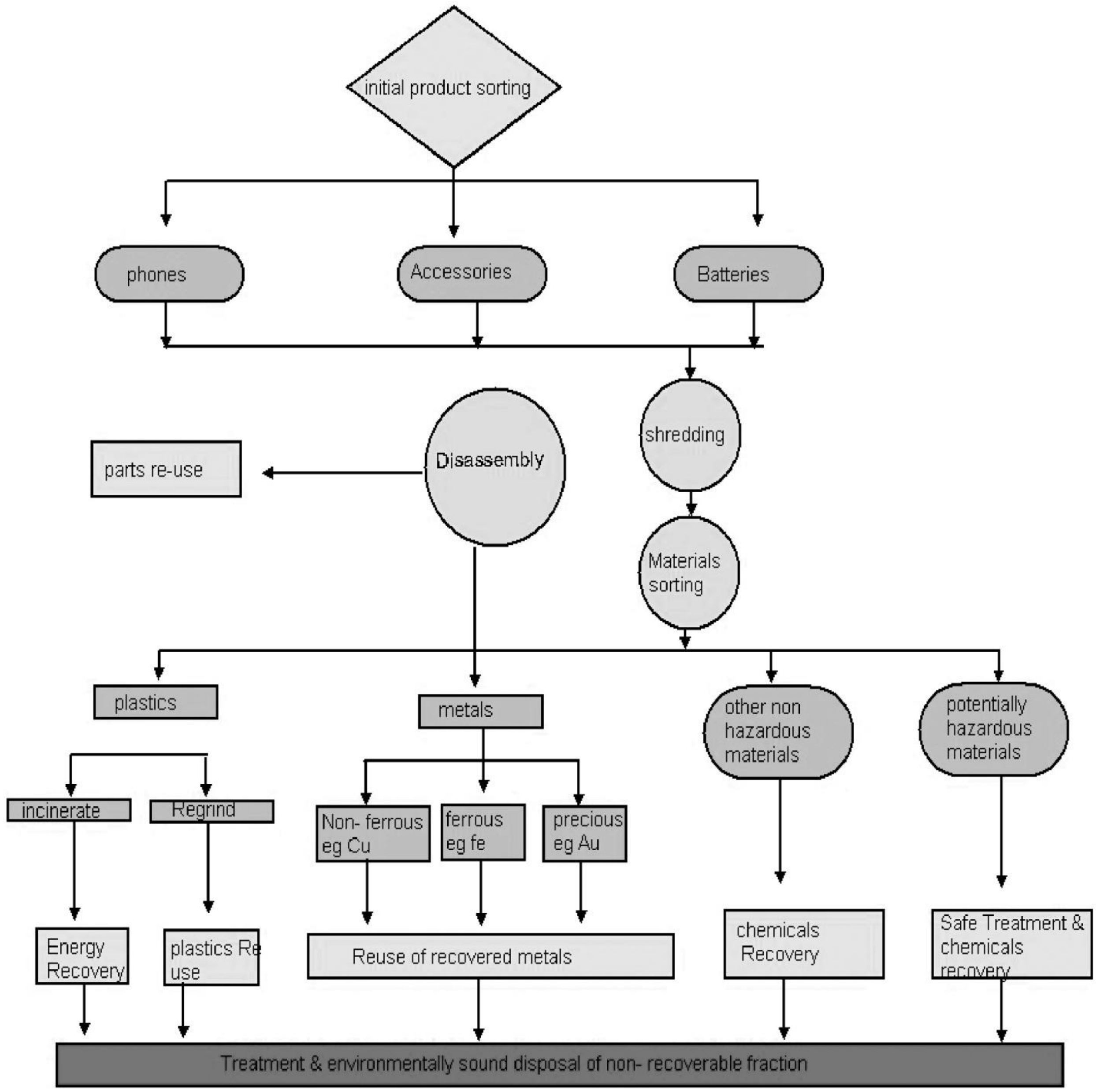
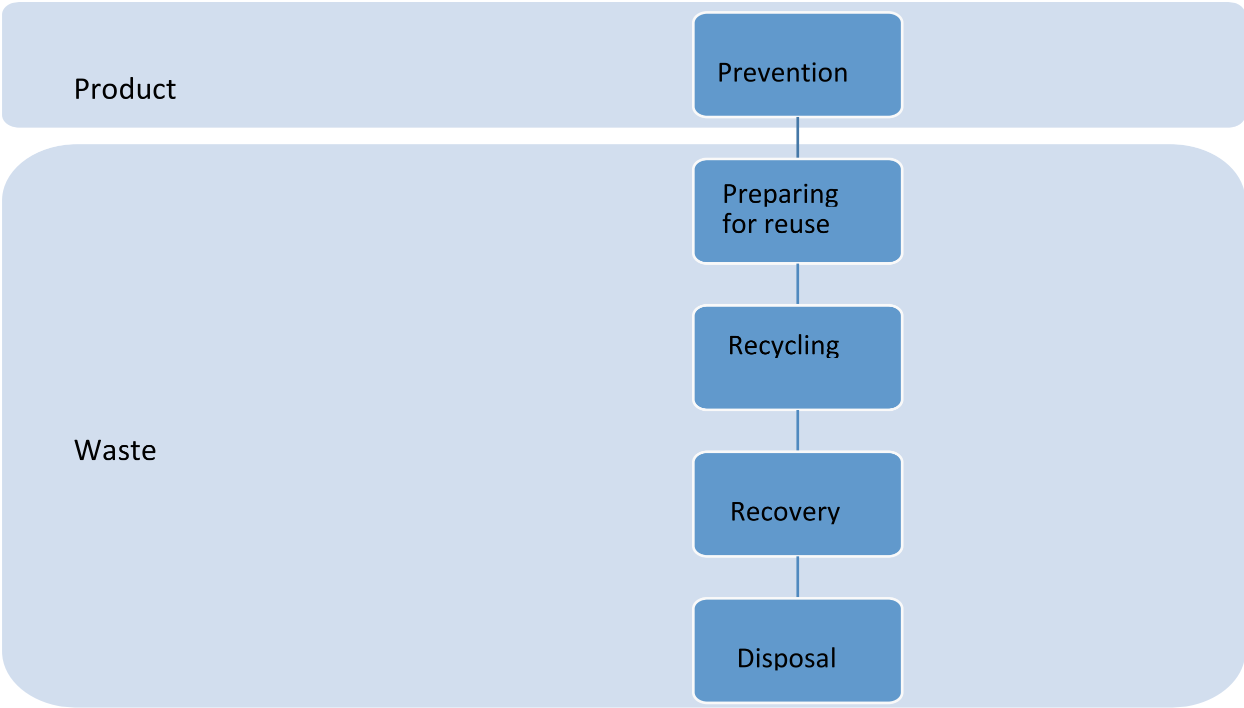
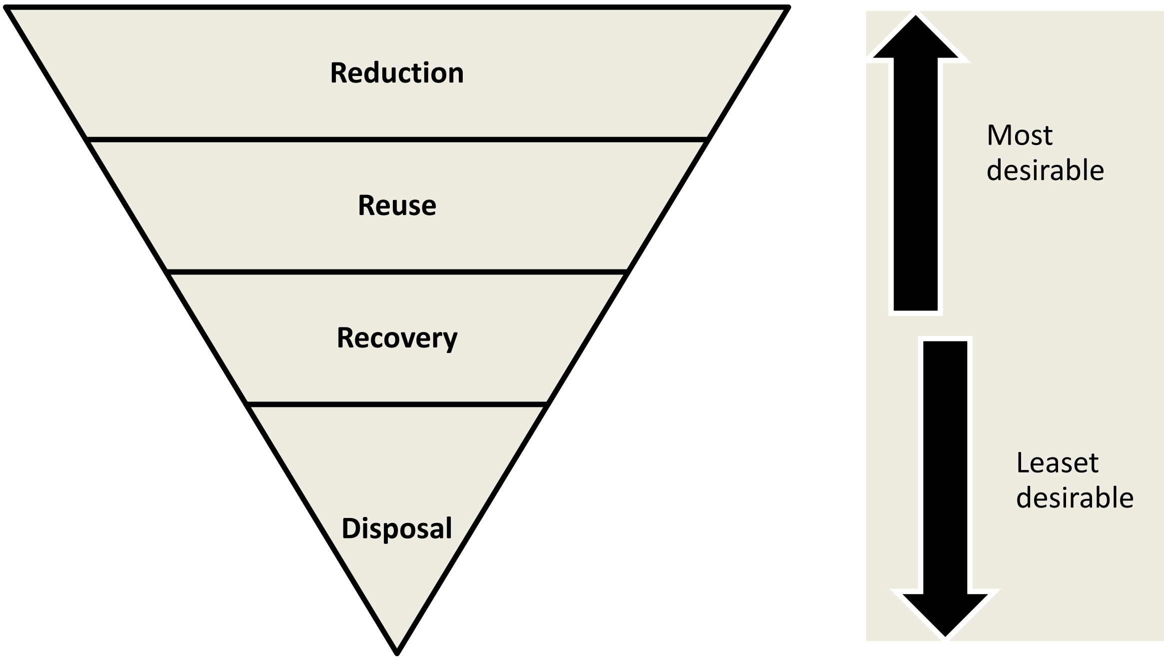


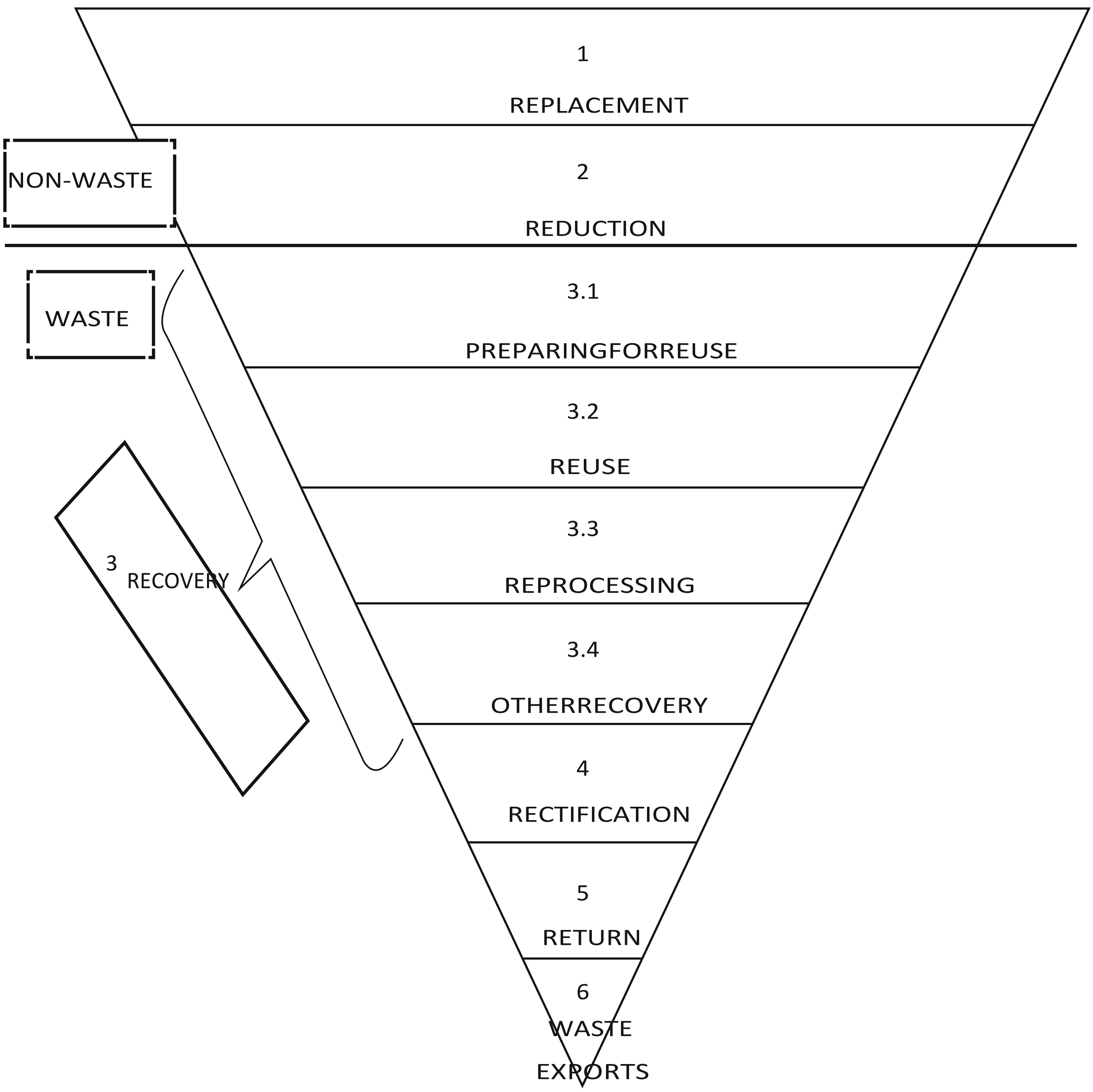
Figure 3.14Typical end-of-life route for mobile phones.



(a) Waste prevention



(b) Hierarchy for most and least desirable



(c) Six stages of the hierarchy of resources use

Figure 3.15Solid Waste Management Hierarchy

Table 3.4Composition and property of burnable wastes in Chuo incineration plant

Category		Mean value
Composition, wt%	Burnable components	98.45
	paper kitchen waste plastics wood and grass textile rubber and leather others	45.00 22.92 15.97 5.74 4.61 0.51 3.70
	Inflammable contaminants	1.55
	metal glass stone and ceramics others	0.46 0.32 0.13 0.64
Proximate analysis, wt%	Moisture content Combustible matter Ash content	38.69 54.58 6.75
Elementary analysis, %	Carbon Hydrogen Nitrogen Oxygen Combustible sulfur Volatile chlorine	28.5 4.24 0.34 21.33 0.02 0.17
	Higher calorific value, kJ/kg Lower calorific value, kJ/kg	12,263 10,335
	Bulk density, kg/L	0.130

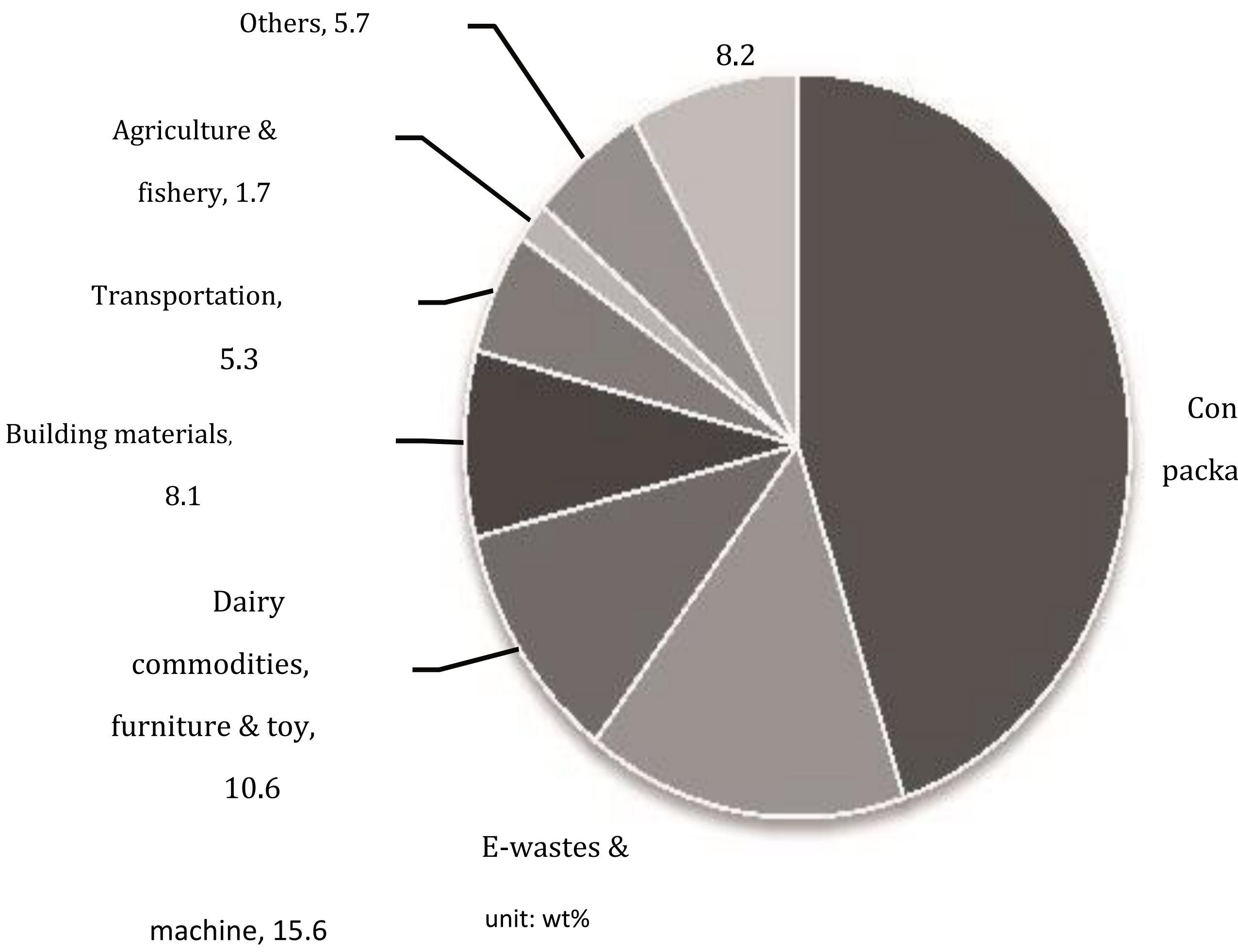


Figure 3.16.Waste plastics generation by user's application (Total generation 9.45 million tons, 2010)

3.5 Zero Waste Cities Though Drop off and Buyback Centres

A global need of waste management which always take a seat of driver for the public growth in various fields like population, and urban area expansion, economic and constructional development. Mainly food wastes and food production always being the top in drop off issues in the waste management criteria. To minimize this issue, we have to recreate some of the centres that can deal withoffences like this one. One-third of the total global food production is being wasted every year. In high-income countries like western countries, they waste much more in food waste. But being to need to think about the poor one, manufacturing cost, distribution cost and the retailing value of the grocery items everyone should not be waste food items and if no need, no need to cook!

There are some environmental factors that always plays role in waste management and waste drop off system. They are mainly concerning topic of being the need of drop off and they are mainly-

- Environmental issues: Mainly drop off properly of the municipal waste will consume nothing loss in the environment and help to build a green and clean planet.
- Socio-economic issues: Much production of wastes will cost the dirty society and hence will pronounce a less economic development.
- Financial issues: A proper drop off facility will help not to think people about it and no need to roam for the disposal site visit.
- Legal issues: Some legal norms will help to create control over the waste issue.

Some public company like EDCO and its fellows help to reduce the optimum high in waste management and controlling the drop off movement. It's convenient to be the movement party! They will collect all the wastes from waste collection boxes placed by municipal and public bodies and drop off all the items in the disposal plant. It's called recycling transfer. Also, the recycling point member will check all these wastes and help them to classify the items that can be used under their convenient and try to sell with local people and buyback process starts.

Some recycling drop off levels are:

- Public truck scale for certified vehicle
- weights Courteous staff
- Weekday and weekend hour E-waste drop off location
- Household battery drop-off location

- Home-generated sharps drop-off location
- Fat, Oil, Grease (FOG) drop-off location Certified used motor oil and oil filter drop-off Polystyrene (styrofoam)

9. Municipal action plan of 15 years to reach a *zero-waste* situation

1) Year 1 Disseminate the program and the specific methods to be used among construction companies and health care institutions.
2) Year 2 Stimulate construction companies to anticipate the law and develop their treatment and recycling infrastructure. Initiate the collection of dry separated residue from residences by existing reverse logistics operators. Organize pilot units of decentralized composting and collect bio-waste from restaurants and pioneering apartment buildings.
3) Year 3 Establish voluntary drop-off points for large-volume trash items. Instruct medical establishments to separate their contaminated refuse.
4) Year 4 Pass the municipal law of solid waste. Irregular or clandestine deposits receive fines. Source separation becomes compulsory and is checked by municipal agents. Bio-waste is collected from residences in closed containers by operators of decentralized composting units.
5) Year 5 Existing reverse logistics operators absorb all separated dry material.
6) Year 6 The precarious rubble landfill is closed. Health care residues are collected and treated by private companies against payment.
7) Year 7 Centralized composting facilities are started by private operators Year 8 All industries have their waste management programs.
8) Year 9 Recycled material begins to appear as raw material on the local market.
9) Year 10 Recycling industries establish themselves in the city.
10) Year 11 All producers of bio-waste have their management programs. The municipal landfill ceases to accept bio-waste.
11) Year 12 Barrels for collection of dry and clean packaging material are posted in the streets.
12) Year 13 Fines are applied to people who do not separate their waste.
13) Year 14 The municipal collection crews do no longer take away separated residues. They only take refuse, which does not fit the definitions of bio-waste or inert recyclables, to the correct destination to be defined by the city administration. Year 15 There is no more waste to be tipped at the landfill.

- *Objectives for bottom-up warfare against the landfill*

In current system, the more consumption leads to more waste production. And enormously everyday huge amount of waste is being continuously produced in the field of different sectors. The issue is how to deal with them and how to manage with all these waste products. Currently, to prevent the waste resource hazard, mainly need is to save the global resource and develop sustainable consumption in good way. Evidently a significantly high number of global nonrenewable sources are found where we are using a huge amount of resources from them. But to accomplish the global need and global supply within some next decades we have to make sure to use the 3 'R' laws-Reduce, reuse and recycle. The recycling rate of very rare metals is currently high, and people are significantly covering this matter in some high economised country. The 100% recycling concept of municipal wastes and recovering the 100% of it is the toughest task in time, but some countries like, Britain, Canada, Germany and Portugal make it happen. These over the use and over the consuming countries are alike in western counties and they are challengingly becoming the "Zero waste" country.

Mainly these zero-waste conceptswere firstly distinguished by the factors of management issues and the better the management tends to no waste places. The different study proposed that as more be the consumption, more depletion and degenerating the more wastes its now conventional that to prove a no waste city. In India, Alappuzha, a coastal city in Kerala has grown its landmark, by developing a zero-waste city, which is only and only one in India. "Zero Waste Cities" programme has been developed with the aims of: -

- reducing waste produce;
- increasing and maintaining participation in recycling and composting schemes within the university
- raising and maintaining awareness of waste issues;
- promoting the Waste Hierarchy – reduce, reuse, recycle;
- providing a diverse range of ways of increasing education and awareness within the university;
- giving a message that is consistent;
- linking in with regional and national campaigns;

Summary

The third block reported the types of waste bank include food, furniture, e-waste and industrial waste. As can be seen from the above waste collection methods and reusing strategies, waste problem can be managed, and also local economy is improved. Impact on management of food waste, agro-industrial waste, e-waste and plastic lethal waste on local economy is discussed. Method of collection, process and recycling with the support of firms are detailed in this block. In addition, zero waste cities through drop off and buy back centers are explained in detail.

Activity

- Prepare caselets for different types of waste bank (2 Pages)
- Prepare caselets for trash in cash (2 Pages)
- Report possible ways of local economic development though waste banks (2 Pages)
- Prepare caselets for zero waste cities in developed and developing countries (2 Pages)

Review questions

1. Detail the following
    (c) Trash in cash
    (d) Types of waste banks
    (e) Drop off and Buyback centers
    (f) Impact of waste banks on local economic development
2. State the importance of 3Rs such as reuse, recycle and reduce in local economic development?
3. What is mean by zero waste city and how to achieve it though waste management?

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Chapter 4 Waste to Wealth through Banks

Introduction

The concept behind "Waste to Wealth" solely means moving on such a platform where un-necessary items can be utilised for desiring and valuable goods. This is an exit plan for waste production and blue print for waste management. Science requires energy in terms of this transformation and productivity ensures economic growth. Exclusively, a new concept got started where; no waste can be a wealth without discarding the generator. As price rises, market always demands most of wealth and wealth comes at that time from the waste with high implication of waste generation. But every waste product is not a secondary benefited product unless and until waste is potentially treated. The highly attained slogan and everyone should shout it like "Waste to Wealth" movement could provide the management tactics and hence it enhances the process for valuable energy services. Mainly this type of operation creates social awareness in collaborating with local and zonal economic growth for this upcoming green and clean planet.

4.1. Community-Based Waste Management

Current problems in municipal waste management and mainly household waste management worldwide can be observed and conventionally operate to justify the issue and to get the solution interview questionnaire is needed. Any community-based simulation gives result of the local level problem and it's a good practice for operation of how the different factors influence the global environment from the solid waste landfill. In any particular area, the need forcommunity-based system for waste management like recycle and reuse monitoring mitigates the different issues involved in this matter and a well-organised community can easily solve such an issue. Current SWM problem and conditions arising due to this in entire global level can be carried to revision and this should be managed.

Due to low waste collection and illegal dumping widespread, the incineration caused by this has created some impacts in natural health. This is the reason for increasing many health issues and social hygiene. A clean environment always feels us a cleaner and good mood, but after having some weird dirty places near to household seems a bad environment for health and wealth also. Open waste damping landfills are house and prime sites for breeding and developing for insects and serpents like houseflies, mosquitoes and different disease spreading vectors. These vectors are mainly causing some of the life threaten disease like fever,diarrhoea, cholera, dysentery and malaria.

Also waste burning is a natural hazard. This causes the disease threaten fumes that consume different chemicals and acidic materials and they are the most volatile particles in the environment. Also, these fumes causeodour and infection related to our skin disease which is an uninhabitable environment. In residential area need of water is just covered from ground waste, but due to landfills in dumping site the leachate causes the pollution to the ground water and this is an important problem for the residents itself. Also,wind blows the loose paper sheer and plastic material from an industrial area to the environment and this intrusion is another aesthetic problem from waste also.

Mainly in the recycling technology those are proposed on the based on some conditional and to be achievement strategy, the municipal solid waste management practice is being performed. Huge number of improvement and importance were seen in last 20 years of this waste management practice. Also, in the next 20-30 years, a recent study reveals that the impact of waste management will decrease to a lower rate and in upcoming years, global look will change to cleaner and greener version.

4.2. Local Economic Development

The main objective of any unimodal explanation is how to develop the sustainable economy from the waste management services. Global reach is much needed for this kind of development through the waste management, especially in developing countries. In this type of authorization, mainly the need is how to overcome a problem with highly appetite social activity. Descriptive research reveals that in depth study in a municipal area always performs some explanation of how the local household and stakeholders manage their wastes through the waste banks.

Our society lives in some proper number of rules. All this waste produced from the solid waste management can be of forming different results. The operational result from World Bank in 2012 shows approximately 1.5 billion MT (Metric tons) solid waste and out of this only 16% is treated properly. This is expected to be 2.5 billion MT by 2025. Regarding the industrial waste, a study by Frost & Sullivan estimated that (2011) by the end of 2020 globally 10 billion of MT wastes will be generated and for this issue, the Gross Domestic Product of any county is lowering because no use of item for 2^{nd} life and due to un-avoiding condition in recycling issue.

World widely, wastes are just a problem, and no one wants to raise this issue to a global level. Wastes are collected and they are just dumped in a landfill area. This is unauthorized and generated in the control facility and the control facility tries to prepare the items for the damping site.

Incineration also applied for the waste treatment in landfills area. But wide spreading in landfills area is still an issue in waste management.

Main need in the solid waste management is just to increase its management atglobal level. And in logical reality, the waste is a huge cost to be actively formed. But as high is the waste, the active normalization in the waste management involves the intensive manpower to exhaust it from the waste bank to wealth bank. Also,operational cost in energetic need, consumable diet and parts of management equipped are very important. Hence cost of waste management is likely to be expected highly in drastic global need.

LED mainly proceed for local members of waste management board and then they think how in locality the economy can be recovered from this waste fills. Defining the participatory influence in the local economic holders, the joint blue print of this strategy is mainly based on how these can be implemented in the flow. Basic use of common local resources mainly based on some sustaining jobs and economic activity to be achieved in resources development (Canzanelli and Giordano, 2001).

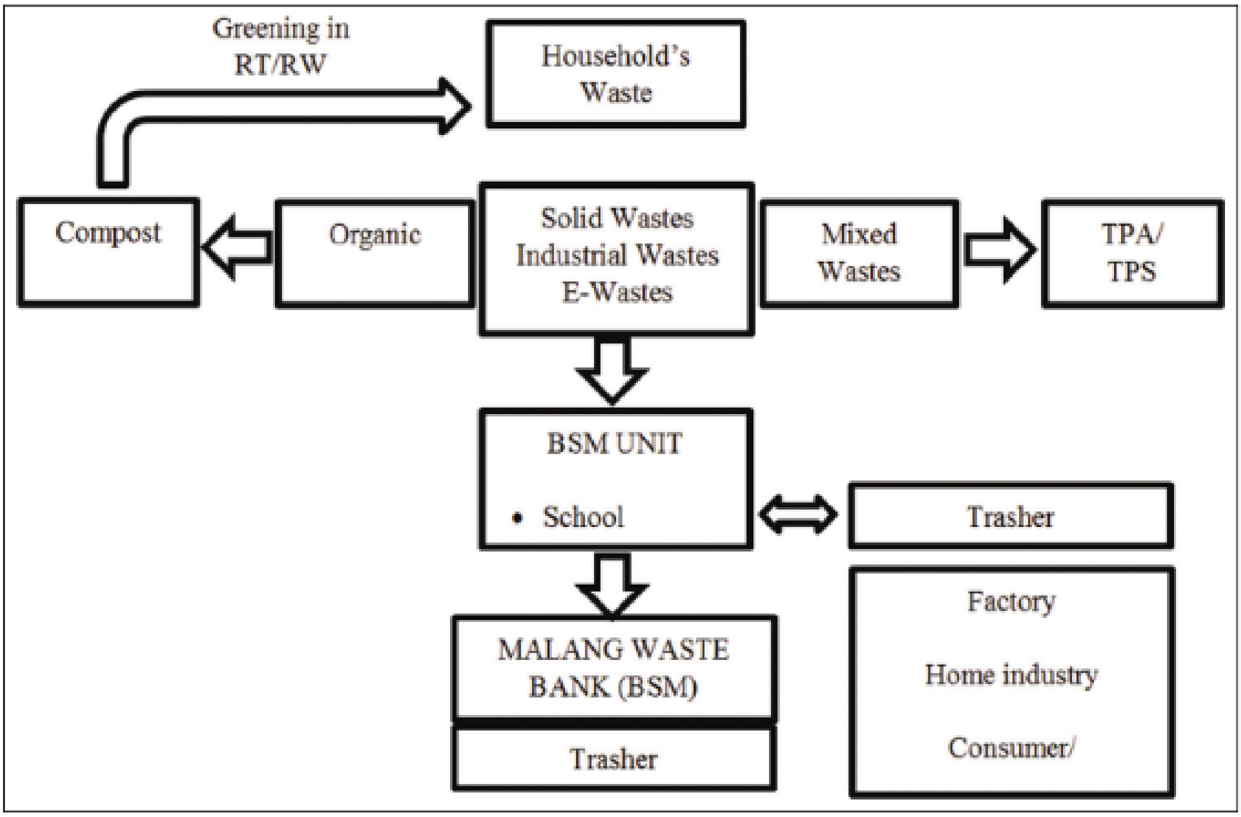


Figure 4.1 Showing solid waste management flow chart in a case study in waste bank- Malang waste bank (BSM)

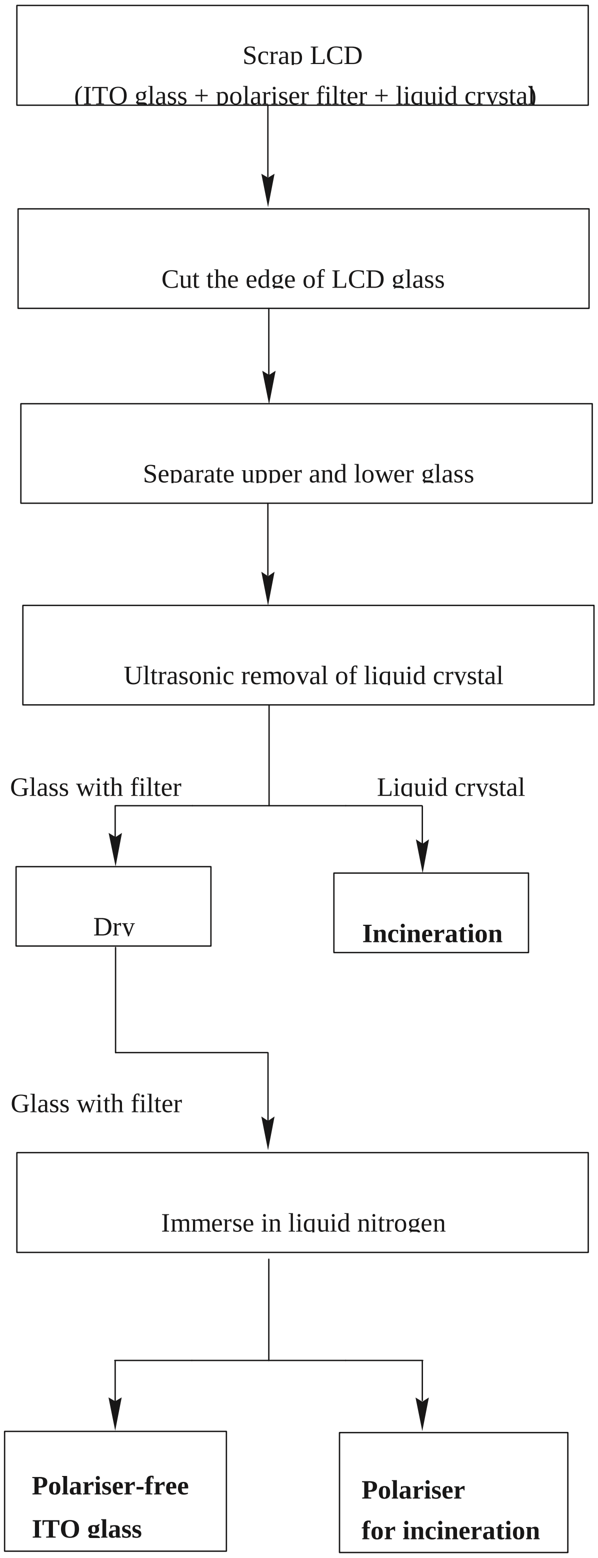


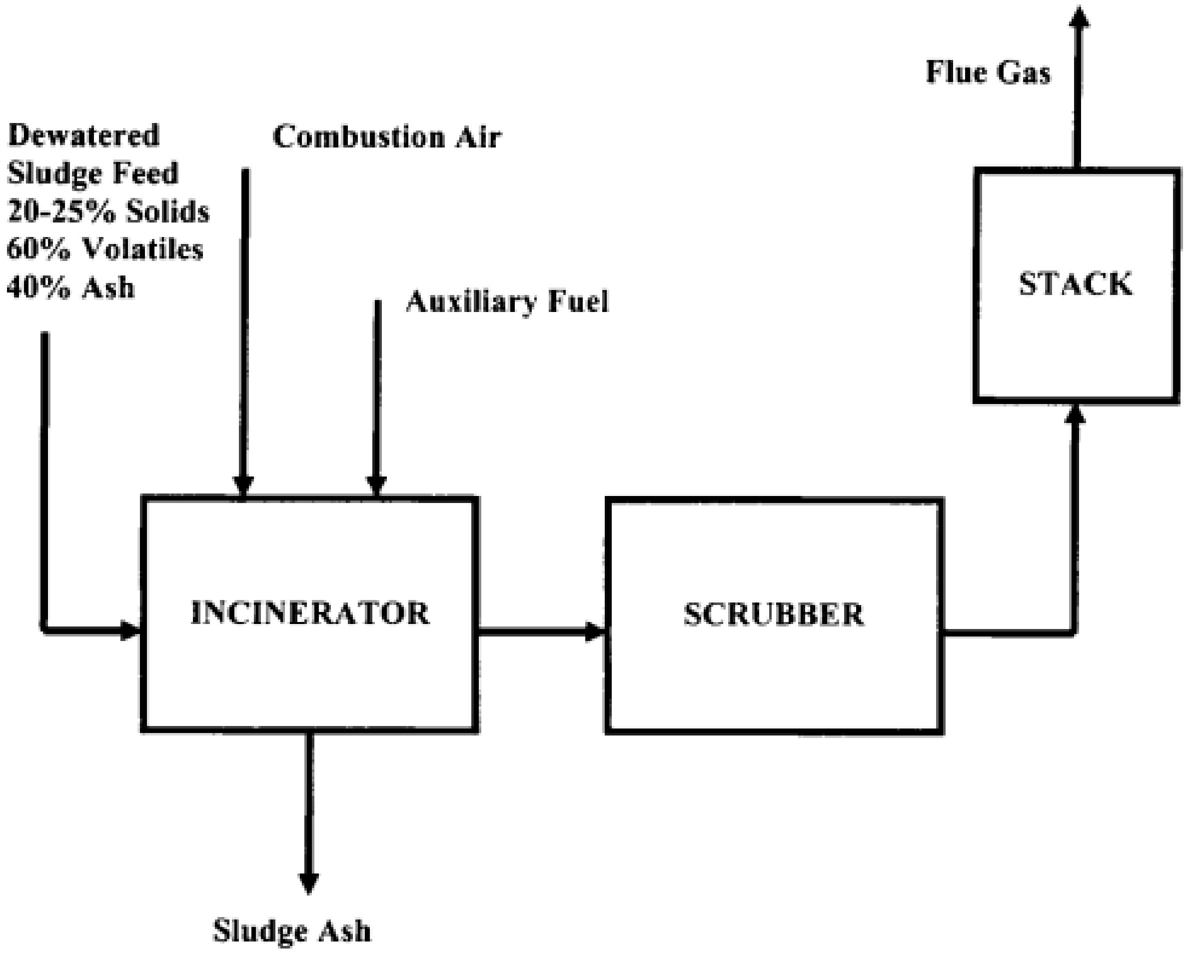
Figure 4.2 Li and Yang's method for panel disassembly.

4.3. Community Economic Development

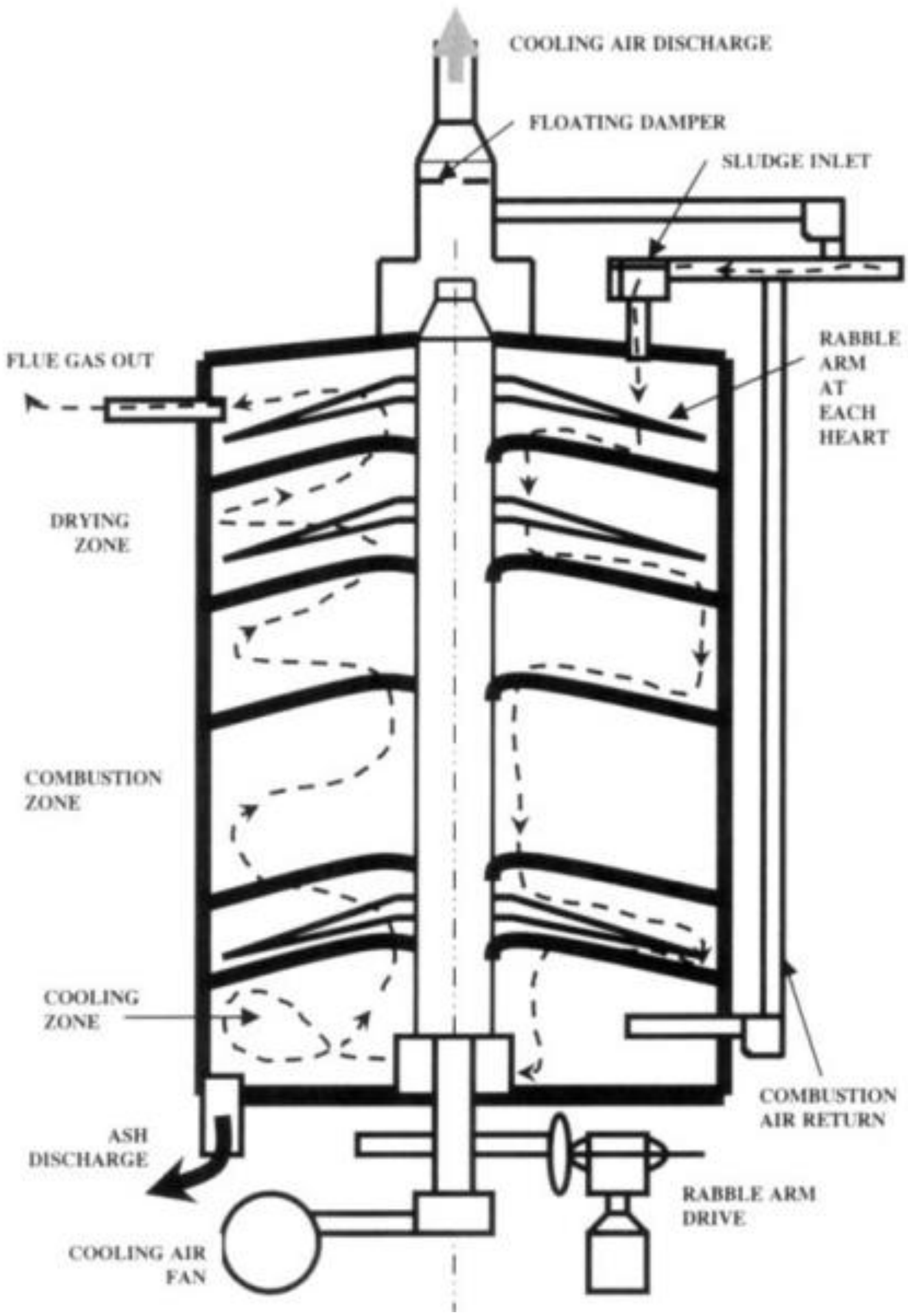
The part of today's economy and its forward movement is totally now becoming a part of waste management, such a folding product of household and business strategy. Another term reveals that economic implication of any waste production always relies on its productivity and how is it be used for different expenditures.

Many decisions over the waste management impact the profitable development. The benefits always over pressure in the firming cost and it tries to reduce the overall other cost with improvement in productivity. The reducing way of waste material is improved by the productivity in developing the raw materials from different sources and by recycling the materials is some insomanistic way. An equal level of optimising for the management of waste arises in some level but if some public bodies like govt. spends authorities to waste collection from different sources and rely them to manage all this in some technical skills then waste could be a community wealth.

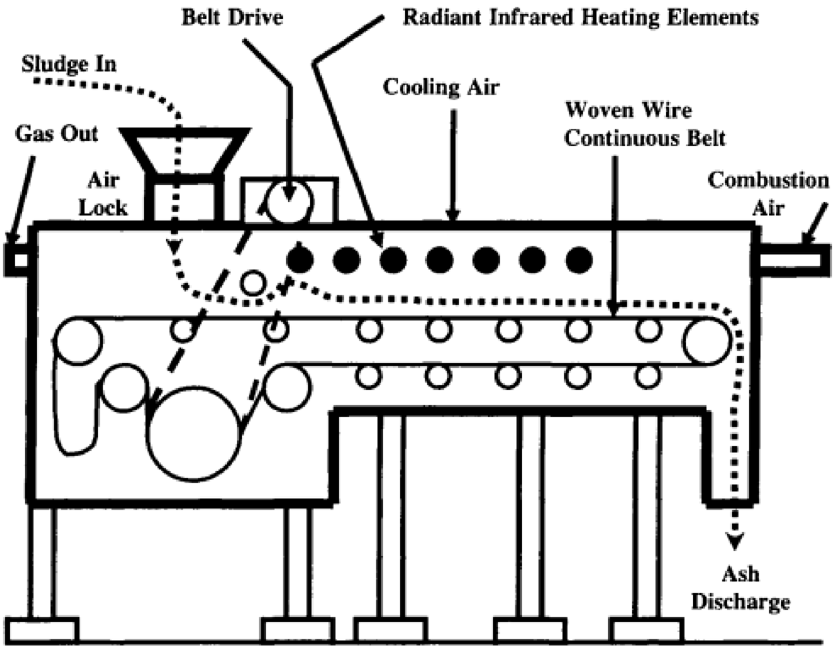
Applying the effective heat transfer of a heating medium in an external-heating rotary kiln, waste polyethylene was gasified in the coprocessing with asbestos-containing waste building material. The resulting flammable gas was used as fuel for a heating gas to melt asbestos(Figure 6).In asbestos removal works, waste polyethylene generates as protective clothing and shielding curtain Addition of a flux to asbestos-containing demolition wastes makes the melting range of asbestos at 800 to 900 °C. At the similar temperature range, polyethylene was readily converted into a mixture of hydrogen, methane, ethylene and other hydrocarbons. The gaseous products were supplied to a furnace to generate heating gas for the pyrolyzer of the asbestos melting system.



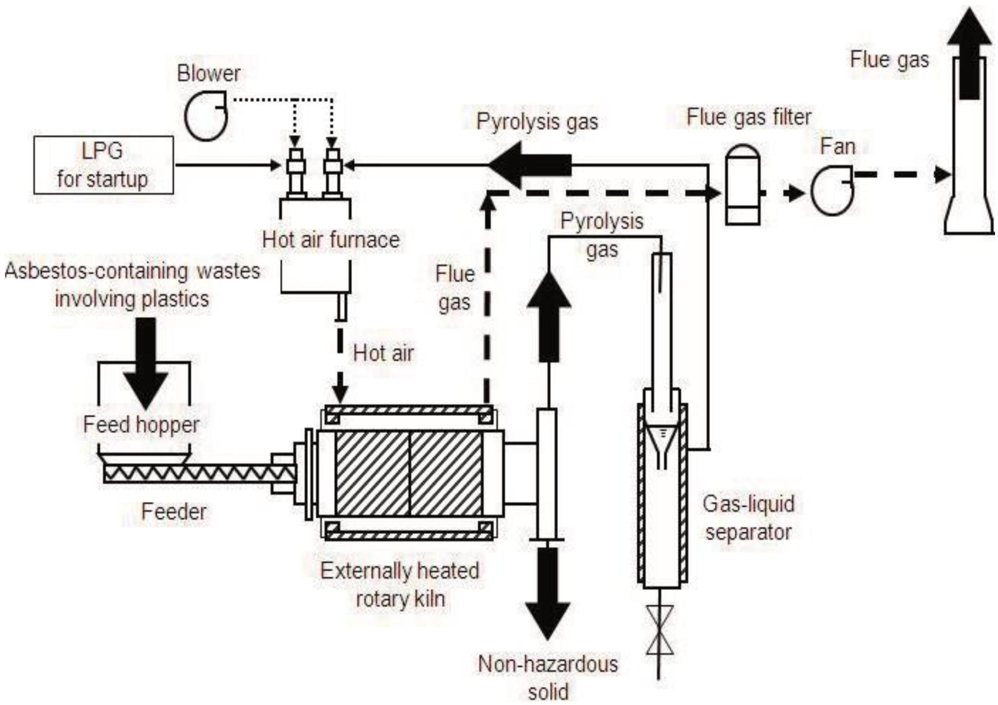
(a) Sludge incineration process



(b) Multiple hearth incinerator



(c) Electric arc furnace



(d) Gaseous fuel production from waste polyethylene in the coprocessing with asbestos containing demolition wastes

Figure 4.3 Waste management process

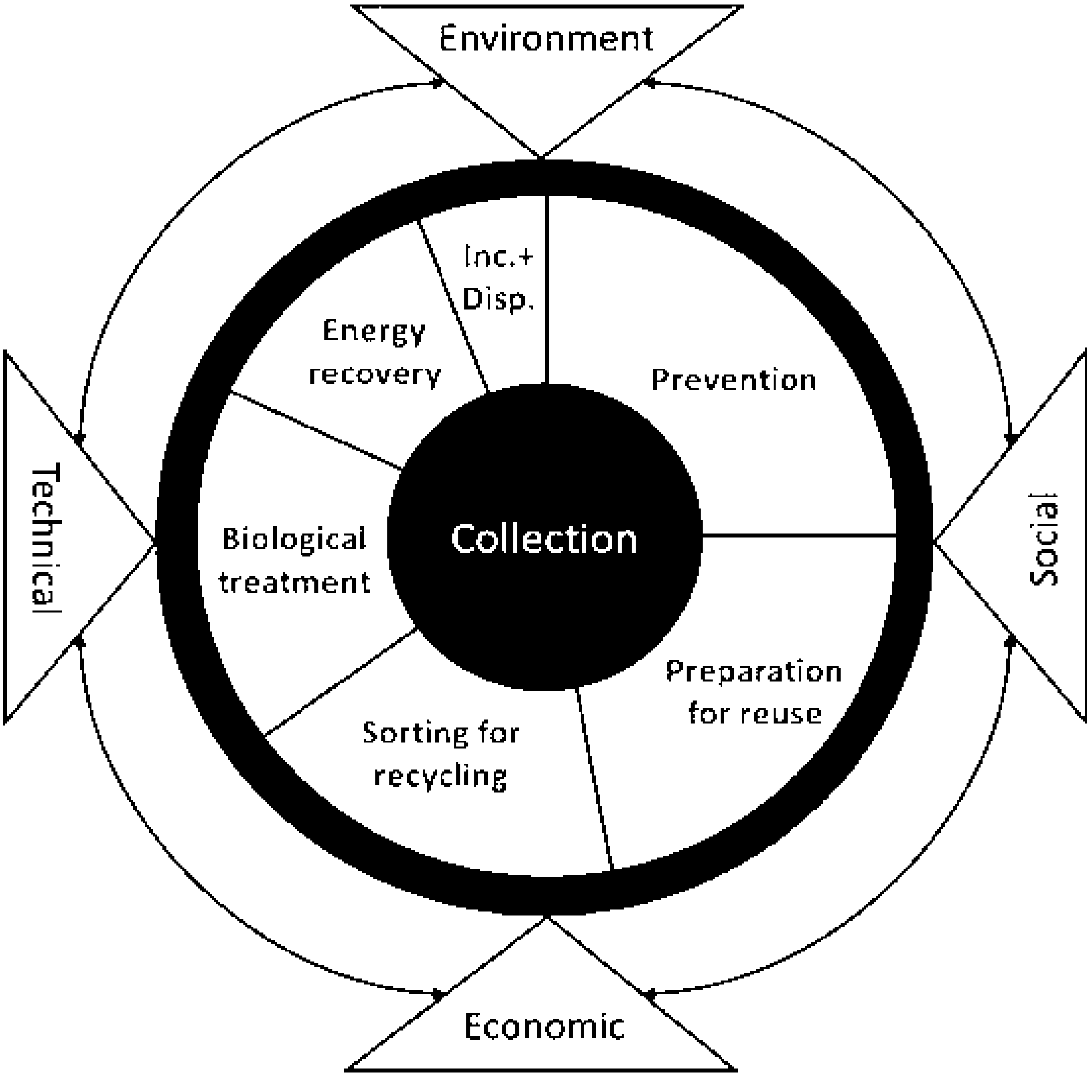


Figure 4.4 Integrated waste collection

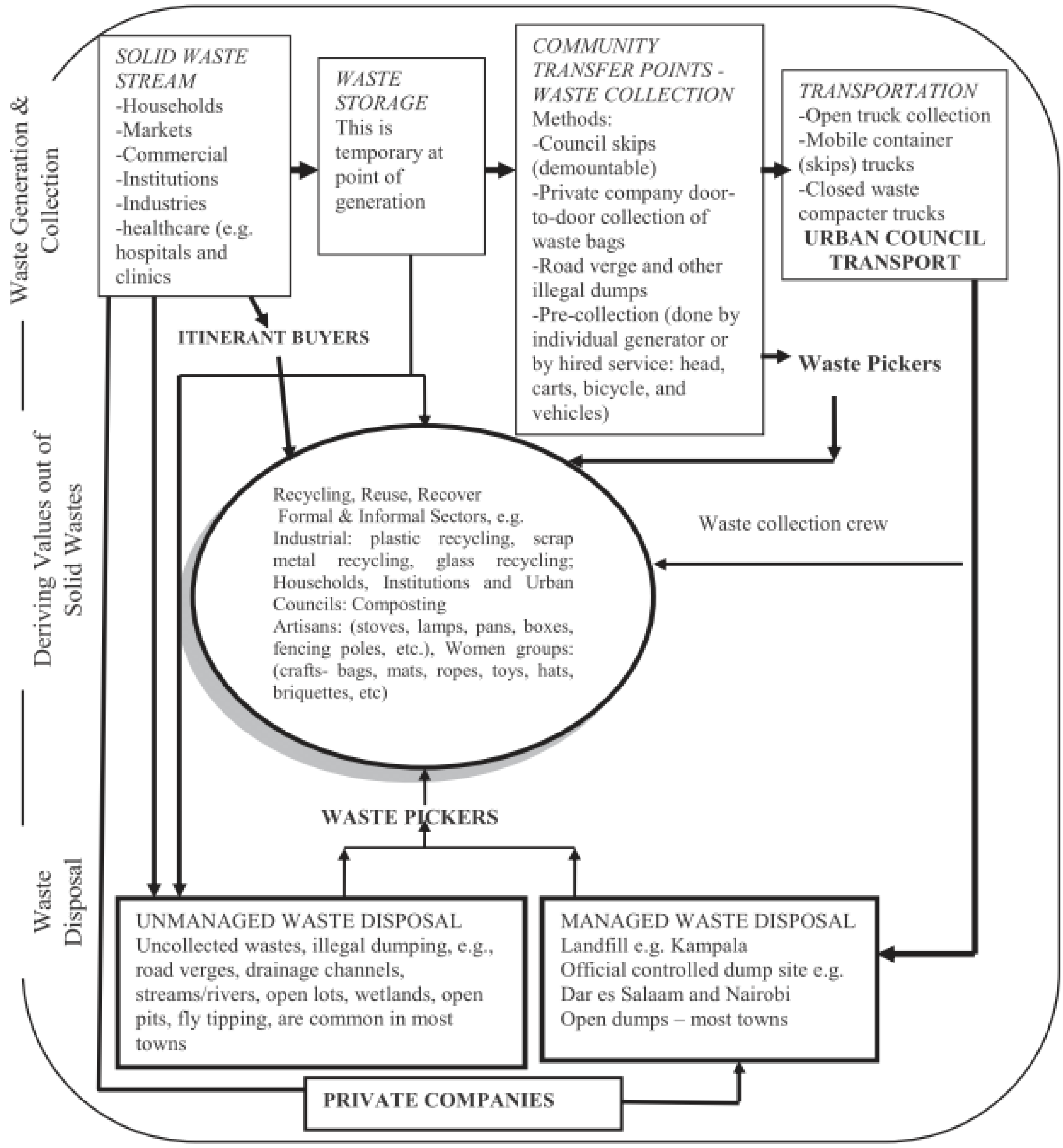


Figure 4.5 Urban waste management

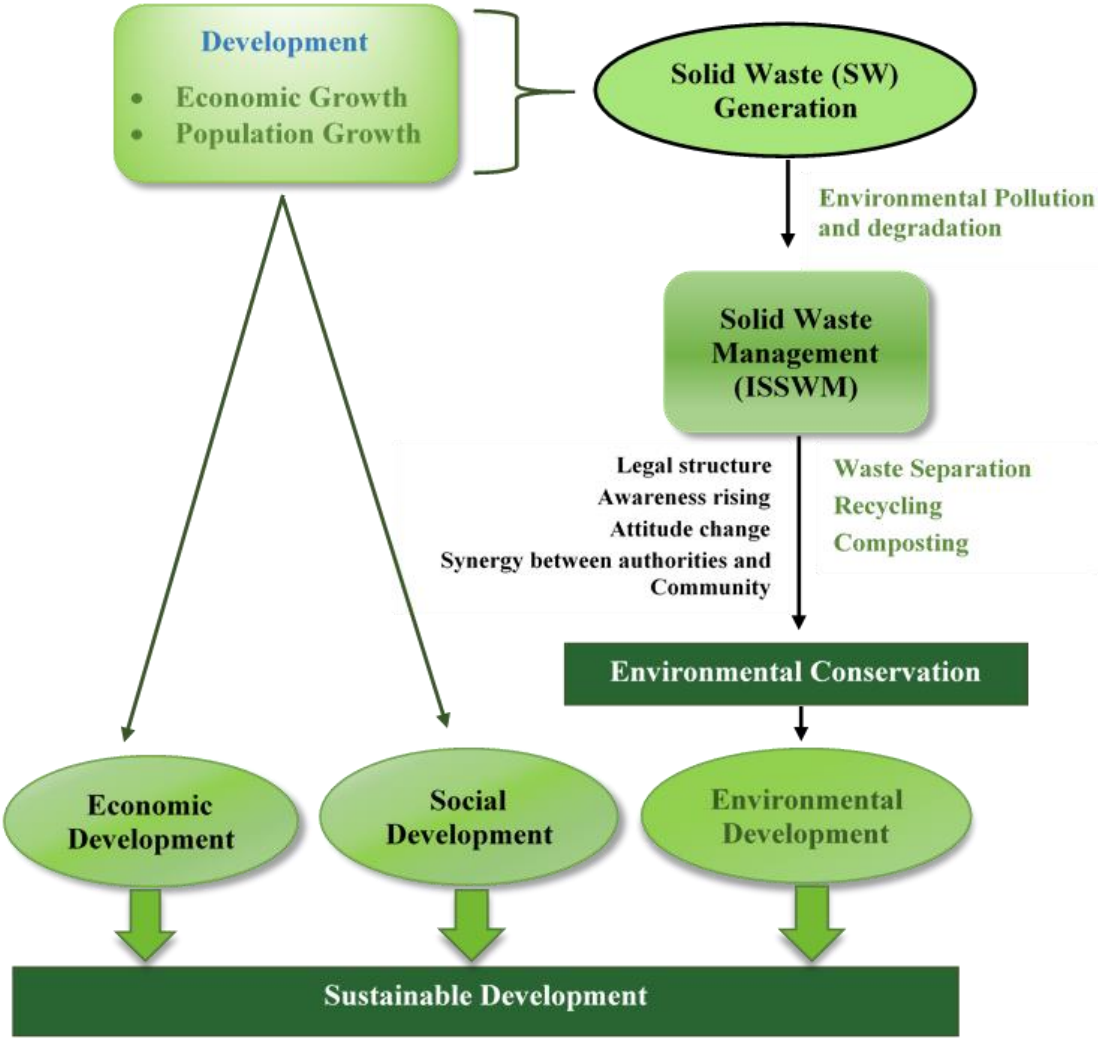


Figure 4.6 Flowchart for sustainable development

Table 4.1 summarizes the hierarchy for policy directives and decisions relative to urban waste.

Level 1	World Summits emit general and universal directives for the advancement of sanitation services
Level 2	National governments structure their pretensions to improve sanitary services in general and urban waste management in particular through legislation
Level 3	Local administrations are faced with the need for applying the national legislation within their geographical area of responsibility by way of detailing it and defining specific procedures of operation with precise timeframes
Level 4	The community at large is expected to obey the established local procedure, supported by private reverse logistics facilities

4.4. Decentralized Waste Banks

The main aim behind the centralized waste bank is to find a result how to lower the waste material from the waste banks. The present situation for the waste habit can be profoundly changing in some of the advantage modes. They are detailed below

- Actually,waste bank can be profound change in waste storing habit and can be classified in different zones.
- By sharing some economic caring, waste could be source of money for wasters and demote.
- Waste has to be collected more rather than throwing away.
- The used to be waste have to be separate in waste bank and need to sell at point.
- The value of waste material has to be high before not getting in contaminated.

Mainly 3 'R's application of waste material is i.e. reduced, reuse and recycle is the waste management model for the further application of waste design and waste demonization. So, for having a clean and green planet thesis need to be followed strictly-

- Greener is cleaner as this will no more produce any unwanted waste.
- Simply logistical in management.
- In any neighbouring situation, compost is easily sold.
- Avoid the GHG (Green House Gas) to be from in landfills.
- Largely recovering waste material operates low-cost separation.
- In proper damping site, low volume needs for disposal.

In real, no need for limit in waste bank is feasible as the whole area have to be properly developed for the community wise development.

4.5. Trash and Garbage Banks

To do reduce of any waste people generally goes for waste bank. The activity of the waste through the establishment of garbage bank and damping it for the trash bank is a very breakthrough operation, as people need to save the money in terms of different exchangeable manner. The main objective of in this research is to find the inhibiting issues and the development of impetus modules for targeting the waste bank covering entire need. The waste behaviour and its community participation along with understanding and motivation have to be lightened through different study and to process it we need waste management bank's trashing and garaging centre.

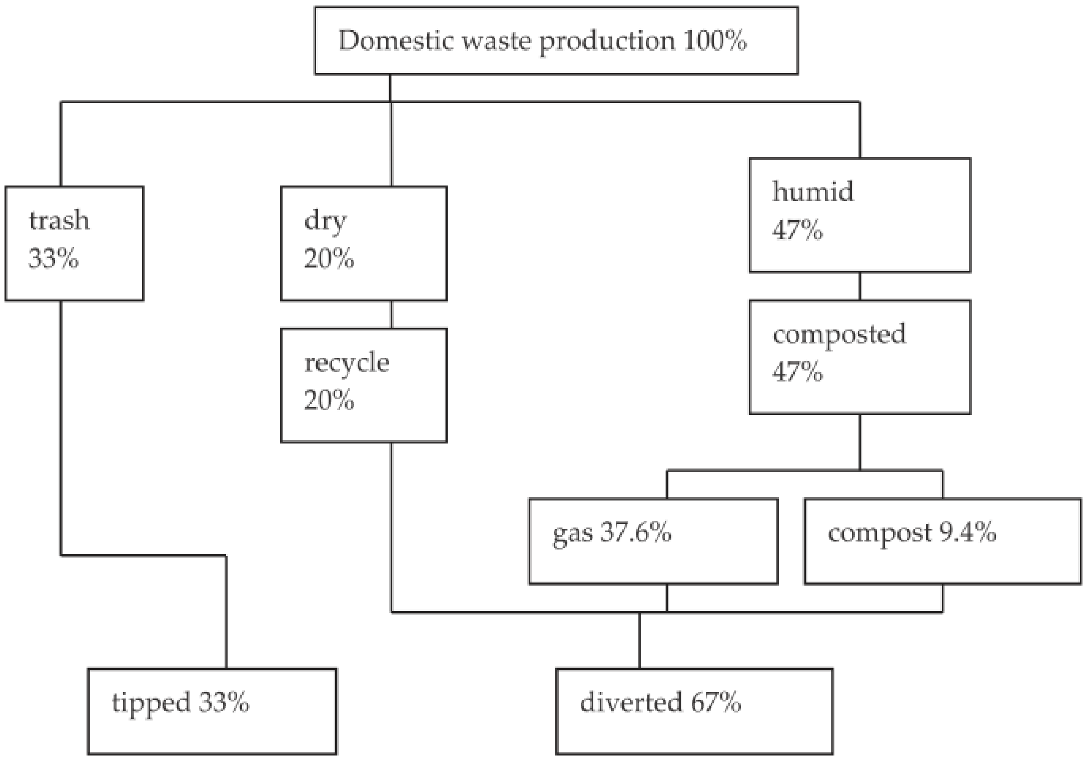


Figure 4.7 Management model for sorted waste

Table 4.2 Wastes from different source

Industry	Wastes produced
Chemical manufacturing	Spent solvents and still bottoms White spirits, kerosene, benzene, xylene, ethyl benzene, toluene, isopropanol, toluene diisocyanate, ethanol, acetone, methyl ethyl ketone, tetrahydrofuran, methylene chloride, 1,1,1-trichloroethane, trichloroethylene Ignitable wastes not otherwise specified (NOS) Strong acid/alkaline wastes Ammonium hydroxide, hydrobromic acid, hydrochloric acid, potassium hydroxide, nitric acid, sulfuric acid, chromic acid, phosphoric acid Other reactive wastes Sodium permanganate, organic peroxides, sodium perchlorate,

	potassium perchlorate, potassium permanganate, hypochlorite, potassium sulfide, sodium sulfide Emission control dusts and sludges Spent catalysts Ignitable paint wastes Ethylene dichloride, benzene, toluene, ethyl benzene, methyl isobutyl ketone, methyl ethyl ketone, chlorobenzene Ignitable wastes not otherwise specified (NOS)
Construction	Spent solvents Methyl chloride, carbon tetrachloride, trichlorotrifluoroethane, toluene, xylene, kerosene, mineral spirits, acetone Strong acid/alkaline wastes Ammonium hydroxide, hydrobromic acid, hydrochloric acid, hydrofluoric acid, nitric acid, phosphoric acid, potassium hydroxide, sodium hydroxide, sulfuric acid
Metal manufacturing	Spent solvents and solvent still bottoms Tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, toluene, benzene, trichlorofluoroethane, chloroform, trichlorofluoromethane, acetone, dichlorobenzene, xylene, kerosene, white spirits, butyl alcohol Strong acid/alkaline wastes Ammonium hydroxide, hydrobromic acid, hydrochloric acid, hydrofluoric acid, nitric acid, phosphoric acid, nitrates, potassium hydroxide, sodium hydroxide, sulfuric acid, perchloric acid, acetic acid Spent plating wastes Heavy metal wastewater sludges

	Cyanide wastes Ignitable wastes not otherwise specified (NOS) Other reactive wastes Acetyl chloride, chromic acid, sulfides, hypochlorites, organic peroxides, perchlorates, permanganates Used oils
Paper industry	Halogenated solvents Carbon tetrachloride, methylene chloride, tetrachloroethylene, trichloroethylene, 1,1,1,-trichloroethane, mixed spent halogenated solvents

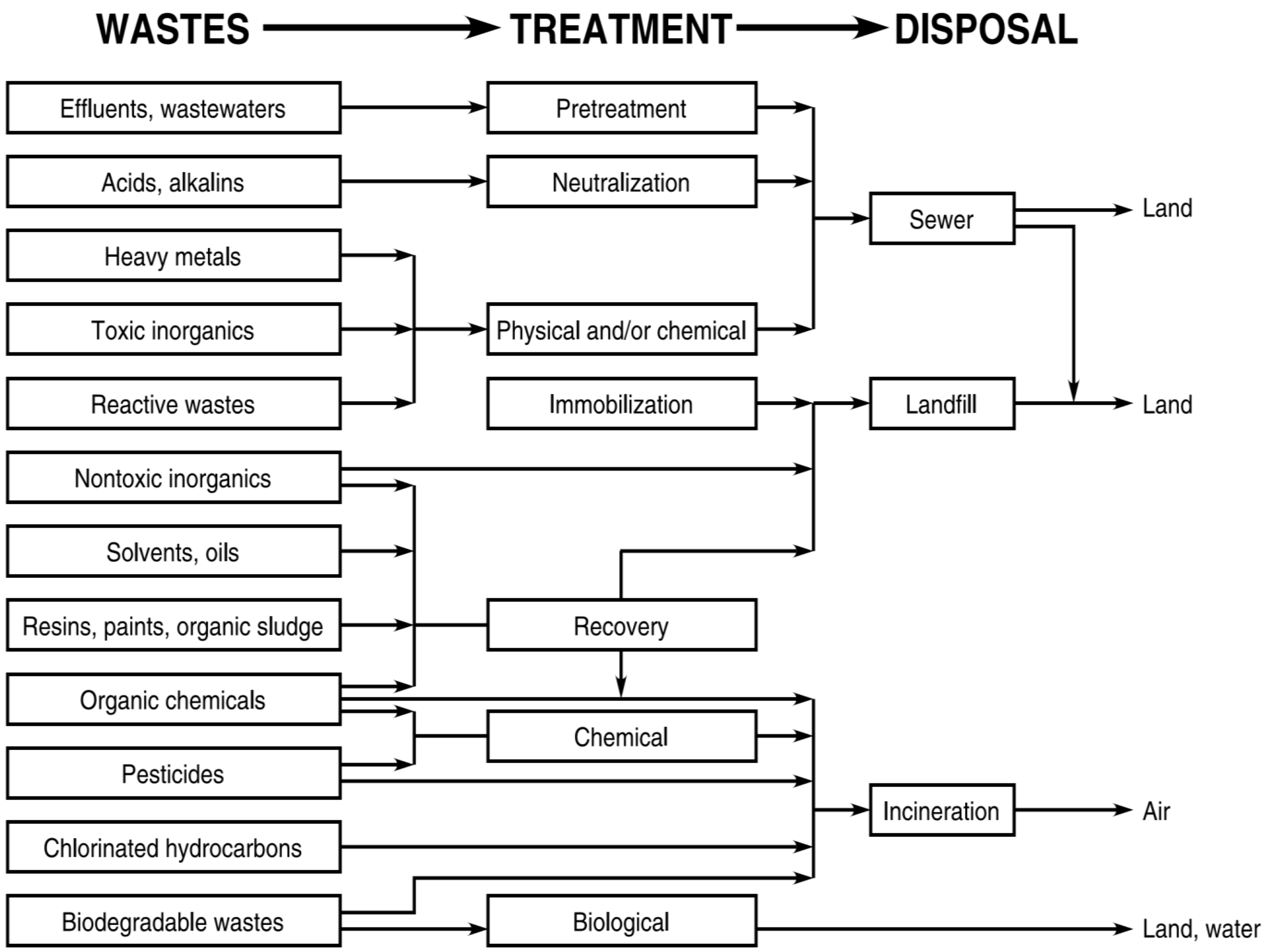


Figure 4.8 Treatment and disposal alternative for industrial waste

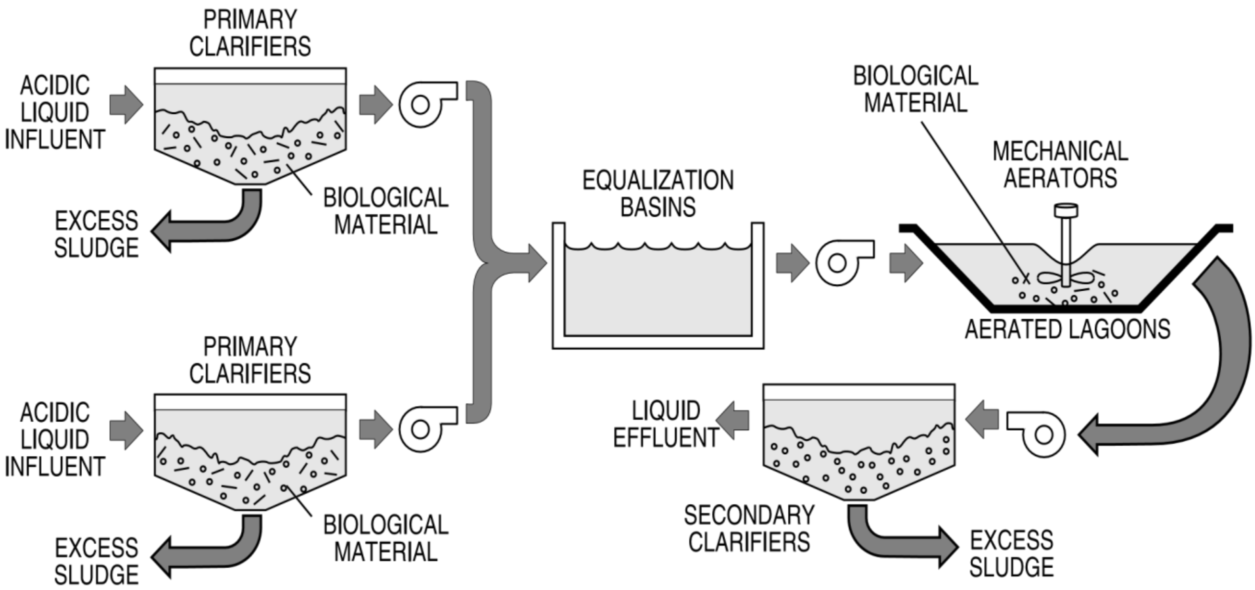


Figure 4.9 Biological treatment of industrial waste

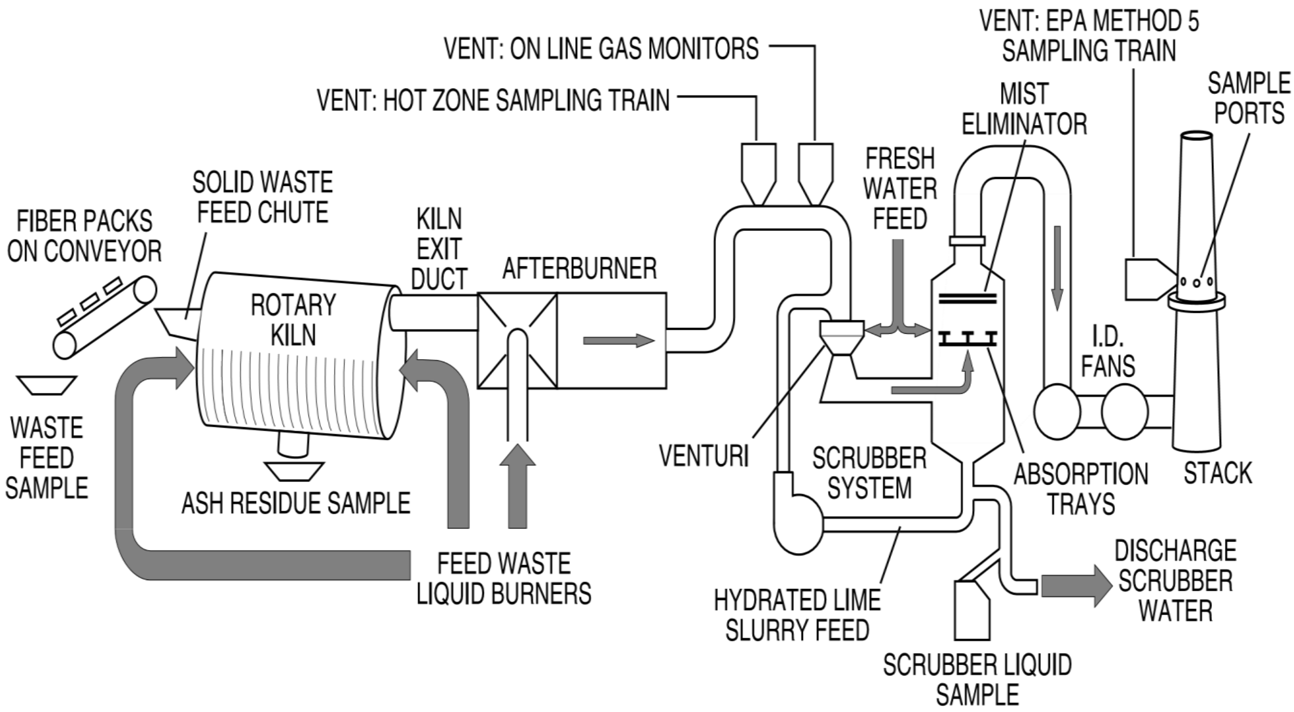


Figure 4.10 Rotary kiln incinerator

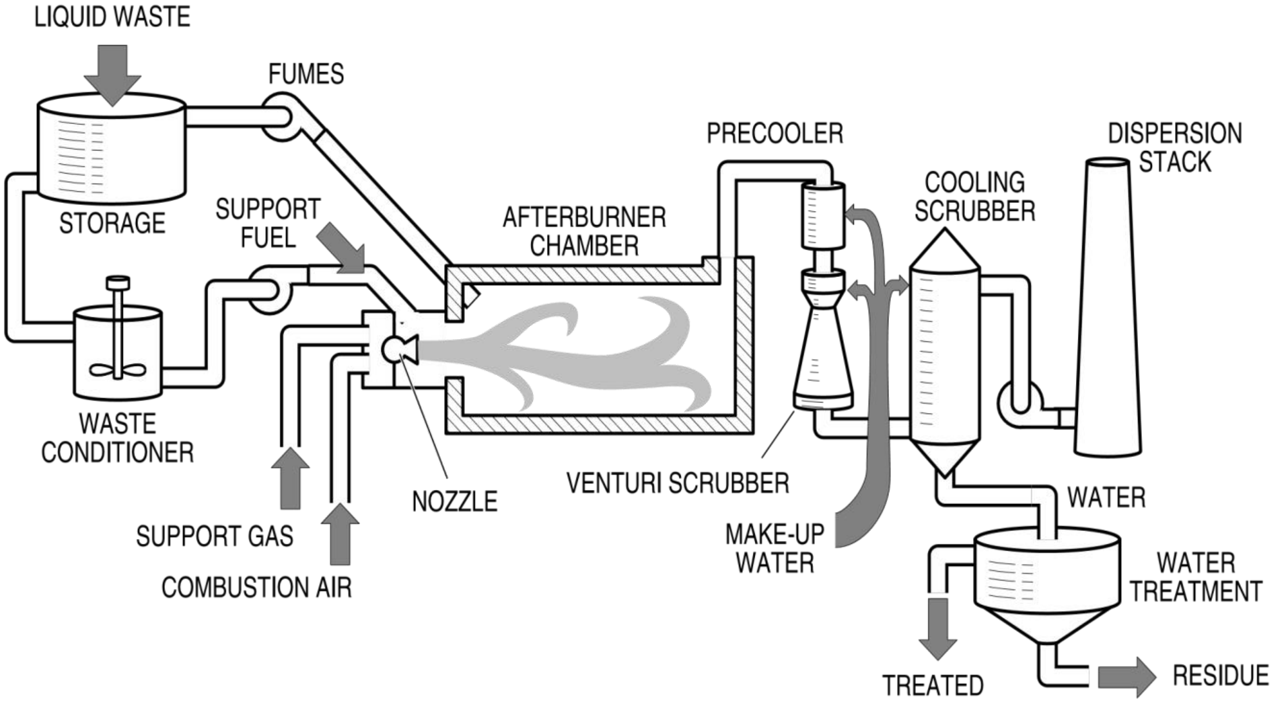


Figure 4.11 Liquid injection incinerator

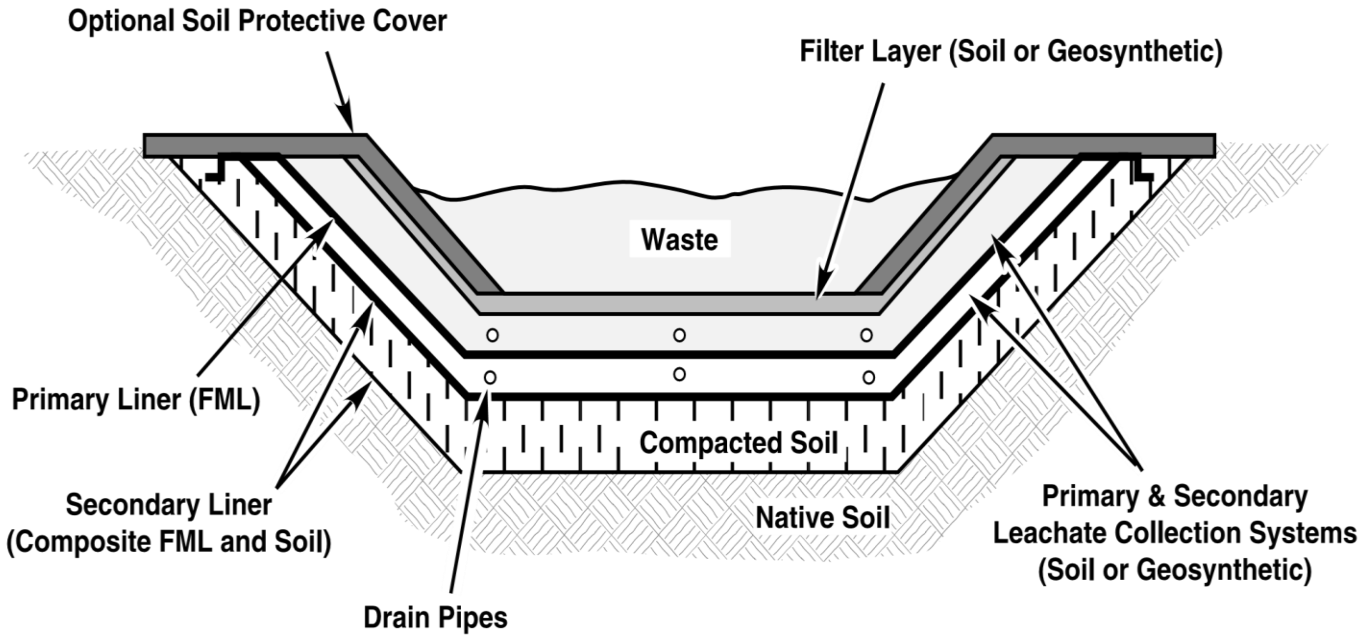


Figure 4.12 Cross-section of a secure landfill double-linear system

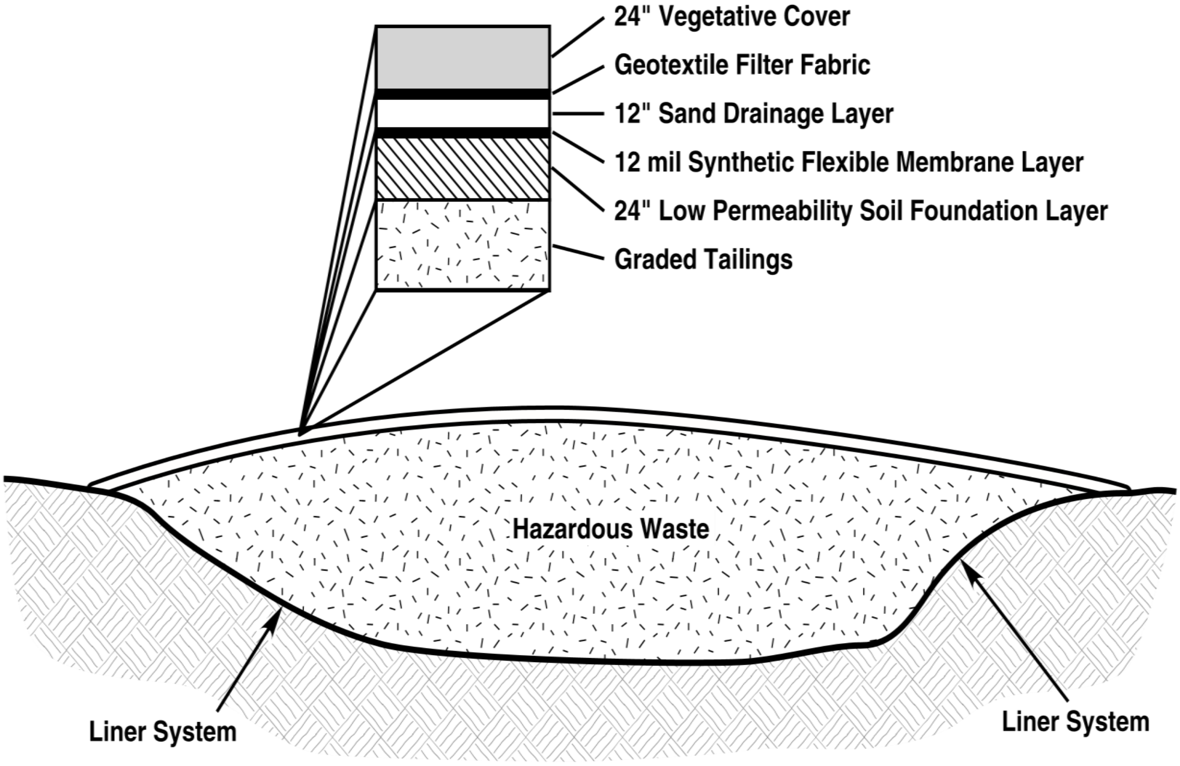


Figure 4.13 Land disposal site cap designed for maximum resistance of infiltration

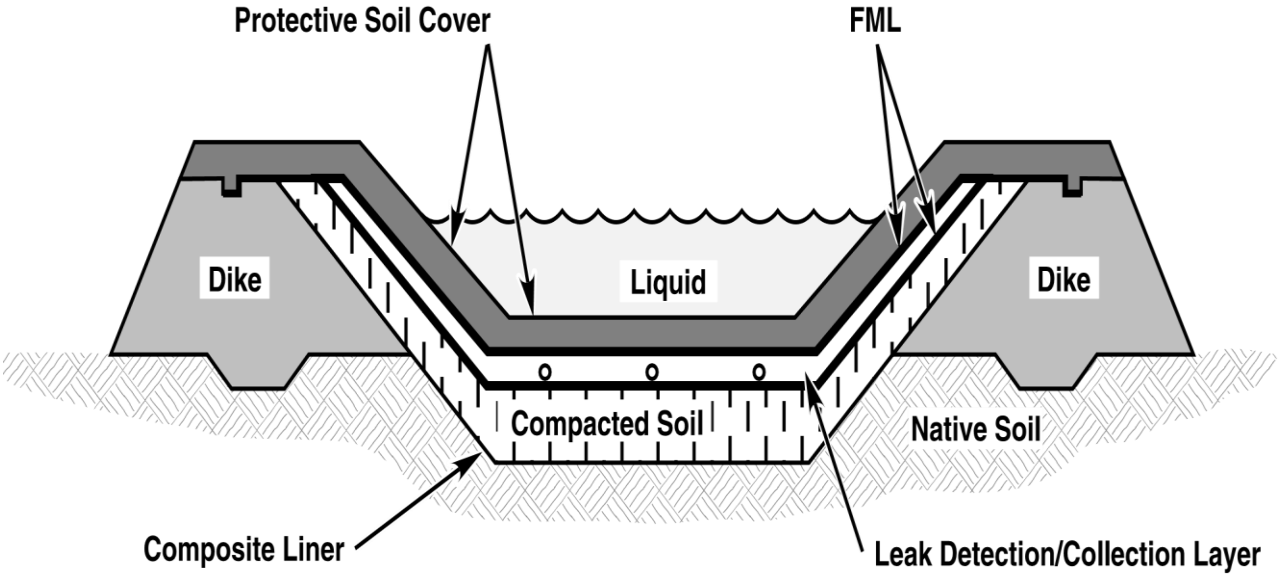


Figure 4.14 Cross-section of a liquid waste impoundment double-liner system

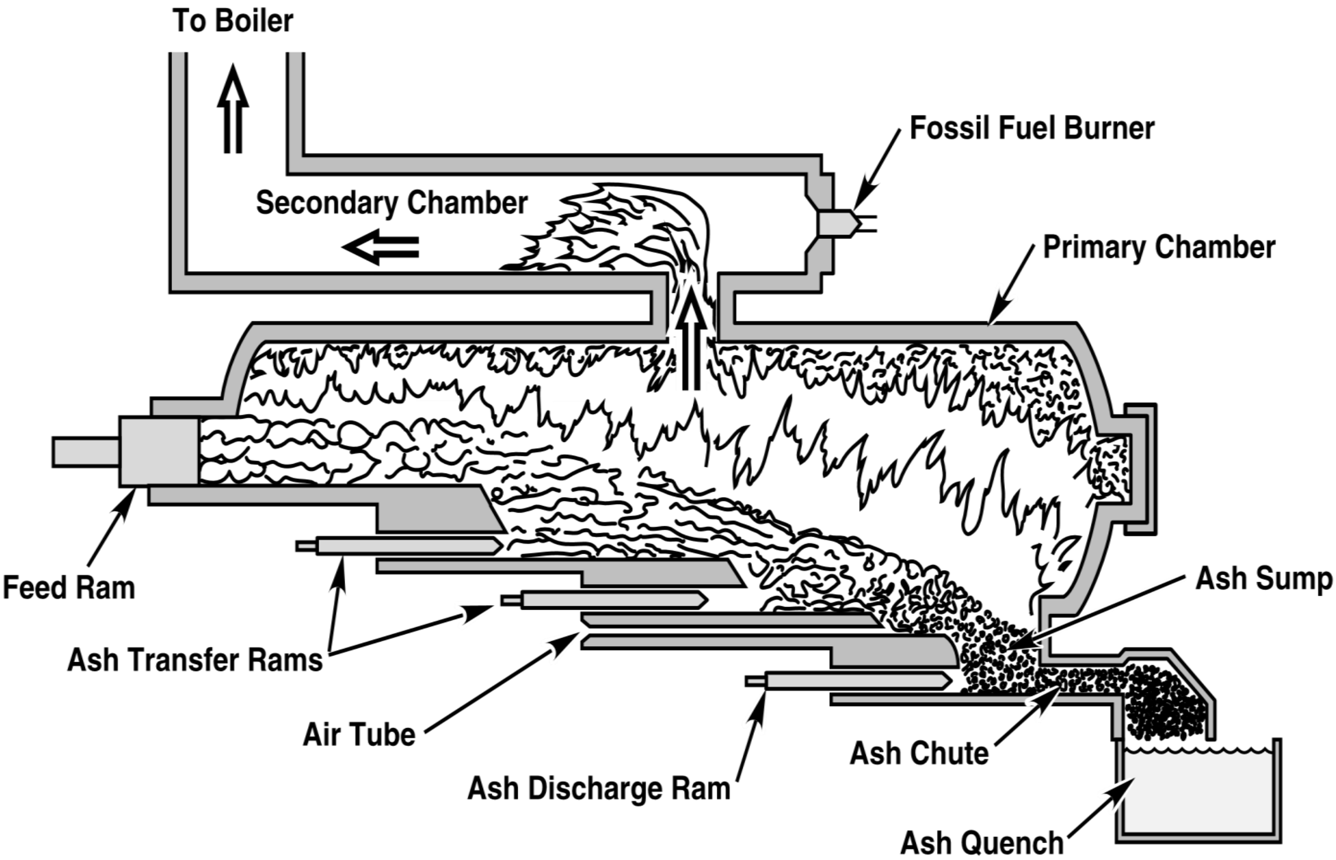


Figure 4.15 Cross-section of an incinerator for infectious waste

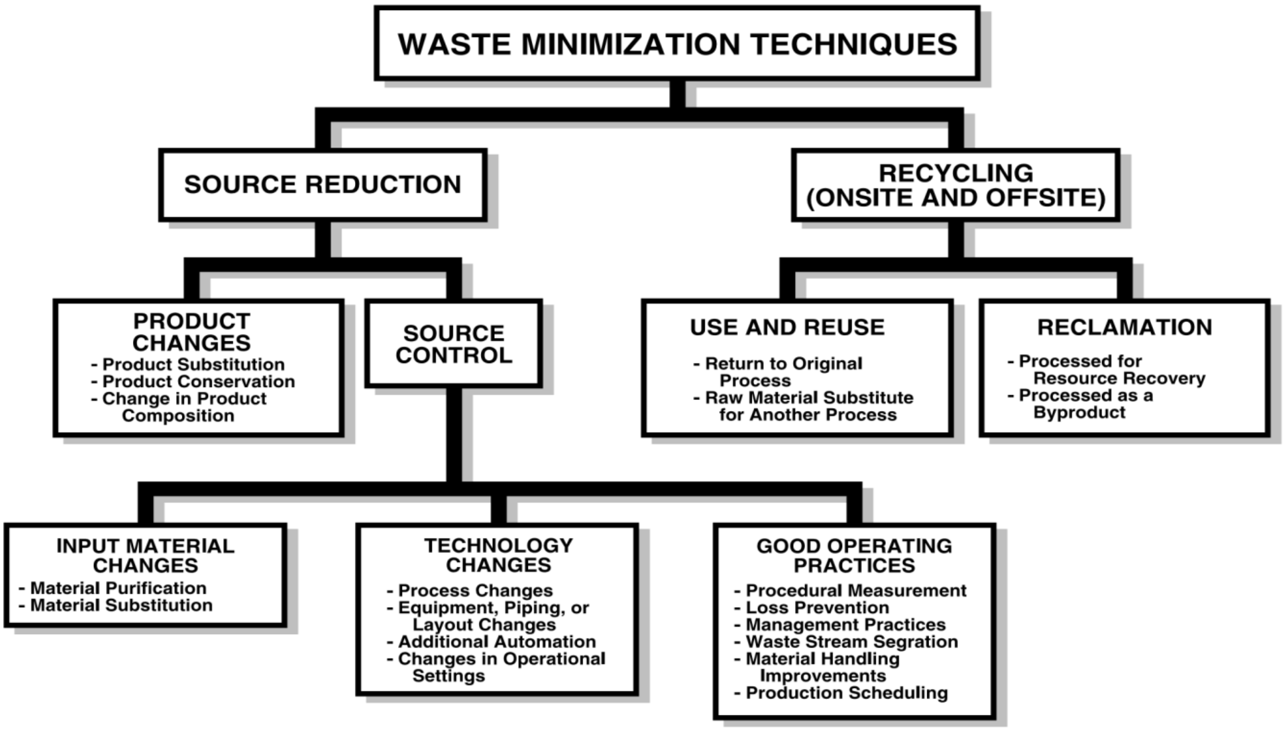


Figure 4.16 Waste minimization techniques

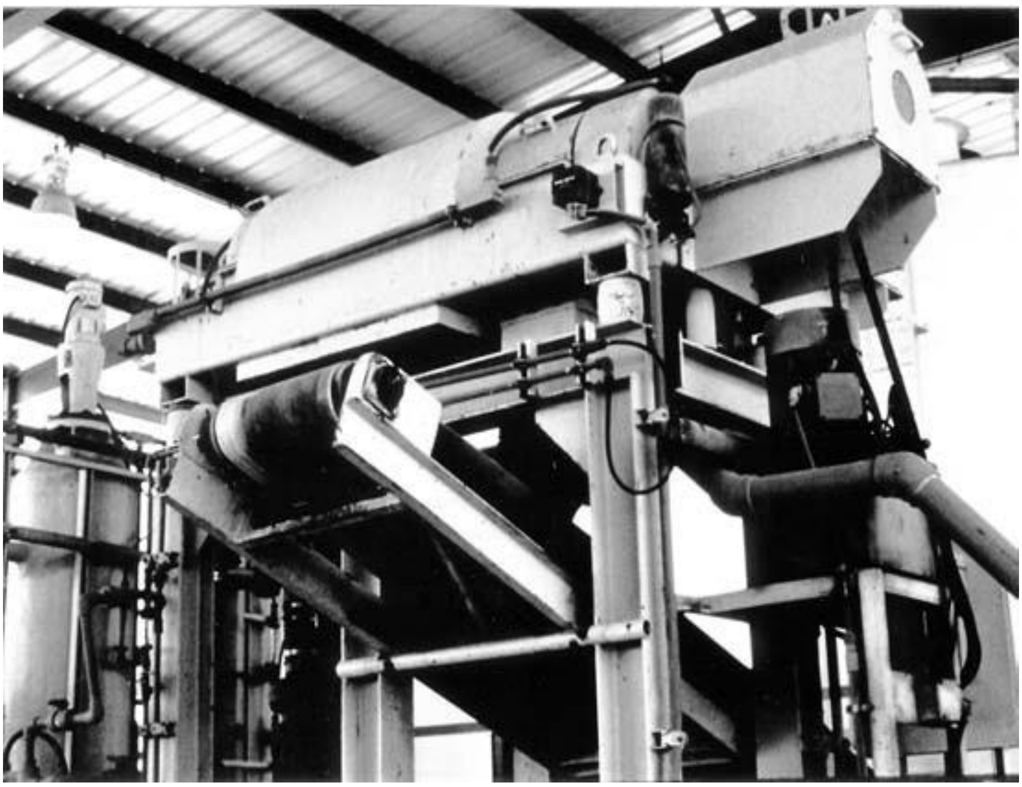


Figure 4.17 Centrifuge. Component of a hazardous waste solidification system.

Figure 4.18Gravity separation cones. (From ROMIC Chemical Corporation, 2081 Bay Road, Palo Alto, CA 94303. With permission.)

The exploratory search in this qualitative and quantitative approach implements the different need in this field and hence we have to do data surveying in depth need. Data collection process in this need is very important as different purposive sampling is issued. Mainly result oriented active waste banks in the community is motivated by other different community as the other community member have to be motivated in this field of research.

Existing garbage have to be develop in the sustaining way and the society needs to be support in this provision. Various progress and parties have to denote this entire trashing site and its splashing manner that waste should not in any open manner in open landforms.

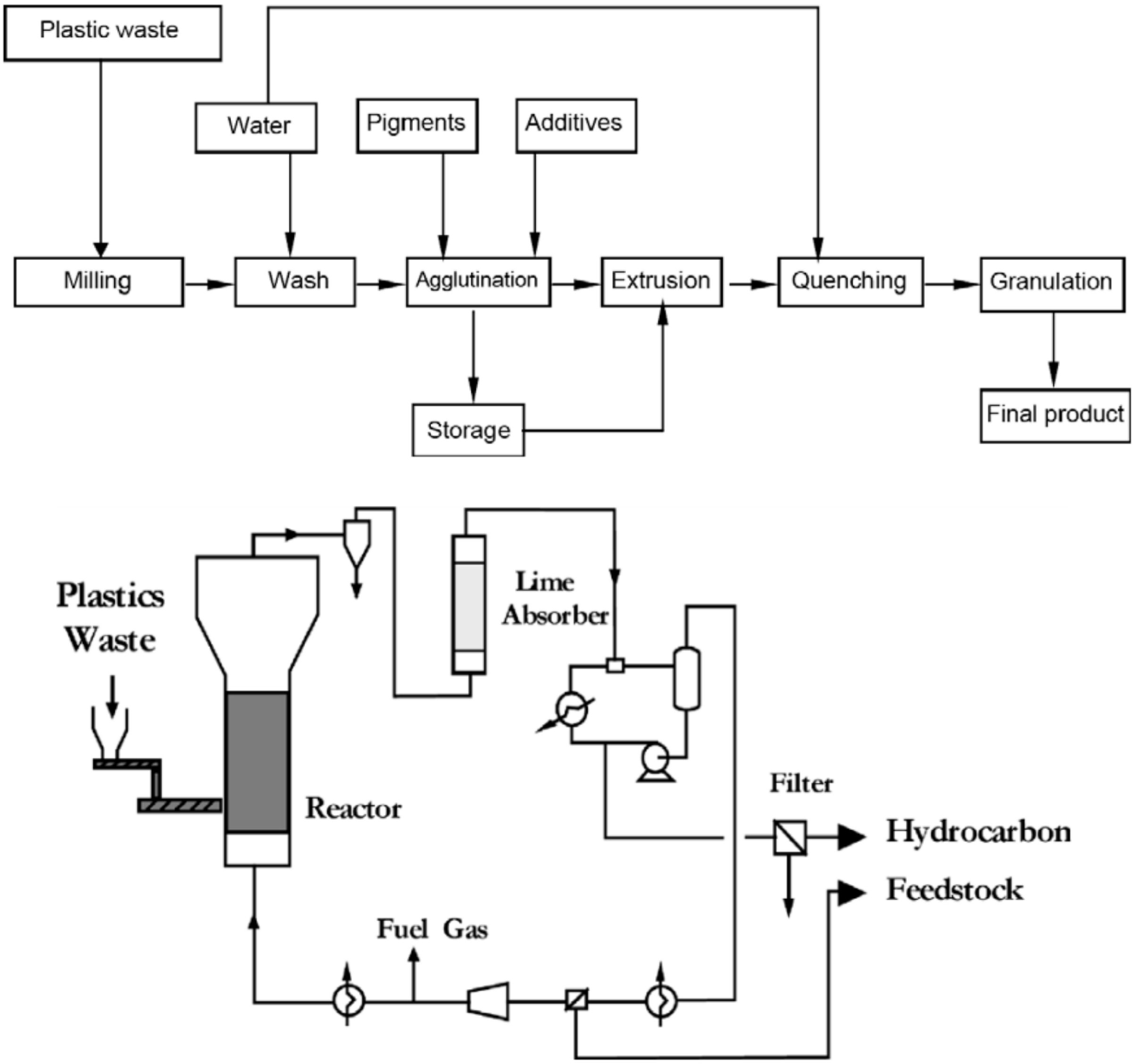


Figure 4.19 Mechanical and chemical recycling steps of plastic waste

Summary

Fourth block reported about waste to wealth though waste banks. Also, it detailed community-based waste management, local economic development and community based economic development though banks. As can be seen from the above waste collection methods and reusing strategies, waste problem can be managed, and also local economy is improved. Management thought decentralized waste banks are discussed. Trash and garbage banks, method of collection, process and recycling with the support of firms are detailed in this block.

Activity

- Prepare caselets for community-based management (2 Pages)
- Prepare caselets for community economic development though waste banks (2 Pages)
- Report possible ways of local economic development through wastes (2 Pages)
- Prepare caselets for decentralized waste banks, trash and garbage banks (2 Pages)

Review questions

- Explain following
  - Community based waste management
  - Community economic development through waste banks
  - Local economic development though waste banks
- What is mean by decentralised waste banks?
- State the importance trash and garbage banks?

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Chapter 5 Strategies and Precautions

Introduction

The waste management strategy has developed rapidly in last few decades due to needs in urbanization development and rapid waste generation. The main issue overwhelming in solid waste management is a challenging task in different areas of the people. Mainly in India, around 42 million tons of waste products generated yearly. And this annual increase is increasing at a rate of 5% per year which is mainly a great task to overcome and to need to take this in pilot basis. Possible strategies and precautions on waste management banks are discussed in this block. this block detailed leadership management and incentives, household waste management in Indian scenario, safety equipment for waste handlers and schemes for sustainable waste management.

Objective

To study the strategies and precautions followed for an effective waste bank

5.1. Leadership Management and Incentives

Leader is the head for any movement may it is static or dynamic. Here also,in this case, to move over from the waste management situation, we need some leadership, and this has to manage all well for incentive and identical development. The important and how it could be developed for a public issue is the main reason to be analysed. Some stratification like a leader has to do for waste hazard movement in different field and have to file it in top priority.

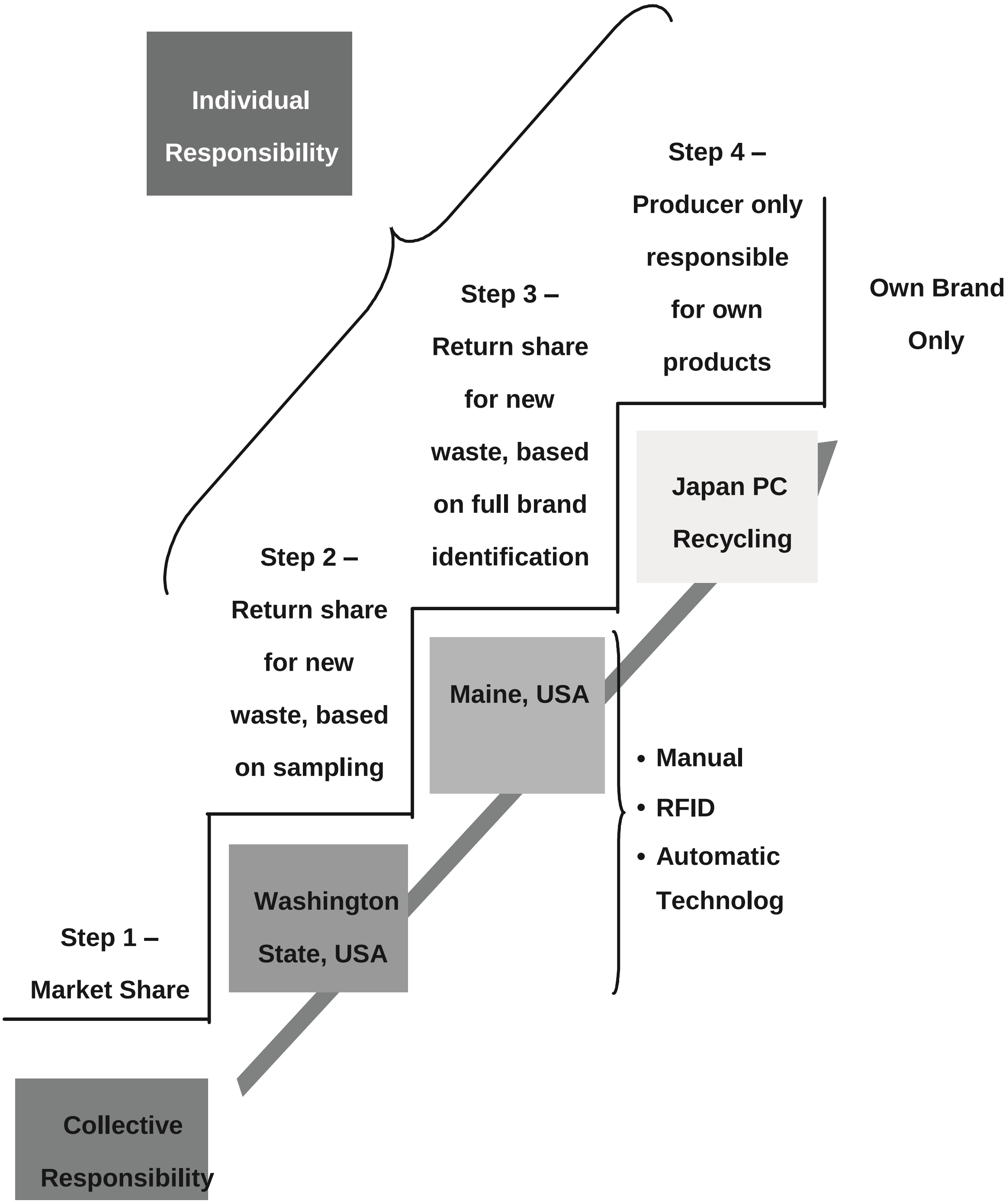
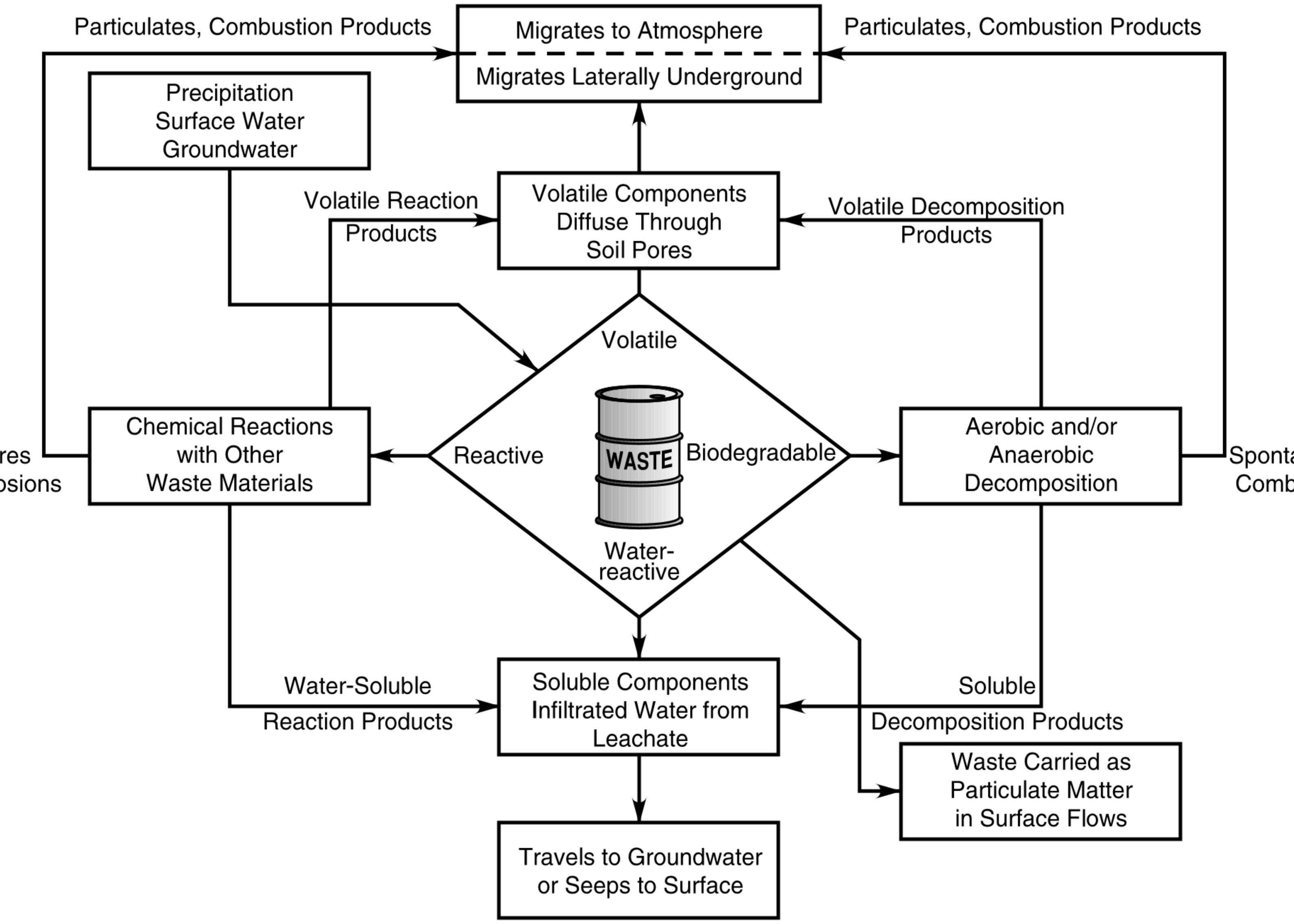


Figure 5.1 A phased approach to the implementation of individual producer responsibility.

Figure 5.2 Initial transport process at waste disposal sites



- Improving solid waste service delivery and fee collection

For the lower income and developing country, mainly public figures have to increase the waste delivery services, and this can be utilised in some other sections like to provide some organic services to the poor one. Though this is inappropriate,but this will help the waste collection support for the nationalism issue, and this will lead to a major challenge. This movement will also help to jump and start waste fragile service and conflict over the situations. This will be done if any private sector leadership strategies come for earthy interest and have to find some public support.

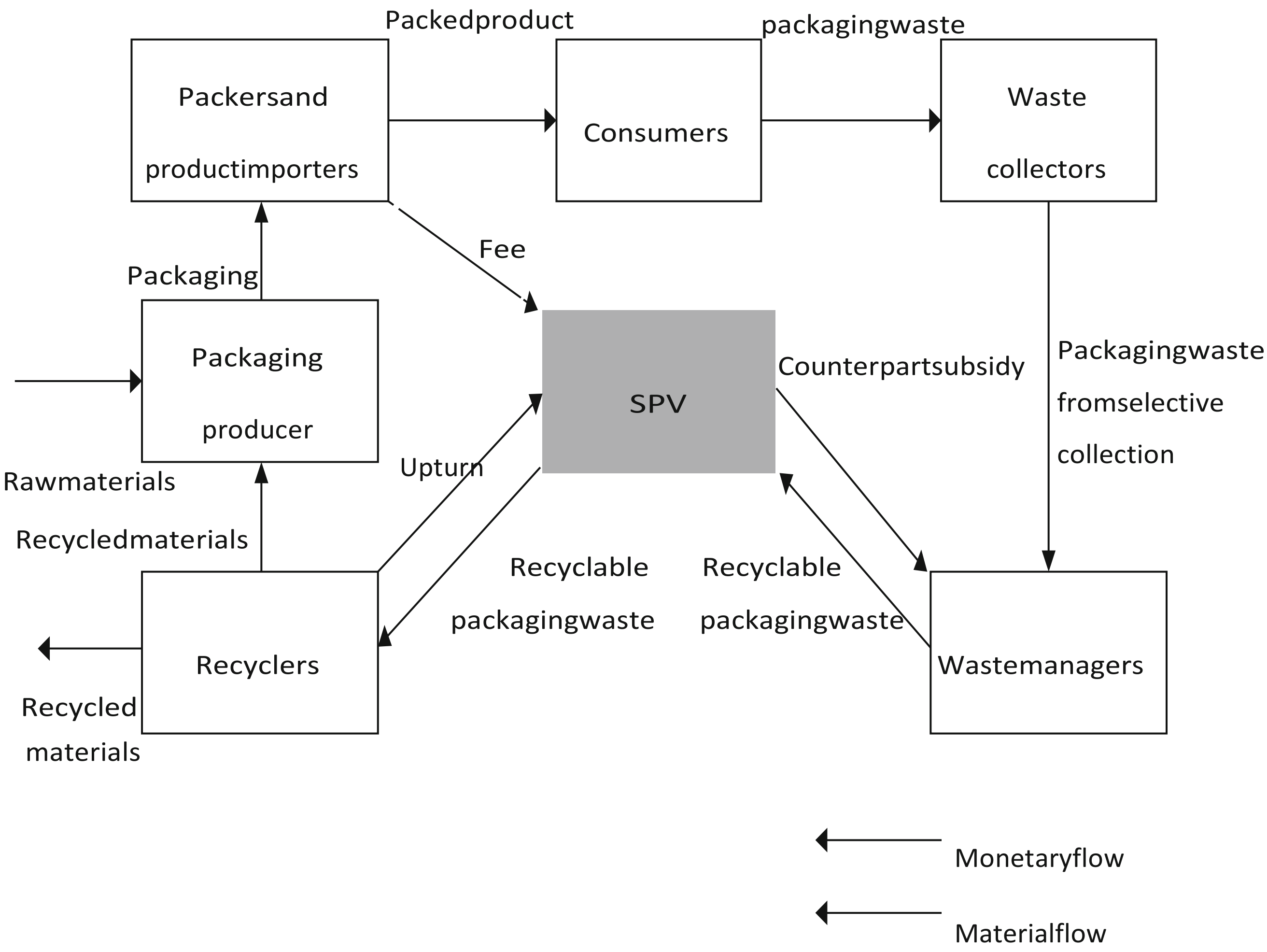


Figure 5.3The extended producer responsibility scheme

- Developing waste collection and waste transportation served community

Mainly focusing on the most relevant issues like to develop the developing county, this aims to improve the services to be served in waste management field and how communities within an area are accessing the benefit of this services. Some this kind of project will design community development from slummy to cleaner movement. A result-based work in financing and technological development would help in improving the movement of solid waste. This is not a universal worthy panacea, but rather this will be the most effective and most helpful investments for the fourth side development of earth.

There are some rules and govt. introduce regulations which can be very effectively ruled for waste management development. The following regulations are developed for the waste management system for controlling the public effectiveness (*ASHFAQ, AHMAD, and AMNA KHATOON. "Prevention of Environmental Degradation by means of solid waste management." I Control Pollution 29.1 (1970)*) –

- Municipal Solid Waste (Management and Handling Rules) 2000: Rules lay emphasis on seeking participation of citizens in waste segregation, prohibiting littering of garbage, proper storage of waste and efficient transportation of waste for its processing and final disposal.

- Hazardous Waste (Management and Handling Rules) 1989: To put in place an effective mechanism to regulate the generation, collection, storage, transport, treatment and disposal of hazardous wastes both indigenously generated and imported.

- RCRA- Nation's primary laws governing disposal of solid and hazardous waste. Passed on Oct 21, 1976. Hazardous and Solid Waste Amendments to RCRA came in 1984.

- Bio-medical Waste (BMW) (Management and Handling Rules) 1998: Adopted and notified with the objective to stop the indiscriminate disposal of hospital waste/ BMW and ensure that such waste is handled without any adverse effect on human health and environment.

- Recycled Plastics Manufacture and Usage Rules: Notified in 1999, with an amendment in 2003. The objective of rule is to ensure proper collection, segregation, transportation and disposal of plastic waste (Rajput et al., 2009).

Table 5.1 Model to distinguish between individual and collective producer responsibility and individual and collective recycling systems

<table>
<tr><td>Financial responsibility</td><td colspan="3">A: Collective Producer Responsibility:

Based on market share of producers.

E.g. legal requirement within WEEE Directive for historic waste.</td><td colspan="3">B: Individual Producer Responsibility:

Based on amount of producer’s products returned for recycling.

E.g. legal requirement within WEEE Directive for future waste; legal requirement within Maine and Washington legislation.</td></tr>
<tr><td rowspan="2">Recycling system</td><td rowspan="2">A1: Non competitive

Monopolistic schemes

E.g. Sweden, the Netherlands, Belgium, Switzerland</td><td colspan="2">Competitive:

E.g. Germany, the UK, France</td><td rowspan="2">B1: Non competitive

Monopolistic schemes

E.g. ICT Milieu 1999–2002</td><td colspan="2">Competitive:

E.g. Japan</td></tr>
<tr><td>A2: Collective recycling system

E.g. Compliance schemes such as ERP</td><td>A3: Individual recycling system

E.g. Direct take-back events or systems</td><td>B2: Collective recycling system

E.g. Group A and B compliance schemes</td><td>B3: Individual recycling system

E.g. PC recycling in Japan</td></tr>
</table>

5.2. Household Waste Management-Indian Scenario

In Indian view, industrialization is the most important and significant role for developing its natural nomination and also this helps in to overcome the need toincrease in population. Rapid development of urban areas and growths in industry also leads to the more waste generation. Recently, mainly e-wastes and paper-plastic wastes are also contributing their values in waste banks by consuming areas. Electronic and other goods, material and clothes are the main house hold wastes that are generating the waste field gain. Also wastes may be a potential form of hazard for the human health and also for another livelihood in environment, as they aspects more in natural pollution.

Table 5.2 Waste banks

Solid waste banks	Contribution (%)	Waste characteristics
Domestic (Residential)	52 -80	Major: food wastes. Waste quantity increasing with population increase Minor: paper; plastic; textiles; glass; ceramics; ashes; leather; compound E-waste is emerging as significant wastes Wastes collection by: urban councils; private companies, NGOs and CBOs
Markets	4 -20	Major: vegetable wastes, spoilt fruits; Markets in all (leaves, stalks), Number increasing with population increase Minor: damaged packaging materials- (e.g., sacks, bags,paper, timber) Waste collection: urbancouncils and private
Commercial (excluding markets)	3.7-8	Major: packaging materials; food wastes; Shops, scrap metals in hotels, restaurants, offices, through open pavement trading Minor: glass, hazardous - Mobile open-air traders wastes (e.g. contaminated - Increasing business containers, batteries and - Increasing waste volumes cleaning textiles E-wastes has become significant Waste collection: urban council and private collectors
Institutional (e.g. Government and private-Ministries, Educational establishments, sports facilities, clubs)	5	Major: food wastes, - Expanding in numbers stationery with population increase; Minor: packaging (e.g., cardboard, paper, - E-wastes has become significant plastics) Waste collection: mainly by private companies.
Healthcare(hospitals, clinics, drug 1	1	Major: domestic type of Major hospitals treats own wastes hazardous wastes. Minor: hazardous (e.g., - Clinics dump with other anatomical, contaminated wastes, materials, sharps)
Others	11-11.4	Examples: street sweepings, public park wastes, construction, wastes: collected by: Urban council and private companies

Mainly the approach towards the solid and organic waste management in India is still un-scientific. And that's the reason why we lag behind other developing countries. Report estimated that, solid waste collection in efficiently in India is 70% (Sharholy et al. 2007), whether this proper 100% in the others developed counties. In India the situation of solid waste generation is tabled in (**Table 5.1**) and the main sources of solid generation and its types are discussed.

In Indian scenario, even these days also solid waste is dumping without any proper authority and proper scientifically that treats to a bad impact in environment and heaths. Without any treatment the dumped wet fields are storing of many indiscriminately unhealthy products and results are overcoming to neighboring people and environment. Leading from groundwater to air pollution, release of Smokey and leachate gases and various diseases causing environment is mainly found in such damping site in India. Study reveals that out of this waste, 80% of them can be utilized if, the proper measure of recycling or reused are used. Due to outdated technology and no innovative, improper waste isolation is mitigated in India. Some materialistic item has to be sort and they have to be properly dumped. Commodities like plastic and paper have to recycle and some other item that likecloths have to use to replace it. The issues revealing in systematic effort to maintain the illegal implementation to legal work, developing the human resources, earning the economic increase from reused method and arrangement in institutional framework will definitely develop India for sustaining the solid waste mitigation.

Table-5.3 Type of Industrial Waste

Source	Typical Waste Generators	Type of Solid Waste
Residential	Household activities	Food waste, paper, cardboard, plastics, wood, glass, metals, electronic items etc.
Industrial	Manufacturing units, power plants, process industries etc.	Housekeeping wastes, hazardous wastes, ashes, special wastes etc.
Commercial & Institutional	Hotels, restaurants, markets, office buildings, schools, hospitals, prisons etc.	Bio-medical waste,Food waste, glass, metals, plastic, paper, special wastesetc.
Construction and Demolition	New construction sites, demolition of existing structures, road repair etc.	Wood, steel, concrete, dust etc.
Municipal services	Street cleaning, landscaping, parks and other recreational areas, water and wastewater treatment plants	Tree trimmings, general wastes, sludge etc.
Agriculture	Crops, orchards, vineyards, dairies, farm etc.	Agricultural wastes, hazardous wastes such as pesticides
Mining	Open-cast mining, underground mining	Mainly inert materials such as ash

5.3. Safety Equipment for Waste Handlers

While handling waste material and waste products, the personal, which is acquainting with this work, have to protect him from self-security before securing the environment. The protection from the safety, and this needs in some insomnia and wearing the personal protective equipment (PPE). While handling all this waste items PPE reduces the direct contact of sharp item to body, protects from germ to the bodily fluid and blood also secures from splashes present in chemicals. While handling wastes mainly needed item are:

- Face mask
- Heavy duty, gloves
- Plastic apron
- Clothes that cover the body
- Heavy duty, boots

1. Safety Hats/Helmets

(a) Helmet

1. Safety hats protect the employee's head from injury caused by falling or flying objects.
2. Should be worn in places where construction work is going on or risk of objects falling or flying is high. Ought to be worn where equipment operation work is going on.
3. They come in various types depending on the task being performed and risk involved.

2. Ear Protection

(b) Ear protection

1. Ear Protection is meant to protect the employee's ears from damage as a result of excessive noise levels at the work place.

2. They should be worn while the employee is performing a task where noise levels are above normal.

3. Respirators and dust masks

(c) Respirators and dust masks

1. Respirators and dust masksprotect employees from inhaling harmful substances that may pose a threat to their health thereby making them unproductive.
2. They also minimize odors from especially decaying solid waste.
3. Others protect the employee from inhaling dust that might cause respiratory problems.
4. They come in various types and designs depending on the task being undertaken or being performed and degree of safety risk involved.

4. Safety Coveralls

(d) Safety coveralls

In Solid Waste Management coveralls are meant to:

1. Protect the employees from hazardous Chemicals that may be in the waste in the courseof solid waste operations.
2. Protect the employee from harmful disease-causing Pathogens.
3. Hinder the spread of disease-causing pathogens from the waste by the employees.

5. Safety footwear

(e) Safety footwear

1. Safetyfootwear protect employees from foot injury as a result of Sharp objects piercing through the soles or from falling objects.
2. They also protect the employee from water borne disease causing pathogens.
3. They ought to have reinforced soles and toe caps to enhance the safety of the employee's feet.
4. For employees involved in solid waste management operations, rubber boots are preferred. This is because of the wet conditions that exist in these operations.
5. They come in various types and designs depending on the task and risks involved.

6. Eye protection

(f) Eye protection

Eye protection is important in the following ways:

1. Protect the eyes from sharp objects that may cause injury or lead to eyesight loss.
2. Protect the eyes from harmful chemicals that might be in waste from spilling into the eyes.
3. Protect the eyes from harmful Ultra-Violet sun rays. They come in various shapes, types and designs to suit different tasks and the safety risks involved. Choose one that fits your task and assures your safety.

7. Safety gloves

(g) Safety gloves

Figure 5.4 Safety Equipment

1. In Solid Waste Management operations, hand gloves are important to ensure the employee is protected from hand injury and diseases causing pathogens.
2. Latex or rubber gloves are suitable for solid waste management operations. However, Leather gloves are used when dealing with sharps and sharp objects such as metal waste, glass among others.

In incinerator and waste plant to protect the body from the different sources of harmful activities that comes in all in one place one need to protect itself well before handling. In such a situation personal protective equipment (PPE) operates the safe guard when handling waste and working an incinerator. In that materialistic time mainly need of items are-

- Helmet
- Safety goggles

- Respirator mask
- Heavy duty, heat-resistant gloves
- Apron
- Clothes that cover the body
- Heavy duty, heat-resistant boots

(a) Hazardous waste handling by workers

(a) Hazardous waste handling by workers

(b) Hazardous waste handling by workers

(c) Workers wearing protective clothing with supplied air respirators (SAR).

(Courtesy of URS Corporation, 100 California Street, San Francisco, CA.)

(d) **4** Workers in Level C protective clothing. (Courtesy of URS Corporation, 100 California Street, San Francisco, CA.)

Figure 5.5 Hazardous waste management by handlers

The site investigation plan should address include

- Scope of the inspection that depends upon the purpose and objectives: The scope is expressed in terms of issues to be addressed, areas to be inspected, depth of detail required, time allocated to conduct the inspection, etc. For example, inspections performed in response to information received concerning alleged violations will generally be comprehensive in scope and entail a detailed evaluation of all RCRA regulated activities at the site.
- Coordination required with other offices, agencies, or services
- Procedure regarding prior notification, denial of entry, denial of access to records, areas, units, etc.
- Entering the facility: Is there to be an opening conference? What items should be covered? Should the inspector proceed with a visual inspection immediately to preclude hasty adjustments or concealment?
- Summarized findings from the background report
- Applicable regulations, policies, and guidance documents
- Procedure regarding records review, i.e., review on-site, copy for later review, or other arrangement
- Personnel assigned and duties
- Sampling plan, including list of equipment
- Protective clothing and safety equipment requirements
- Site safety plan — as appropriate
- Contingency plan for emergencies that may arise during the inspection
- Checklists (if any) to be used
- Data Quality Objectives

Risk factors that may increase a worker's risk for workplace assault as identified by NIOSH are

1. Contact with the public
2. Exchange of money
3. Delivery of passengers, goods, or services
4. Having a mobile workplace, such as a taxicab or police cruiser
5. Working with unstable or volatile persons in health care, social services, or criminal justice settings

6. Working alone or in small numbers
7. Working late at night or during early morning hours
8. Working in high crime areas
9. Guarding valuable property or possessions
10. Working in community-based settings

5.4. Scheme for Sustainable Waste Management

Experts agrees about waste management that this field will stable if we have a long-term procedure to act this and to achieve such a term end, one need to be very cost effective. The production of any from waste house should be minimal rather it can be prevented. Dangerous wastes not only cost the environment but also ageing of live. Another long-term issue can be cover by this though by preceding some fines for making the environment dirty. This will drop knowing environment pollution, because for human, money is matter than the environmental cluster. CID (Centre for Innovation and Development) in 1992 had already experienced this in New Delhi and this is high in developed country. Try and true method is used for this convenience where test site is firstly assessed for experimental basis than a sustain management is planned.

Table 5.4Waste plastic treatment methods

Sl.No	Treatment method or products	Type of waste plastics*
1	Mechanical recycling	Mixed plastics, C&P recycling law (household) PET Bottles, C&P recycling law (household) Industrial wastes of good quality
2	Solid fuel (RPF)	Industrial wastes of moderate quality
3	Blast furnace treatment	Mixed plastics, C&P recycling law (household) Mixed plastics from industry
4	Cokes oven treatment	Mixed plastics, C&P recycling law (household) Waste plastics from industry
5	Liquid fuel production	Mixed plastics from household Mixed plastics from industry
6	Gasification	Mixed plastics, C&P recycling law (household)
7	Cement kiln treatment	Industrial wastes of moderate quality
8	Incineration with power	Mixed wastes from household Mixed wastes from industry

	generation	
9	Incineration (no energy recovery)	Mixed wastes from household Mixed wastes from industry
10	Landfill	Industrial plastic wastes

Table 5.5 Types of laws for recycling and waste management

Law	Content
Basic law for establishing the recycling-based society	Basic framework determining the role of stakeholders for establishing the sound material-cycle society.
Waste management and public cleansing law	Defines municipal wastes and industrial wastes. The roles and duties of a municipality, waste generator, waste management company, and other stakeholders are strictly provided. The related regulations and rules define both technical and social conditions and guidelines to keep the sound business in addition to construction of a facility, installation and operation of equipment.
Law for promotion of effective utilization of resources	Promotion of waste reduction through recycling. The roles and duties of the stakeholders are mentioned. Promoting reduction of wastes through recycling and suitable disposal in several fields of industries and products such as steel production, paper production, construction, automobile, electric and electronic equipment, batteries, metal cans and PET bottles.
Containers and packaging recycling law	Promotion of recycling containers and packaging through separate collection of those wastes made from paper, metal, glass, PET and the other plastics by municipalities with cooperation of citizens. Producers of the material, manufacturers of the commercial products with containers and packaging and retail stores cover recycling costs. Recycling methods are provided in the related regulations.

Electric household appliance recycling law (Home appliance recycling law)	Forcing consumers to give wastes of home appliances to retailers with paying recycling fees. Air conditioner, refrigerator/freezer, television set, washing machine and cloth dryer are recycled with suitable treatment of fluorocarbons and other potential hazardous substances.
End-of-life vehicle recycling law	Forcing car owners to cover the cost for suitable disposal of hazardous wastes and wastes of no commercial value with recovering valuable resources from end-of-life vehicles.
Construction material recycling act	Reducing the amounts of construction and demolition wastes through recycling.
Food recycling law	Reducing the amounts of food residues from restaurants, food processing industry and supermarkets through recycling waste foods.
Law on promoting green purchasing	Promoting the national and local governments to buy products that made from recycled materials.

Table 5.6General recommendations concerning plastics.

Materials, plastics	Reasons for recommendation
Use as few different types of plastics as possible	Facilitates sorting materials for recycling Larger amounts of similar materials increase the value of the scrap
Choose plastics which:3 can be recycled, i.e. thermoplastics (PET, polystyrene) and polyolefins (HDPE,LDPE and PP)3 are compatible on recycling	Increases possibility of recycling
Choose plastics which can be incinerated without emission of hazardous substances. Avoid PVC and other halogencontaining polymers	Incineration of plastics is often the most realistic disposal route In the event of fire in electric and electronic systems, PVC will evolve chlorine and subsequently hydrochloric acid
Do not use brominated flame retardants	Legal constraints of RoHS Toxic substances are emitted during incineration at low temperature. Some ofthe flame retardants are themselves toxic (PBB, PBDE)
Avoid adhesive labels on plastic surfaces	Contaminates material on recycling

We have to adopt and have to move our living policy. The past 3 'R's policy is still in running mode in developing countries. But developed countries adopt 4 'R's and these are:

- **Refuse** – Instead of going market to buy a new item one has to try to not to use if is not too need to use. Refusing to buy non-need item will help in diminishing the waste.
- **Reuse**–Instead of throwing away a material use innovative mind to create a new one which is useful and seems to be ethnic design.
- **Recycle**–Collection of segregate waste and then deriving them which one can be used again will help to store our resources and not to increase in waste.

- **Reduce**–Also need to reduce the unnecessary item, avoiding over using and trying to be eco-friendly will reduce waste for wealth.

Table 5.7 Policy instruments on waste prevention

Policy instruments	Waste prevention instruments
Regulatory	Landfill ban, incineration bans, plastic bag bans, disposable cutlery bans, to-go or single-use products ban
Market-based	PAYT, landfill tax, incineration taxes and fees, extended producer responsibility principle, precycling insurance, recycling insurance, taxes on products (packaging, plastic bags)
Information	Awareness campaigns, school campaigns, procurement guidelines, information exchange platforms
Voluntary	Home composting, ecodesign of products, designing out waste, bottleless water, nappy laundry services, planning food meals

Certain amount of waste cannot be prevented while manufacturing a big product. But if we use the needed item for that particular serviceable material than waste will be reduced. However, we have to develop our own innovative mind to create something new from the primary wastes which is easily reusable material. Central Industrial Research (CIR) ministry now implemented some regulations for disposing waste in some of the heavier factories. Mainly people cooperation is the only thing in this sustains planning for waste management.

This could be offer for public demand:

- Easy analysis in elaborating the material flow assessment wills asset their importance and impacts.
- A proper way to find the material flow of any household.
- Accessing public or private trainees in this field for accessing of data collection and providing report to govt.
- Assist in waste management plan with own interest for the neighboring clean.

If we could plan such a sustain management then the dirty earth which we are living i.e. Earth-1.0 will directly flow and a green and clean earth will come which will be people friendly, environment friendly, health friendly and mostly technically developed the “Earth -2.0”.

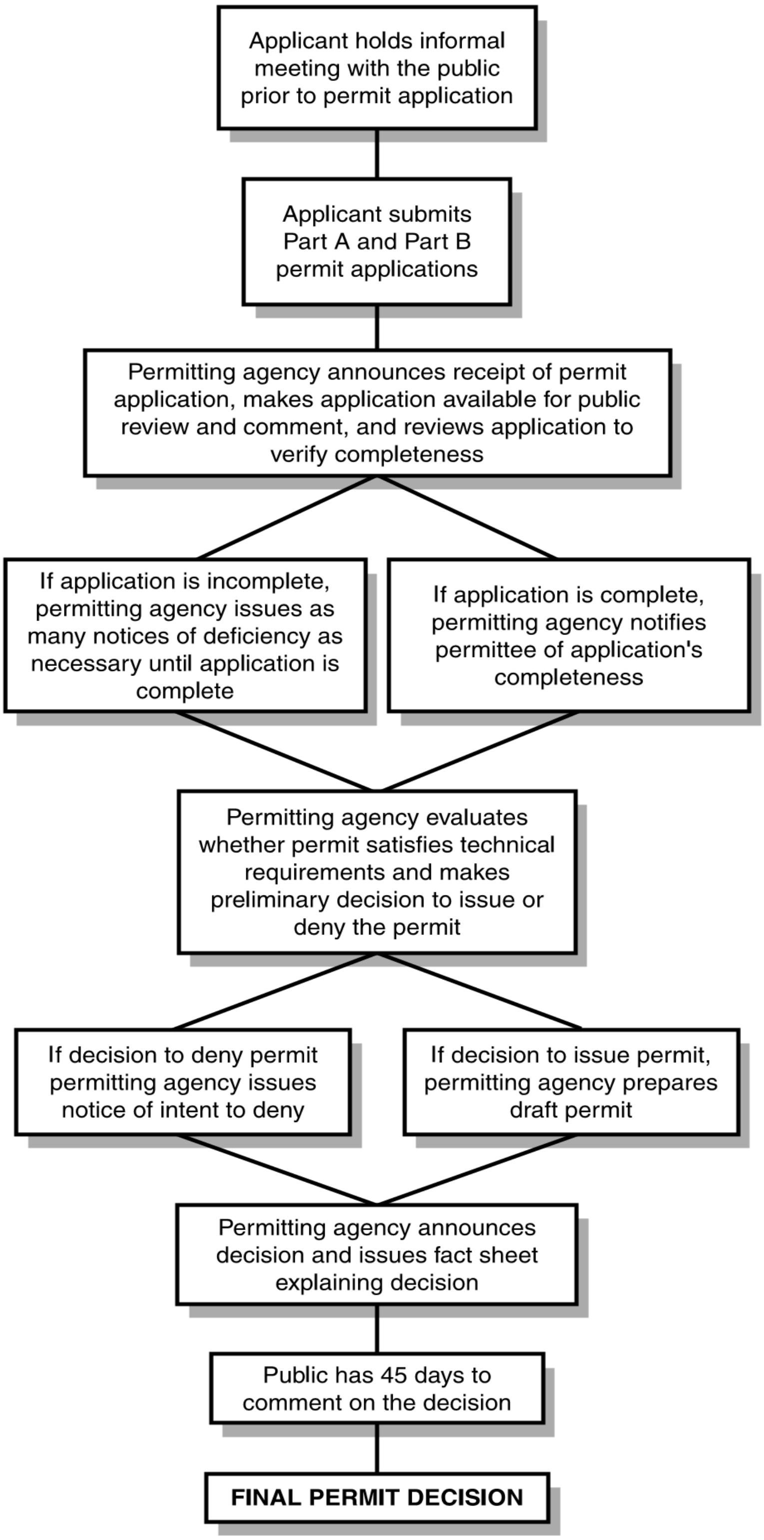


Figure 5.6The permitting process (EPA 1998d, Chapter 8).

Summary

Block 5 summarizes leadership management in waste banks, and the incentives given for waste collection and disposal. Also, it explains the household waste management of Indian scenario. It lists the equipment required for waste handlers. Lastly, it enlists the schemes for sustainable waste management.

Activity

- Prepare caselets for household waste management in Indian scenario (2 Pages)
- Nature of incentives given to waste handlers and success story (2 Pages)
- Report framework for sustainable waste management (2 Pages)

Review questions

1. Draw flowchart of following
    (a) Leadership management
    (b) Household waste management – Indian scineario
2. State the importance of safety equipment for waste handlers?
3. List out schemes for sustainable waste management?

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Block 4

Reclamation and Remediation

Swachhta Action Plan

Mahatma Gandhi National Council of Rural Education

Department of Higher Education

Ministry of Human Resource Development, Government of India

Hyderabad - 500004

सत्यमेव जयते

Where there is Rural Wellbeing
there is Universal Prosperity

Contents

Chapter 1 Assessment of Contamination before Reclamation and Remediation

Introduction

Waste handling professionals, who are involved in collection, transport, processing, recycling or disposal of waste, are in direct contact with the waste, touching it or inhaling it and being at the risk of even ingesting it accidentally. However, even the most innocuous of wastes, such as the municipal solid waste generated from households, can have components with properties detrimental to the health and well-being of the individual as well as the environment, and create untold harm. For instance are the everyday items like batteries, paints and insecticides that have been categorized as household/ domestic hazardous waste.

The hazards associated with other wastes coming from manufacturing industries (chemical), nuclear power plants (radioactive) or hospitals and healthcare institutions (biomedical) are several degrees more harmful and the exposure to such wastes – in the absence of adequate safety precautions – can lead to morbidity or even be fatal.

In addition, the contingency of accidental spillage, mishaps, and security lapses emerging from human error or mechanical failure, cannot be denied. Be it the Chernobyl tragedy or the Bhopal gas tragedy, the loss of life and property due to hazardous chemicals still haunts mankind's collective memory.

Hence, irrespective of whether it is the question of following day-to-day routine or remaining prepared for untold disasters, it is of the utmost importance for a waste management professional to understand the hazards associated with waste – not only to the individual but to the surrounding environment as well.

Objectives

The objective of this Chapter are to help the reader fully comprehend

- The hazards associated with wastes from different sources, i.e., impact of a given waste item on human health and the environment
- How to identify a waste as hazardous, based on its labels, physical features and/ or source
- How to protect oneself from hazardous wastes by following adequate safety protocols

- The risk assessment procedure
- The associated policy framework

1.1 Understanding Associated Hazards with Different Waste Types

Industrial waste – here, the waste is largely chemical, and based on their nature, these chemicals may be explosive, corrosive, flammable or toxic. Synthetic organics, inorganic metals, salts, acids and bases, and flammables and explosives are the five categories into which hazardous chemical waste can be divided. They may injure the handler through direct dermal contact, accidental inhalation or ingestion.

Biomedical waste – the risk of infection is the most potent risk associated with biomedical waste. Injury and risk of infection from sharps (syringes, scalpels, and lancets) is another hazard.

Radioactive waste – Wastes generating radioactive radiation (alpha, beta or gamma rays) are extremely hazardous and can cause immediate death or chronic symptoms depending on the degree of exposure. Radioactive substances persist in the environment, depending on their half-lives. The time taken for the radioactivity of a specified isotope to fall to half its original value is called its Half-life.

Electronic waste – The recycling of electronic waste exposes its handlers to several heavy metals such as lead, mercury, cadmium, chromium etc. In addition, brominated flame retardants pose a threat, too. E-waste components such as accumulators and other batteries, glass cullets from Cathode Ray Tubes (CRTs), Polychlorinated biphenyls (PCB) capacitors and mercury-switches can be potentially harmful to the handler and need to be regulated.

Municipal Solid Waste – In the absence of cautious segregation, even domestically generated municipal solid waste may contain some hazardous waste elements. These include - aerosol cans, batteries, and household kitchen and drain cleaning agents, car batteries and car care products, cosmetic items, chemical-based insecticides/pesticides, light bulbs, tube-lights and compact fluorescent lamps (CFL), paint, oil, lubricant and their empty containers.

Another problematic component of the municipal waste that may have health hazards is sanitary waste. These include used menstrual hygiene products like tampons and sanitary napkins, soiled diapers, condoms, bandages, soiled cotton and bandages etc. Such items can be infective, and their careless disposal without adequate segregation at the source creates a serious managerial challenge.

Table 1.1 Comparison of hazards associated with different types of waste

Type of Waste	Source	Examples	Nature of Hazard	Exposure Risk
Municipal Solid Waste	Individual households and commercials	Batteries, insecticides, paint, lubricant oil, tube lights and bulbs etc.; sanitary waste	Injury from shattered glass, burns from battery acid, corrosion from cleaning agents, harm from toxic waste inhalation/ingestion, infection from sanitary waste	As these are household products sold over-the-counter, and there is lack of awareness about its hazards
Electronic Waste	Households, offices	Heavy metals such lead, mercury, cadmium and chromium; flame retardants	Chronic heavy metal exposure can lead to cancers	Largely the recyclers are exposed to the risk
Industrial Waste	Manufacturing industries	A variety of organic and inorganic chemicals	Corrosion, burning, or poisoning; eco-toxicity	Medium, small and micro enterprises (MSMEs) may not afford the effluent and hazardous waste management costs
Biomedical Waste	Hospitals, clinics, pathology labs, research labs, blood banks, health camps, vet hospitals	Sharps, discarded dressings & bandages, amputated body parts, discarded microbial cultures	Infection, injury from sharps	Unregistered clinics and quacks tend to dispose of such high-risk waste carelessly
Radioactive Waste	Atomic energy plants	Uranium ore tailings, spent fuel rod, radioactivity-infected items	Acute exposure can lead to instant death; chronic exposure in high does leads to cancer-causing mutations; chronic exposure in low doses may cause nausea,	Can be disastrous if containment fails

			hair-loss, gastro-intestinal symptoms etc.	

Recognizing waste as hazardous

- Label – Labels containing chemical names or symbols indicating specific dangers are significant markers in recognizing hazardous waste. Few such labels have been included here:

Bio-hazard

Cytotoxic drug

Figure 1.1: Symbols of hazardous chemicals

- Human senses – pungent odor, visible fumes, dermal irritation, eye watering, corrosive action
- Biological indicators – bleached leaves of plants and dead animals
- Occupancy and location

Point locations where hazardous wastes are likely to be encountered

Such locations as enlisted below show a greater likelihood of encountering hazardous wastes, and hence, visits here must necessarily entail complete awareness regarding the on-going activities and full regards to personnel safety.

- MSW dumping ground – dumping grounds in India still contain largely mixed-type waste, and hence, there is high probability of encountering household hazardous waste and sanitary waste items here. Informal rag-pickers who make their living by collecting dry recyclables from dumpsites and selling them off are often exposed to this risk.
- Industrial areas – Well-demarcated industrial regions have been planned in India, where industries of all categories have their manufacturing plants and offices. Such regions are relatively further from human habitation and the rationale is to –
    - reduce risk of exposure to pollutants (despite zero discharge claims, on-ground reality is that fugitive emissions, spillage and accidental discharge do occur)
    - ensure better crisis management

Major industrial regions in India are:

- Mumbai-Pune Industrial Region
- Hugli Industrial Region
- Bangalore-Tamil Nadu Industrial Region
- Gujarat Industrial Region
- Chhotanagpur Industrial Region
- Vishakhapatnam-Guntur Industrial Region
- Gurgaon-Delhi-Meerut Industrial Region
- Kolfam-Thiruvananthapuram Industrial Region

- Hazardous waste Treatment Storage and Disposal Facilities (TSDFs) – Such TSDFs are mandatory in India for effective resource recovery and safe disposal of hazardous waste in India. A list of these TSDFs, as per CPCB, has been provided in Table 1.2 below:

Table 1.2: List of hazardous waste TSDFs in India

S. No.	Nameofthe State/UT	IntegratedTSDFs(withbothSLFand Incinerator)	TSDFswithOnlyCommonIncinerators	TSDFswithonly CommonSecuredLandfills
1.	AndhraPradesh	1	-	-
2.	Gujarat	4	2	3
3.	Haryana	I	-	-
4.	HimachalPradesh	-	-	1
5.	Jharkhand	1	-	-
6.	Karnataka	-	6	2
7.	Kerala	-	-	1
8.	MadhyaPradesh	1	-	-
9.	Maharashtra	3	-	1
10	Odisha	-	-	1
11	Punjab	-	-	1
12	Rajasthan	-	1	2
13	TamilNadu	1	-	I
14	Telangana	1	-	-
I5	UP	2	1	1
16	Uttarakhand	1	-	-
17	WestBengal	1	-	-
18	Daman,Diu,Dadra& NagarHaveli	1	-	-
	TOTAL	18	10	14

Source: http://cpcb.nic.in/uploads/Projects/Hadzardous-Waste/Common_TSDF.pdf

- Bio-medical waste incineration sites – CPCB has enlisted more than 120 common bio-medical waste incineration facilities all over India, where such waste collected from the smaller clinics, labs and healthcare institutes can be safely incinerated and disposed.
- E-Waste recycling centers –formal e-waste recycling centers, as discussed above, expose the recyclers to several heavy metals and flame retardants, which can severely hamper human health.
- Cement kilns co-processing waste – Ambuja cement kiln at Vapi, Gujarat co-processes the waste from local paper mills. Similarly, ACC cement kiln near Madukkarai, Tamil Nadu uses

unrecyclable plastic waste generated in the town as fuel. 52 more such cement kilns, which co-process non-recyclable plastic or hazardous waste have been enlisted by CPCB.

- Illegal dumping of waste – Unfortunately, hazardous waste generation in India is much in excess of the volume that can be treated in our current number of TSDFs. As a result, it is inevitable that significant quantities of such waste are either dumped illegally or released into the environment with little concern for human health and the environment.

To-do Activity: Make a hypothetical analysis of the quantity of E-waste that will be generated in various sectors such as malls/ offices/ hospitals/ IT parks, etc. in coming five years considering all the factors that leads to its generation. Also, based on the kind of E-waste generated estimate its commercial value.

1.2 Safety Considerations

For hazardous waste -

Detailed awareness about the hazardous waste item being handled

- Material Safety Data Sheet - A Material Safety Data Sheet (MSDS) is a detailed dossier on almost all chemicals, chemical compounds and chemical mixtures, containing relevant data regarding the health hazards (health, fire, reactivity and environmental), first aid details, storage & handling instructions, and combating protocol for accidental release and fire hazards. MSDS is especially focused on reducing occupational hazards by giving detailed insights to those working with the chemicals.
- Cross-reactivity

Engineering interventions to reduce risk

Ideally, engineering interventions should render a procedure safe enough to reduce the requirement of personal protective equipment (PPE). Such interventions include –

- Design change
- Improved ventilation
- Mechanical handling
- Automation

However, in several cases, such interventions still leave space for human exposure to hazards. Hence, the importance of PPEs cannot be denied.

Personal Protective Equipment (PPE)

PPEs must essentially cover the intended body part fully, and be of a suitable material that will withstand the hazard against which it is being worn. Other important aspects that would be of import while selecting the appropriate PPE are –

- Comfort of the wearer
- Duration of wearing it
- Ease of cleaning and maintenance
- Meeting the country-specific or universally acclaimed quality assurance criteria

PPEs can be divided into two categories –

- Respiratory – PPEs preventing inhalation of air-borne hazardous elements
- Non-respiratory – PPEs preventing dermal contact and injury to the other parts of the body

Given below in Table 1.3 are some PPE designs –

Table 1.3: Personal Protective Equipment

<table>
<tr><th>Body Part Protected</th><th>PPE</th><th>Comments</th></tr>
<tr><td>Head</td><td>Helmet</td><td>Depending on whether used for fire-fighting or general protection, the material used for the helmets will differ</td></tr>
<tr><td rowspan="3">Eye</td><td>Safety goggles</td><td rowspan="5">Aimed at protecting the eye and face from mechanical injury or radiation or chemicals; wearing contact lenses or hardened glass lenses should never be considered a replacement for safety goggles</td></tr>
<tr><td>Safety spectacles</td></tr>
<tr><td>Safety clip-ons</td></tr>
<tr><td rowspan="2">Eye & Face</td><td>Face-shields</td></tr>
<tr><td>Wire-mesh screen guard</td></tr>
<tr><td rowspan="3">Hand & Arm</td><td>Gloves</td><td>Gloves should extend well beyond the wrist but have no flaring cuffs; when one is handling chemicals, gloves that extend up to the elbow are preferable</td></tr>
<tr><td>Finger-stalls</td><td>Where only finger-protection is necessary</td></tr>
<tr><td>Hand-pads</td><td>Protect palms from excess heat</td></tr>
<tr><td rowspan="4">Foot & Leg</td><td>Safety-toe shoes</td><td rowspan="4"></td></tr>
<tr><td>Foot guards</td></tr>
<tr><td>Conductive Shoes</td></tr>
<tr><td>Gum boots</td></tr>
<tr><td>Full body protection</td><td>Overalls</td><td>Preventing spillage on the person</td></tr>
</table>

On several occasions, it has been observed that workmen tend to avoid wearing PPEs, finding them cumbersome or complaining that it reduced their working efficiency. Raising awareness about the harms caused in the absence of PPEs and if possible, associating it with economic sanctions or disciplinary action can help tackle this.

Understanding the procedure of final disposal of the hazardous chemical

The complete path traversed by the waste from collection and packaging to transport and final disposal of hazardous waste must be managed by observing every precaution and following the standard protocols. Awareness among the personnel about this is a must.

Handling emergency situations

Each personnel must be familiar with the crisis management protocol, use of fire extinguisher, emergency contact numbers and gathering point and basic first aid. The onsite and offsite approach to crisis management has been outlined in Table 1.4 below:

Table 1.4: A Comparison of Onsite and Offsite Approach of Crisis Management

Onsite Approach	Offsite Approach
Emergency planning for combating accidents where industrial activities are carried on	Emergency planning for the contingency when impact of an on-site accident crosses the boundary of the industrial site and impacts other locations
Alarm system, followed by assemblage and evacuation are critical	Alarm system/timely information relay to prevent entries and hasten exits of individuals
Prepared by the local crisis group	Prepared by the district crisis group
Calling for assistance from other agencies	
First aid and medical assistance	

For Biomedical waste

The World Health Organization lays stress on –

- Proper training to the healthcare workers so they understand the risk associated with the type of waste they are handling – aspects for which they must be trained are –
    - Identification of waste type based on color coding
    - Packaging of waste to prevent spillage
    - Personal hygiene
    - Appropriate storage (prior to transportation)
    - Appropriate transportation to the own or community bio-medical waste incineration facility

- Immunization of the healthcare workers against common infections that they may be exposed to – for this, especial attention has been directed at viral hepatitis B and tetanus.
- Provision of appropriate PPEs

In Table 1.5 below, a list of PPEs for those handling bio-medical waste and their degree of requirement has been outlined:

Table 1.5: PPEs for those handling Bio-medical Waste

PPE	Requirement
Helmets (with or without visor)	May or may not be obligatory, depending on the activity
Face masks	May or may not be obligatory, depending on the activity
Safety goggles	May or may not be obligatory, depending on the activity
Respirators (gas masks)	May or may not be obligatory, depending on the activity
Overalls	Obligatory
Industrial aprons	Obligatory
Industrial boots	Obligatory
Heavy duty gloves	Obligatory

World Health organization (WHO) further stresses the response to injury and exposure:

- Immediate first-aid measures, such as cleansing of wounds and skin, and splashing of eyes with clean water
- Immediate report of the incident to a designated responsible person
- Retention, if possible, of the item involved in the incident; details of its source for identification of possible infection
- Additional medical attention in an accident and emergency or occupational health department, as soon as possible
- Medical surveillance
- Blood or other tests if indicated
- Recording of the incident
- Investigation of the incident, and identification and implementation of remedial action to prevent similar incidents in the future

Further, management of cytotoxic waste must be given due attention in hospitals, with a detailed protocol and emergency response team for managing the same.

For household hazardous waste

Given the lack of awareness, household hazardous waste is often:

- Dumped with the other dry and wet waste
- Poured down the drain
- Carelessly disposed of on the ground
- Burnt

In all these cases, the risk of harm to the individual householder, formal or informal waste handler, or even the general public and the environment increases. The most significant way of managing this risk is –

Raising public awareness

Today, there is little awareness regarding the hazards associated with innocuous-appearing items of our daily use. Raising public awareness about the same should be managed as a twin approach –

- On the part of the manufacturers of such items, warning should be given regarding careful handling and safe disposal in large font size, if possible in the local language or at least with the appropriate symbols so that the message is driven home to the user
- On the part of the local municipality/Panchayat, door-to-door awareness campaigns to the effect must be planned and executed; it may be of interest to note here that under the Swachh Bharat Abhiyan (2014-2019), municipalities were funded to organize massive awareness drives regarding municipal solid waste segregation at source.

Setting up Collection centers

The Solid Waste Management Rules, 2016 mandate the setting up of such common Collection Centers by the local municipality or Panchayat where information-rich householders can come and deposit their domestic hazardous waste items.

Planning collective disposal to nearest TSDF

Finally, it is within the purview of the local municipality or Panchayat to co-ordinate with the nearest hazardous waste TSDF and plan the transport of their collected household hazardous waste for safe disposal or resource recovery. Understandably, there are much fewer than the required numbers of TSDFs in the country so far. Hence, the Solid Waste Management Rules, 2016 direct the local municipality/Panchayat to approach their State Pollution Control Board or Pollution Control Committee for guidance.

For Electronic waste

The safety concerns here are largely similar to those outlined above, with stress on –

- Maintaining basic protocols to ensure proper packaging, storage and transport
- Using sturdy work gloves/chemical-resistant disposable gloves, safety goggles, overalls, boots, and a respirator if need be

For radioactive waste

Several considerations for handling radio-active waste are similar to those outlined above for hazardous waste. However, the most significant concern in the case of radioactive waste is that of, of course, penetrative radiation. PPEs to be worn by radioactive waste handlers must ward off radiations such as the alpha, beta and gamma rays. The type of protection required to prevent radiation exposure depends on the type of radiation – or more specifically, its penetrative ability. The same has been outlined in Table 1.6 below:

Table 1.6: Protection against Radiation

Type of Radiation	Nature	Penetrative ability	Can be stopped by	PPE	Comment
Alpha	2 protons, 2 neutrons	Range in air about 10 cm	Normal clothing; even a sheet of paper can stop it from penetrating skin	Overalls; wounds should be doubly protected	Respirators prevent inhalation of radioactive rays
Beta	A fast-moving electron	Range in air up to 2 m; can penetrate skin up to 0.2-1.3 cm	Walls of a room, 1.3 cm thick plastic and aluminum sheet can prevent it from penetrating skin	Protective plastic suits	
Gamma	An electro-magnetic radiation	Highly penetrative; Range in air up to 1.6 km	13.8 feet of water, 6.6 feet of concrete, or 1.3 feet of lead	Gamma radiation suit should match the gamma rays blocking ability of 13.8 feet of water, 6.6 feet of concrete, or 1.3 feet of lead	

To-Do Activity – Visit to your nearest cement kiln co-processing waste/common bio-medical waste incineration facility/hazardous waste TSDFs and study hazards associated with further making a MSDS for the same.

1.3 Sampling & analysis protocols

The significance of sample planning

The first two aspects to be considered when one initiates the planning for any sampling exercise are –

- The scientific purpose to be served through the sampling exercise – largely, whatever the larger scientific aim, the sampling exercise is planned to help assess the physical and chemical properties of the waste.
- The regulatory framework – the regulatory thresholds or 'safe limits' of nearly all types of hazardous waste items have been enlisted by the MoEFCC.

Other aspects of planning include collection of basic secondary information (location, type of waste, timing of operation etc.), appointment of well-trained manpower, planning the sampling locations (apart from project-specific considerations, physical accessibility is important here), number of samples, efficiently managed logistics (travel to and fro sampling site, time of sampling, sample transport to laboratory), state-of-the-art equipment for sampling as well as analysis and finally, well-established protocols. These aspects have been explained in the figure below:

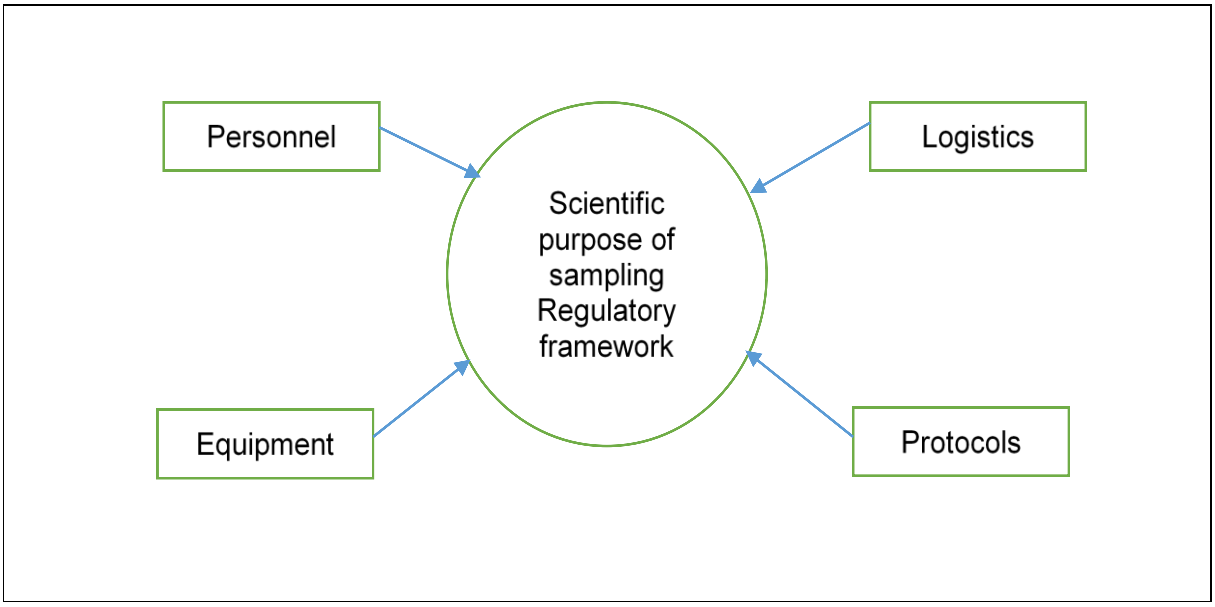

Figure 1.2: Planning Considerations for a Typical Scientific Sampling Exercise

Fundamental statistical concepts

- Size of sample
- Number of samples (spatially, across the site)

- Sampling frequency (temporally, across the timeline of the study)

Neither time nor budget can feasibly support the testing of 100% of a given population, in most cases. The best approach is to collect a smaller-sized sub-population from the larger population as a representative sample. A representative sample is one that accurately mirrors the larger population and the central tendencies of the population are exhibited by the sample as well. Given the heterogeneous nature of hazardous waste, the number of samples and frequency of sampling should be sufficiently high, but volume or size of the sample should be low enough to make safe transport feasible logistically. Finally, the statistical criteria on the basis of which project-specific sample size, number and frequency will be determined are the pre-decided error percentage and confidence level.

Considerations –

- Authoritative sampling or random sampling

As is clear from its name itself, in the case of authoritative sampling, the researcher purposely selects sampling units based on his/her judgment. It is hence, also called as Judgmental or Purposive sampling. On the other hand, in the case of random sampling, the probability that any one unit from the population will be singled out and included in the representative sample is equal and no will is exercised by the researcher in selecting a particular unit.

If sufficient data regarding the waste to be sampled is available with the researcher, it would make sense to go for authoritative sampling. Clearly, it makes sense to take a judgment regarding the sampling procedure only when sufficient information is available to base one's judgment on. Alternately, when insufficient information is available, it makes more sense to go for random sampling.

- Grab sample or Composite sample

A Grab sample is a sample collected once within a given time-frame; it is collected in a short time-span and hence, yields quicker results. In contrast, a composite sample is an amalgamation of several discrete grab samples collected at a pre-determined frequency within a given time-frame. For instance, once every two hours within a 24-hour period.

While a grab sample is simple, cost-effective and quicker, it may not yield a representative sample if the population is heterogeneous, and the sampling frequency will have to be enhanced to ensure statistically-credible sampling.

Sampling equipment used

The sampling equipment to be used will be decided on the following criteria –

- Physical state of the hazardous waste (solid, liquid, semi-solid)
- Chemical nature of the hazardous waste (flammable, corrosive, reactive, toxic)
- How the hazardous waste has been stored (open pile, drum container, lagoon). Alternately, how accessible the site is

Important considerations are:

- No contamination
- No sample loss
- No change in the physical or chemical characteristics or concentration of the sample in the period between sample collection and sample analysis

On the above bases, following equipment have been described in Table 1.7 below:

Table 1.7: Sampling Equipment for Hazardous Waste

Sampling Device	Suitable for	Brief Description
Composite Liquid Waste Sampler (CoLiWaSa)	Liquid/slurry stored in shallow pits, drums, shallow tanks etc.	Glass/plastic/metal can be used; it is a tube with an end closure that can be manipulated even while the sampler is immersed in the liquid to be sampled
Weighted Bottle	Liquid/slurry	Glass/plastic bottle, sinker, and stopper with a line used to lower, raise and open the bottle
Dipper	Liquid/slurry	A glass/plastic beaker clamped to a two/three-piece telescoping aluminum/fiberglass pole that serves as a handle
Thief	Dry granules or powdered waste (with particle diameter less than one-third the width of slots)	Two slotted concentric tubes (of brass/stainless steel); the conical, pointed tip on the outer tube is rotated to open or close the equipment
Trier	Moist samples or sticky solids (with particle diameter less than half the diameter of the trier tube); it can also be used for loosening soil	It consists of a tube cut in half longitudinally, with a sharpened tip
Auger	Hard or packed solid waste or soil	Sharpened spiral blades are attached to a central metal shaft

Source: CPCB Manual on Hazardous Waste

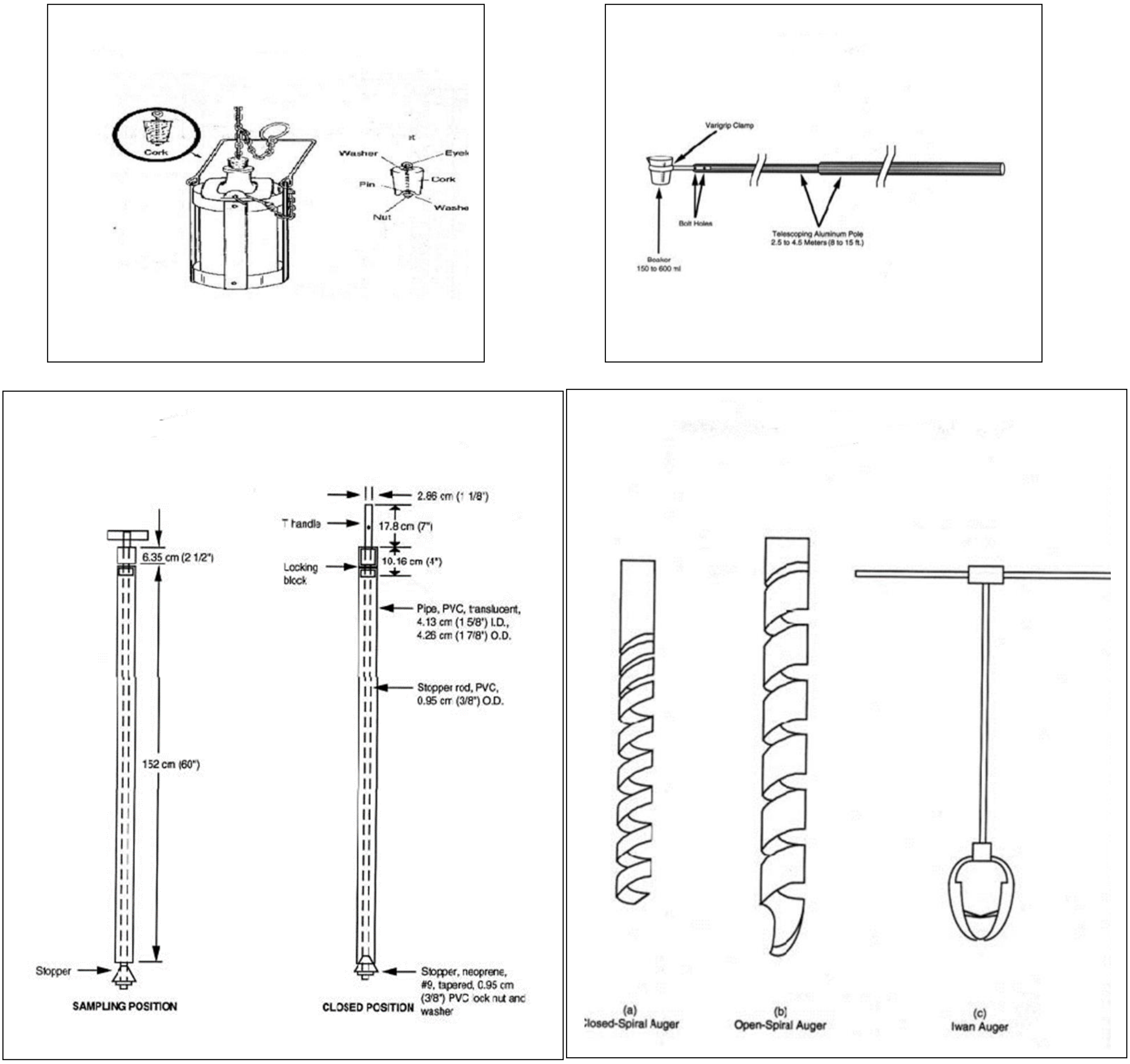

Figure 1.3: Hazardous waste sampling equipment (Weighted bottle, dipper, coliwasa, auger)

Source: CPCB Manual on Hazardous Waste

Thus, to summarize in Table 1.8 below:

Table 1.8: Hazardous waste sampling equipment – suitability as per physical state of waste and container type

WasteType	Drum	Sacks & Bags	Open-Bed Truck	Closed Bed Truck	Storage Tanks/Bins	Waste Piles	Ponds, Lagoons &Pits	Conve y-or	Pipe

Free-flowingliquidsandslurrie	Coliwasa	N/A	N/A	Coliwasa	Weighted bottle	N/A	Dipper	N/A	Dipper
Sludge	Trier	N/A	Trier	Trier	Trier	*	*	*	*
Moistpowdersorgra	Trier	Trier	Trier	Trier	Trier	Trier	Trier	Shovel	Dipper
Drypowdersorgr	Thief	Thief	Thief	Thief	*	Trier	Thief	Shovel	Dipper
Sandorpackedpowdersandgran	Auger	Auger	Auger	Auger	Thief	Thief	*	Dipper	Dipper
Large-grainedsolids	Large Trier	Large Trier	LargeTrier	Large Trier	LargeTrier	LargeTrier	LargeTrier	Trier	Dipper

Source: CPCB Manual on Hazardous Waste

* May have to improvise based on actual site conditions; no specific suggestion can be given

Documentation of the chain of custody

It is the chronological documentation of paper trail, which is maintained to ensure the sequence of collection, transport, processing, treatment and disposal of hazardous waste. It includes sample seals, logbooks/notebooks and sample analysis request sheets.

A crucial aspect of chain of custody is sample labeling, which must be

- Legibly written or printed
- Gummed using adequate adhesive/tied securely
- Contain accurate description of the sample number, date, time & location of sample collection, and finally, name of the personnel who did the collection

The logbook or notebook used by the sampling personnel during sample collection should be further rich in information, including

- Purpose of sampling
- Number and volume of samples
- Details of sampling point location (as from the label, such information cannot be obtained in much detail), including its brief description
- Name and contact details of the field contact
- Name and contact details of the waste producer
- Sampling and sample preservation methodology
- If possible, some details of the process producing the waste to be sampled
- Physical state of the waste

- If possible, the estimated waste composition
- Sample number key (so that the sample number mentioned on the label can be further correlated with other factors)
- General field observations (if anything worthy of note)

The logbook must also contain name and signature of the field

It must be understood that a field logbook/notebook is not a rough document – indeed, it has immense value as being the first formal report of field conditions; the field logbook/notebook is one of the first documents required during inspections – general as well as during exceptional circumstances. Hence, every effort must be made to make legible organized notes, and preserve the logbook/notebook for future reference.

A second document that needs to be prepared is a Sample Analysis Request Sheet, which the sampling personnel fills to provide the laboratory personnel with necessary field information such as sample description, sample identification and the requested analysis.

From the field, post collection, the sample should reach the laboratory for analysis. If the transport of the sample is not being managed by the same personnel who did the sample collection, the next link in the chain of custody becomes the personnel who will transport the waste to the laboratory. Herein, there should be a formal sign-off after which the sampling personnel hands over the sample analysis request sheet and the samples to the transporting personnel with properly packaged samples, in spill-proof containers.

That the vehicle is well-maintained, is in good shape, and is driven by a well-trained personnel who understands the importance of preventing cargo spillage, are basic considerations.

Handing over the samples and the sample analysis request sheet to the laboratory is the next link in the chain of custody. Here, the necessary data that must go on record includes:

- Name and designation of the laboratory personnel receiving the sample
- Laboratory Sample Number
- Date and time of sample receipt
- Sample allocation
- Analyses to be conducted

1.4 Risk assessment of contaminated sites

Risk assessment or hazard assessment is required to decide the extent of contaminant remediation required for a particular site. It helps to arrive at a statistical quantification of the probability that a hazardous or toxic spillage will harm human beings or the environment or both. It is the first step towards risk management, as outputs obtained from the risk assessment exercise will be utilized as inputs for the risk managing exercise.

Purpose of risk assessment

Determining the spatial and temporal extent of contaminant spread in a site is the main purpose of a risk assessment exercise. For spatial extent, one attempts to ascertain the area and depth-wise extent of the contaminant spread. For temporal extent, it is required to estimate the current impact as well as the probability of spread of the contaminant in the future and its future impact on the receptors. The risk assessment exercise can be classified into four phases:

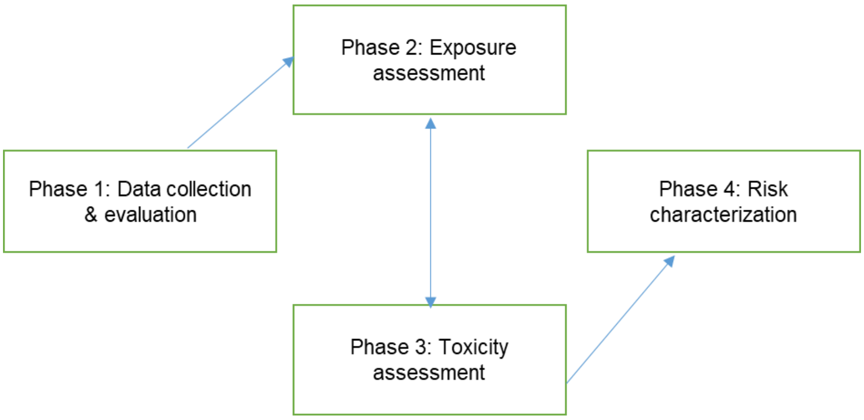

Figure 1.4: Phases of risk assessment

Essential queries raised during the phases of a risk assessment exercise are:

- What is the concentration (load/dosage) and spatial distribution of harmful pollutants under consideration?
- Wherefrom did the contaminants reach the site in question?
- What is the physical and chemical nature of the contaminants?
- What is the spatial and depth-wise extent of contamination?
- Are the contaminants stationery or movable?
- If they are movable, what route will they take (air, water, soil)?
- If they are movable, then can pathways be designed to mobilize them away from the site?
- Can the potential receptors (i.e., human beings?Bird? Fish?Mushroom?) of contaminants be identified?

- Do tolerance limits exist for the potential receptors with respect to the contaminant in question?

Based on the above queries, risk assessment exercise arrives at the pathway that a contaminant from the site will follow to reach a potential receptor. This has been described in Figure 1.5 below:

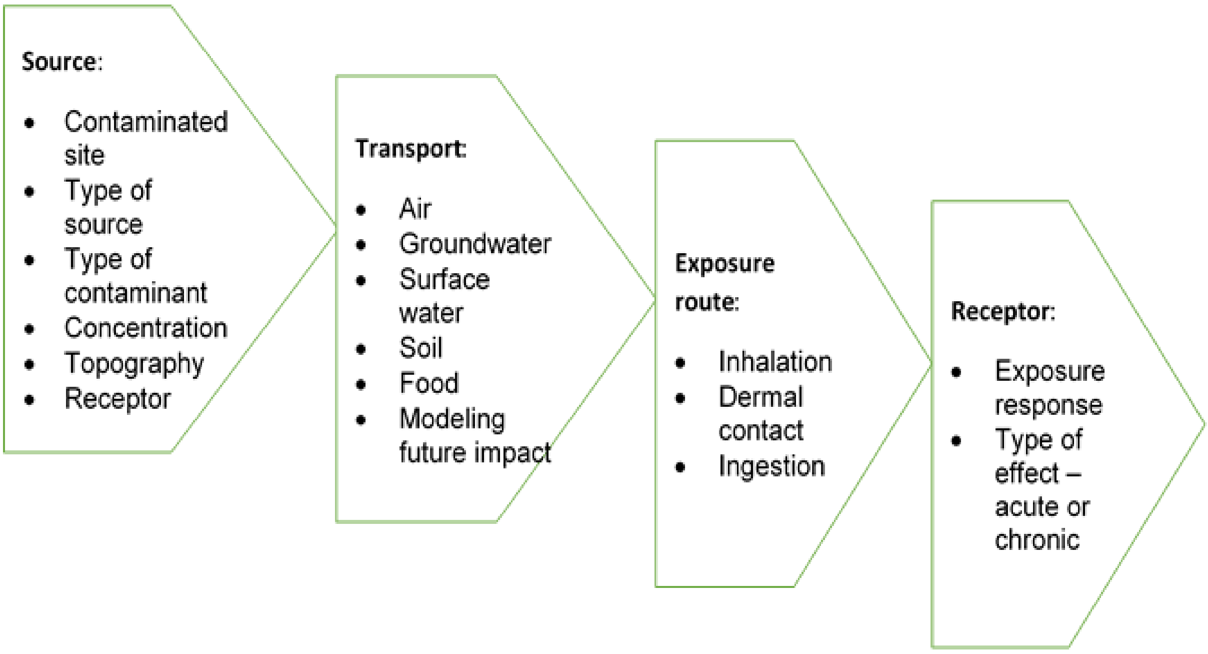

Figure 1.5: Pathway of Risk Assessment

Based on all the above considerations, a final list and flow-chart of actual activities to be conducted for risk assessment of a contaminated site has been provided below:

- After getting intimation of site contamination, the first step of action will be to collate all possible information available
    - Through personal conversation or interview sessions with concerned personnel (owner of the site, local authorities, local residents)
    - Through a quick desk review
- Based on the secondary data so collated, the first site visit is planned
- Logistical considerations to be taken are:
    - Putting together an experienced team
    - Travel to and from the site
    - Safety precautions and PPEs
    - Sample collection equipment

- Once at the site, after observing the basic site conditions, the next step would be sample collection and analysis. This would entail planning as to:
    - Number and volume of samples
    - Sampling locations
    - Sampling procedure
    - Chain of custody
- Laboratory analysis
- Processing of results
    - Identifying the chemicals and their concentrations
    - Identifying their associated hazards (toxicity /corrosiveness /flammability /reactivity)
    - Identifying the receptors on which they will act
    - Ascertaining the tolerance limits of the receptors
- Modeling studies for forecasting future impacts
- Finalizing the remediation procedure

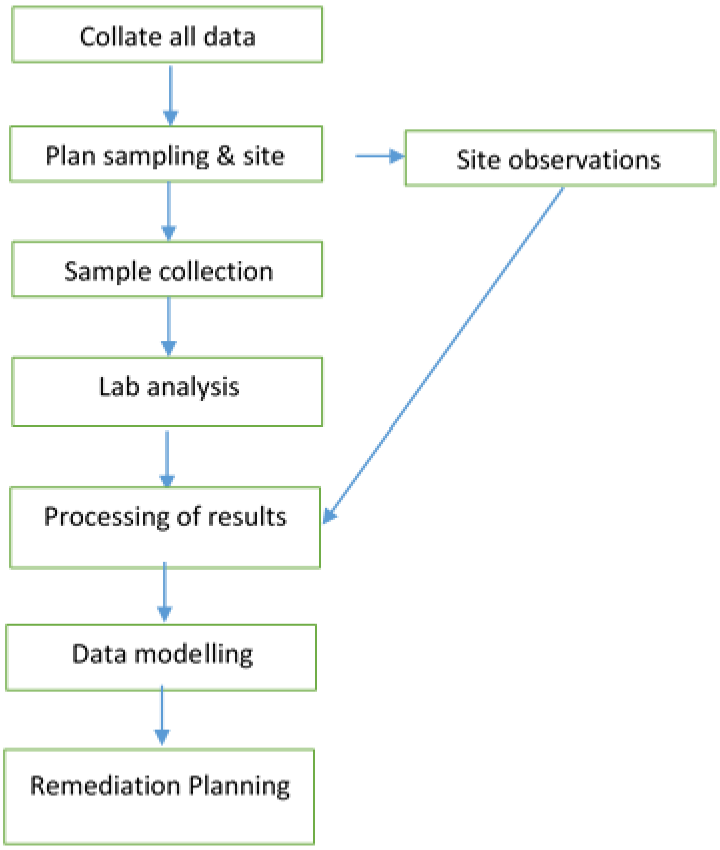

Figure 1.6: Schematic overview of risk assessment

1.5 Policy framework

Hazardous and other wastes (Management and transboundary movement) rules, 2016

"Waste" means materials that are not products or by-products, for which the generator has no further use for the purposes of production, transformation or consumption. "Hazardous waste" means any waste which by reason of characteristics such as physical, chemical, biological, reactive, toxic, flammable, explosive or corrosive, causes danger or is likely to cause danger to health or environment, whether alone or in contact with other wastes or substances.

The responsible agency is the concerned State Pollution Board or the Pollution Control Committees, along with the State Environment Department. It caters to both solid, semi-solid and liquid hazardous wastes.

There is stress on resource recovery, whether through reuse and recycling of other wastes or through energy recovery from co-processing. There are about 1080 registered hazardous waste recyclers in India; 54 cement plants have been permitted for co-processing; also, about 108 industries are permitted for utilization of hazardous waste. In addition, there are 18 hazardous waste Treatment, Storage and Disposal Facilities (TSDFs), as highlighted in Table 1.2.

Figure 1.7: Hazardous waste management hierarchy

Import-export of hazardous waste - The Basel Convention, which is an international treaty aimed at regulating and reducing the transfer of hazardous waste from developed to developing countries, was ratified by India in 1992. The import and export of hazardous waste in India is governed by the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016, keeping into consideration the tenets of the Basel Convention. The Convention was opened for signature on

22 March 1989, and entered into force on 5 May 1992. As of October 2018, 186 states and the European Union are parties to the Convention.

The Chemical Accidents (Emergency Planning, Preparedness, And Response) Rules, 1996 – These rules were promulgated under the ambit of the Environmental (Protection) Act, 1986. These rules recommend the -

- Formation of Central, State, District and Local Crisis Groups for combating chemical accidents
- Setting up a crisis alert system (complete with a functional control room, information networking system, emergency contacts)
- Hierarchy maintenance from local to district to state to center in terms of review, analysis and query-solving
- Detailed scrutiny, analysis and regular monitoring of post-accident conditions
- Raising adequate awareness among the public

This 4-tiered crisis management system is critical for ensuring a comprehensive chemical accident management plan.

To sum-up the duties of the Local Crisis Group:

- Prepare local emergency plan for the industrial pocket
- Ensure dovetailing of the local emergency plan with the district off-site emergency plan
- Train personnel involved in chemical accident management
- Educate the population likely to be affected in a chemical accident about the remedies and existing preparedness in the area
- Conduct at least one full scale mock-drill of a chemical accident at a site every six months
- Forward a report to the District Crisis Group
- Respond to all public inquiries on the subject.

Interact with your Local/District Crisis Group to understand their roles and responsibilities and make a report on Disaster Management Plan for a Chemical Fertilizer Plant.

Atomic Energy (Safe disposal of radioactive wastes) Rules, 1987 – Under the aegis of the Atomic Energy Act, 1962, the Atomic Energy (Safe disposal of radioactive wastes) Rules, 1987 were promulgated. These rules strongly restrict the methodology by which, location where and entity who can handle, store, or dispose radioactive waste. The rules make it imperative to have a Radiological

Safety Officer to oversee the radioactive waste management and disposal process. The Atomic Energy Regulatory Board (AERB) is empowered to undertake specific actions to ensure that the provisions of rules falling within the ambit of the Atomic Energy Act, 1962 are met, with the ultimate aim of ensuring radiological and industrial safety.

The disposal method outlined by these rules includes:

- Burial into pits
- Incineration

The burial of radioactive waste should be in isolated spots that have been adequately fenced off to prevent intrusion. Geological, topographical and environmental factors of the site need to be taken into consideration. Adequate record-maintenance is crucial. Other specific instructions include:

- When more than one radio nuclides is present in the solid waste, the sum of the ratios of the individual quantities of each of the radioisotopes present and their respective maximum quantities allowed have been outlined in the text of the Act.
- The depth of the burial pit must be so that at least 120 cm thick compacted earth may be laid over and above it for closure
- A distance of at least 180 cm is maintained between consecutive pits
- 12 burials per year has been set as the limit
- At least 10 half-lives of the radioactive waste component with the highest half-life need to have elapsed, before the pit can be opened for reuse
- The burial site must be subjected to regular checking by the Radiological Safety Officer
- The material excavated from a closed pit is released for normal disposal, under the supervision of the Radiological Safety Officer before reusing the pit (after 10 half-lives have elapsed)

Another possible option is the incineration of the radioactive waste, though critical care should be taken to ensure that:

- The incinerator is in working condition and well-maintained
- There is no possibility of release of radioactive nuclei in the air
- Adequate environmental monitoring, and scrupulous record-keeping are being conducted

Bio-Medical Wastes (Management and Handling) Rules, 2016 – These rules aim at streamlined segregation, collection, processing and safe disposal of waste generated from hospitals, clinics, pathology labs, research labs, veterinary hospitals, blood banks, various health camps etc. The monitoring agencies, in addition to the State Pollution Control Boards/Pollution Control Committees and Central Pollution Board, following are the prescribed authorities –

- The Ministry of Environment, Forestry & Climate Change
- Ministry of Environment, Forest and Climate Change
- Central or State Ministry of Health and Family Welfare
- Central Ministry for Animal Husbandry and Veterinary or State Department of Animal Husbandry and Veterinary
- Ministry of Defense
- Central Pollution Control Board
- State Government of Health or Union Territory Government or Administration
- Municipalities or Corporations, Urban Local Bodies and Gram Panchayats.

Color-coding of bio-medical wastes and their treatment/disposal options have been outlined in Table 1.9 below:

Table 1.9: Color-coding of bio-medical wastes and their treatment/disposal options

Color-code	Waste	Fate
Yellow	Human anatomical waste	Incineration/plasma pyrolysis or deep burial in sanitary landfill
	Animal anatomical waste	
	Soiled waste (dressing & bandages, cotton swabs etc.)	Incineration/plasma pyrolysis or deep burial in sanitary landfill; if above options not possible, these waste items can be sterilized and shredded and preferably sent for energy recovery
	Discarded/expired medicines	To be returned to manufacturer, or incinerated at ≥ 1200°C; alternately, waste may be encapsulated and transported to a common bio-medical waste or hazardous waste treatment facility
	Chemical waste	Incinerated at ≥ 1200°C; alternately, waste may be encapsulated and transported to a common bio-medical waste or hazardous waste treatment facility
	Chemical liquid waste	
	Discarded linen, mattresses contaminated with blood/body fluids	Non-chlorinated disinfection followed by incineration/plasma pyrolysis; if above options not possible, these waste items can be sterilized and shredded and preferably sent for energy recovery
	Microbiology, biotechnology and clinical lab waste	Non-chlorinated disinfection (as per World Health Organization or National AIDS Control Organization guidelines) followed by incineration
Red	Contaminated waste (recyclable)	Sterilization, followed by shredding; plastic bio-medical waste should not be sent to landfill; instead effort should be made to recycle it (by SPCB/PCC-recognized recyclers) or used in fuel generation or plastic road-making
White	Sharps	Sterilization, followed by shredding and encapsulation; final

(Translucent)		disposal in SPCB/PCC-recognized iron foundries or sanitary landfills or concrete pits
Blue	Glassware (except those contaminated with cytotoxic waste)	Detergent wash and hypochlorite treatment followed by sterilization; it may then be sent for recycling
	Metal implants	

Source: Kharat (2016)

The Biomedical Wastes (Management and Handling) Rules, 2016 set revised emission criteria to be met by the treatment facilities.

Importantly, hazardous micro-organisms and genetically engineered micro-organisms do not fall within the purview of these rules.

To-Do Activity – Visit a bio-medical waste handling facility nearby and understand its operation; N.B. National Accreditation Board for Hospitals & Healthcare (NABH)-accredited hospitals are likely to have bio-medical waste management facilities

The E-Waste (Management) Rules, 2016 – Under the aegis of the Environmental (Protection) Act, 1986, the E-Waste (Management) Rules, 2016 were promulgated to target manufacturers, consumers, dealers, dismantlers, collection-center managers etc. of e-waste (laptop, cellular phones, electrical & electronic equipment). The rules aim at enabling recovery and/or reuse of useful material from e-waste, thereby reducing the hazardous wastes destined for disposal, to ensure the environmentally sound management of all types of e-waste and to address the safe and environment-friendly handling, transport, storage, and recycling of e-waste. The concept of Extended Producer Responsibility (EPR) was introduced through these rules, which made manufacturers liable for safe disposal of electronic goods. Occupational safety and health aspects of the workers engaged in recycling will be monitored annually by the Department of Labor in the State or any other State Government-authorized government agency.

The Batteries (Management & Handling) Rules, 2001 – these rules aim at regulated collection, proper channelization and recycling of used lead acid batteries; the import of such batteries within India are also within the ambit of these rules. While these rules make it mandatory for consumers to return the used batteries (and not dispose them of mixed with their other waste items), it is the responsibility of the manufacturers/assemblers/re-conditioners/importers to collect the same. The final fate of these batteries is their recycling by MoEFCC-registered recyclers.

To outline the responsibilities of the manufacturers/assemblers/re-conditioners/importers:

- ensure that the used batteries are collected back as per the Schedule against new batteries sold excluding those sold to original equipment manufacturer and bulk consumer(s)
- warrant that used batteries collected are of similar type and specifications as compared to the new batteries sold
- file six monthly return of sales and buy-back (in June and December)
- encourage collection of used batteries by setting up collection centers individually or in consortium
- see to it that the next lap of journey – from collection center to the recycler – is also made with every pre-caution for safety
- make sure the all possible pre-cautions have been taken to ensure safe transport
- ensure all possible means of creating awareness among the general public, using social interaction tools such as poster/banners/pamphlets etc. regarding
    - potential health issues caused by lead
    - the fact that it is the solemn duty of each consumer to ensure that their spent lead batteries are deposited with listed dealers or collection centers
    - addresses of dealers and designated collection centers
- the international recycling sign must be imprinted on the batteries
- purchase of recycled lead must be made only from listed recyclers
- ensure that violations by the dealer, if any, are notified to the MoEFCC or State Board, as relevant

It is the CPCB that scrutinizes and registers potential importers of battery scrap in India.

Solid Waste Management Rules, 2016 - As per these rules, the local government (municipality or panchayat) is instructed to "establish waste deposition centers for domestic hazardous waste" wherein the waste generator, having been suitably sensitized to segregate items such as paint cans, expired medicines etc. is required to deposit the hazardous waste generated in his/her household. Finally, the local government is required to arrange the transport of this waste to the closest hazardous waste disposal facility.

Summary:

Thus, to summarize, it is necessary for anyone working in the field of waste management to understand the nature of hazards associated with different waste types – from the innocuous municipal solid waste and electronic waste to the radioactive/ nuclear waste and chemical waste of well-established hazard.

Hazardous wastes are supposed to be adequately labeled to clarify the hazards associated with them, but under dire situations, recognition of the hazardous item must depend on the physical features of the waste item, or its impact on other biological receptors.

Staying alert and understanding the use of safety equipment is key to one's well-being when working under high-risk situations. The individual must acquire adequate information about the features of PPE, and ensure wearing the same.

Risk assessment is a standard protocol for evaluating the risk associated with accidental spillage or other mishaps. Understanding the tenets of a risk management exercise will help a waste management professional stay prepared for contingencies.

Lastly, a very thorough set of rules and regulations provide a policy framework for managing different types of wastes in the Indian context. These rules cover even the minutest aspects of managing harmful wastes emerging from different sources. This policy framework will guide waste management professionals in the right direction.

To conclude, it is anticipated that the risks associated with various types of waste are amply clear for each aspirant who wishes to foray into the field of waste management. These risks need to be understood clearly, assessed rationally, and converted to opportunity.

Model Questions:

Q1. Prepare a business case for used lead acid battery scrap import in India and its subsequent sale to recyclers. Would it be more profitable to collect battery scrap from individual user households in a given Indian city? Compare and analyze.

Q2. Give the details of potential hazards from handling e-waste. Can a sustainable, worker-friendly business model be prepared for profitable e-waste recycling?

Q3. How would you go about planning a sampling exercise for a distant mountain stream where liquid hazardous waste was illegally dumped?

Q4. Plan a hard-hitting awareness raising campaign for household hazardous waste management.

Q5. Analyze where in India would be a likely location for setting up a hazardous waste TSDF, with the aim of maximizing your profit.

Reading material:

United States Environmental Protection Agency

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Chapter 2 Waste Management Technologies

Introduction

Waste is anything that has ceased to have utility or value. However, to all intents and purposes, this definition does not apply to most of the items we daily discard in our bins or flush out. Most of the waste items have the potential to be used as a resource – either as raw material for other products or as a source of energy.

Also, while it is true that most waste items are potential resources, it is possible that some risk of injury /infection/ other harm or environmental damage is associated with them. Hence, waste management acquires a two-fold process –

- Resource recovery from the waste items
- Safe disposal

These twin purposes can be solved with the aid of technology.

While the hazards associated with waste have been described in the previous Chapter, the second Chapter focuses on the purpose of resource recovery.

Both conventional as well as new, upcoming technologies for solid and liquid waste management have been described in this Chapter. While conventional technologies are well-established and their performance criteria researched and documented for different field conditions, the newer technologies need to establish their credibility, one case study at a time. It is important to understand the applicability of conventional as well as newer technologies – while the former have to be applied to situations where experimentation cannot be brooked, the latter, with their lower environmental footprint, need to be established and researched under field conditions.

One non-technical factor that can be often ignored during technical discussions pertaining to waste management is the socio-cultural aspect – in the present Chapter, the socio-cultural attitude towards waste management has been included.

Objectives

Based on the above background, objectives of this Chapter may be enlisted as:

- Understanding the features of different types of waste items

- Understanding the different treatment processes of different types of waste to ensure efficient resource recovery and effective treatment
- Comprehending how socio-cultural aspects can impact effective waste management

2.1 Overview of solid waste management technologies

Solid waste – definition, types and overview

Solid waste may be defined simply as any solid or semi-solid material deemed to be of no value and hence, discarded. However, for effective management and treatment of solid waste one must necessarily acquire deeper insight into its origin, composition and nature.

The policy framework in India puts forth a centralized approach to waste management, with the local government deemed to be the implementing agency in most cases, and the bulk generator of waste in other cases. Clearly, then, the origin of solid waste becomes the most critical step to be determined when planning the execution of solid waste management technologies.

Based on origin, solid waste may be divided into the following categories:

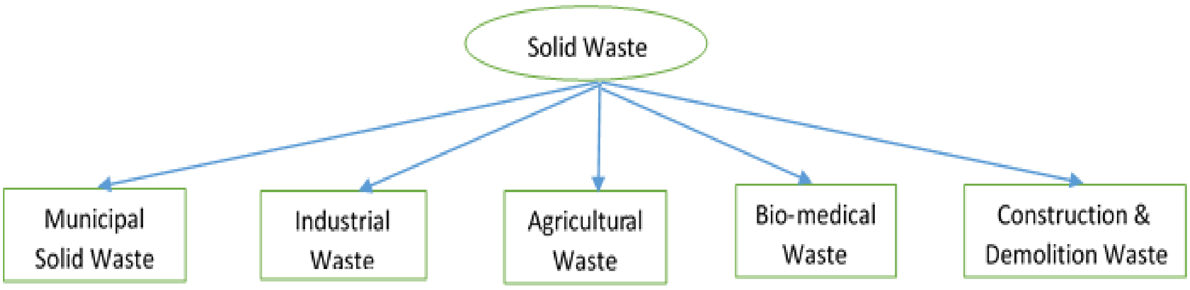

Figure 2.1: Categories of solid waste based on origin

Different types of wastes have different components, and hence, the approach to their management and treatment differs. These components may either be non-hazardous or hazardous. While in the previous case, stress must be on resource recovery and subsequent disposal, for hazardous waste, safe handling and disposal acquires greater importance unless the value and ease of resource recovery from such type of waste is high. Hence, effective solid waste management must aim at

- Effective resource recovery
- Safe disposal

Waste management broadly involves the following basic steps, and technology intervention at each step can help make the process more efficient.

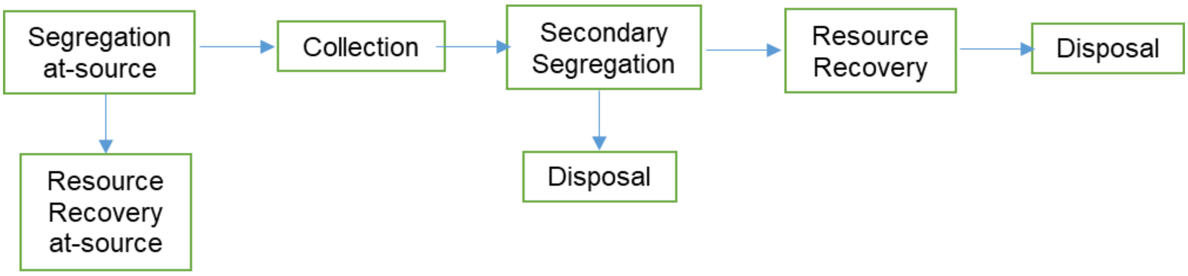

Figure 2.2: Overview of ideal solid waste management process

In **Table 2.1** below, the composition of different waste types has been delineated:

Table 2.1: Components of different waste types with treatment approaches

Type of Waste	Composition	Nature	Treatment
Municipal Solid Waste (MSW)	Kitchen/Wet Waste (leftover food, vegetable/fruit peels, used tea leaves etc.)	Organic, non-hazardous	Composting/Bio-methanation
	Dry Waste (plastic/paper wrappings, newspaper, aluminum foils etc.)	Inorganic, non-hazardous	Reuse/Recycle
	Household Hazardous Waste (batteries, used spray cans of pesticides/paint, spent medicines,	Inorganic, hazardous	Safe Disposal; Recycle
	Sanitary Waste (soiled sanitary pads, baby diapers)	Organic, inorganic, hazardous	Incineration
	Electronic Waste (laptops, mobile phones etc.)	Inorganic, hazardous	Safe Disposal; Recycle
Industrial Solid Waste	Hazardous Waste (Chemical sludge,	Organic, inorganic, hazardous	Incineration/Secure landfill
	Kitchen/Wet Waste	Organic, non-hazardous	Composting/Bio-methanation
Agricultural Waste	Straw & chaff, animal fecal matter	Organic, non-hazardous	Composting/Safe Incineration
Bio-medical Waste	Blood & tissues, bandage & dressings, used needles, sharps, discarded microbial cultures etc.	Organic, inorganic, hazardous	Incineration/Secure landfill
Construction & Demolition Waste	Concrete, bricks, wood, roofing, tiles, etc.	Inorganic, non-hazardous	Reuse/Recycle

Technology to aid resource recovery

Depending upon the nature of waste, the resource recovery technology differs, and can broadly be categorized as –

- Composting – organic waste can be composted, i.e., broken down into a nutrient-rich product that can be used as a fertilizer or soil conditioner. Significant parameters that can impact the time taken and quality of compost produced are - carbon: nitrogen ratio, particle size, moisture content and aeration. Several technologies are available for composting, some of which have been briefly described below –

- Natural aerobic composting – organic waste is collected in a pit and churned manually once or twice a day; in about 30-45 days, the waste has been naturally converted into compost. In densely populated urban areas where it is not possible to dig such pits, composting bins of any locally suitable material (stainless steel/brick/wood/PVC mesh) can be used. For indoor use, tumblers (to aid manual churning) or composting kits with commercially available bacterial cultures to aid composting can be used.
- Waste composting machines – operating on electricity, these are compact and may be automated or semi-automated. Organic waste is fed into the machine wherein it is crushed into bits and churned, inoculated with a bio-culture and provided the optimum temperature and oxygen levels for composting.
- Vermicomposting – this process involves earthworms (Eisenia foetida, Eudriluseugeniae and Perionyx excavatus) to help digest the organic waste, producing castings that can be used as manure.
- Windrow composting – organic waste is spread out into piles and mechanically or manually churned.

Figure 2.3: a) Composting pit b) Tumbler c) Waste composting machines d) Vermicomposting e) Windrow composting

- Bio-methanation – This technology involves the anaerobic conversion of organic waste by micro-organisms into methane gas and a nutrient-rich slurry. Three types of bacteria, i.e., fermenting bacteria, organic acid oxidizing bacteria and methanogenic archaea are involved in the complete process leading to a cascade of reactions. While the methane gas can be used for combustion, the slurry is nutrient-rich and can be utilized as field manure. This model has a potential to generate energy and reduce the load on fossil fuel.

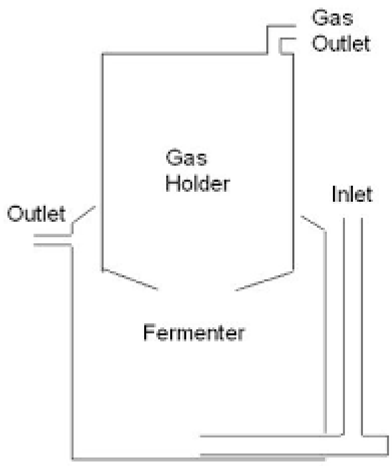

Figure 2.4: Overview of a bio-methanation unit

- Reuse, recycling & upcycling
  - Reusing an article after minor repair (if required) is the simplest and most nature-friendly way of inorganic, non-hazardous waste management. For instance, cleaning up of glass bottles, strengthened cardboard boxes, wooden crates, metal cans etc. C&D waste can also be reused as the base material for making roads, as landscape features, as land-filling material for quarry reclamation etc.
  - Pandey and Sharma (2015) indicates that recycling involves processing of the item, breaking it down into its constituents, and then using these constituents to yield another product. For instance, some types of plastics can be broken down into pellets and, these pellets can be further used to manufacture items like toys, baskets, umbrella handles etc. Likewise, glass can be melted and re-molded. Wood can be refashioned into smaller wooden articles and metals can be melted and made into bars for further use.
- Incineration – Incineration should not be confused with open burning, wherein neither the temperature nor the escape of dangerous flue gases can be controlled and the ash and heat generated may or may not be utilized. Incineration can be one of the best treatments for Municipal as well as industrial solid waste in big urbanized cities, as it reduces the quantity and volume of waste that has to be landfilled. Clearly then, incineration technologies aim at –
  - Temperature control to ensure complete destruction of the type of waste item being destroyed

- Stripping of the flue gases of particulate matter and gaseous pollutants
- Reuse of ash as a resource
- Heat recovery

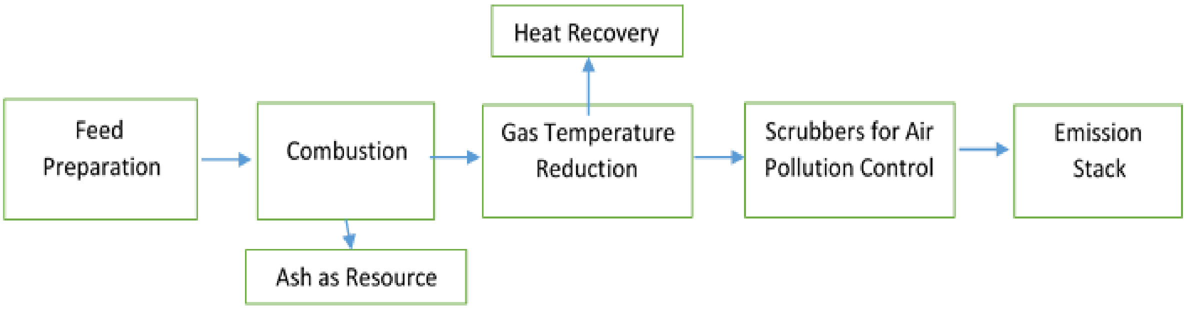

Figure 2.5: Overview of the incineration technology

Bio-medical waste that can be infectious or otherwise harmful to the environment needs to be safely incinerated. Also, several recyclable items that have already undergone 2-3 cycles of recycling cannot be recycled anymore and need to be incinerated. In addition, there are certain waste items that can in principle be recycled but the process is too time or labor-consuming; for such items, the most ideal fate is to be incinerated. For instance, multi-layer packaging material used in wrapping chips, biscuits etc.

Landfilling – Secure landfilling to ensure reduced leachate and non-contamination of groundwater can be the only solution in some cases. For instance, biomedical waste and multi-layer packaging material in remote villages where safe incinerators or transport of such wastes to the nearest incinerator are both too expensive options, secure landfill is feasible. A secure landfill must essentially have the following components –

- A liner system composed of thick clay or geotextile membrane to prevent leachate intrusion into groundwater
- A leachate collection and treatment system
- Gas recovery pipes
- Capping system

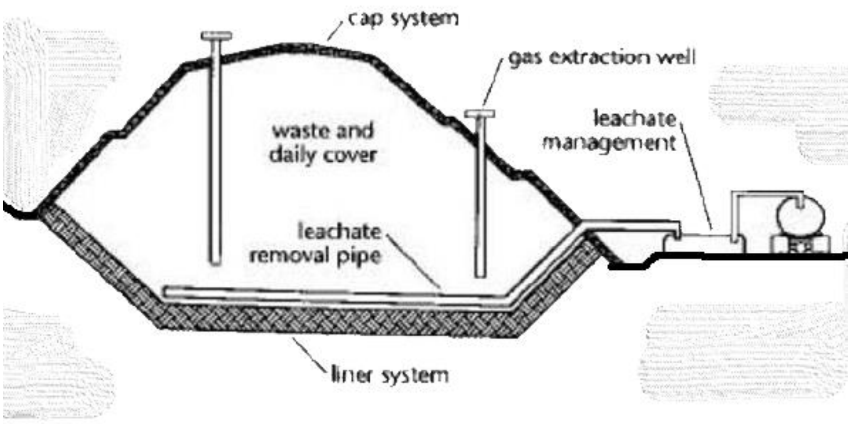

Figure 2.6: Secure landfill design

Hence, to summarize:

- Organic, non-hazardous waste such as kitchen waste can be converted to manure or bio-gas. Agricultural waste such as straw etc. which are low in moisture content can be converted to briquettes and used as fuel; livestock manure can be converted to biogas
- Inorganic, non-hazardous waste can either be reused, recycled or incinerated to yield energy
- Organic/Inorganic, hazardous waste from which no resource recovery is possible should either be incinerated or buried into septic landfills
- Inorganic, hazardous waste from which resource recovery is possible should only be handled and processed taking all possible safety precautions

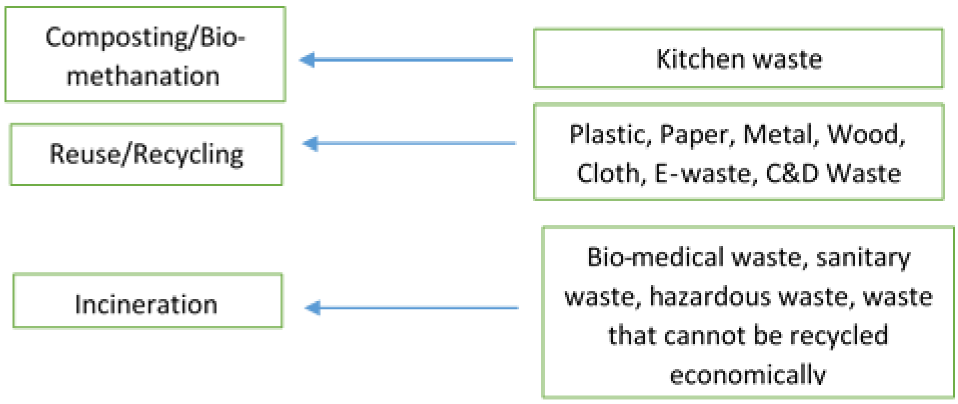

Figure 2.7: Overview of waste management technologies

To-do-activity: Make a team and visit a nearest waste management facility and prepare a Solid and Liquid Waste Management Plan for your college. (Note: The plan should highlight type and quantity of waste generated, sources, ideas for optimum utilization of waste and its further management).

2.2 Overview of Liquid Waste Management Technologies

Wastewater is largely of domestic or industrial origin.

Stages of conventional wastewater management

Sewage Treatment Plant has three treatment stages: Primary, Secondary and Tertiary.

Pre-treatment: Large solids (i.e. those with a diameter of more than 2cm) and grit (heavy solids) are removed by screening. These are disposed of in landfills.

Primary treatment: The water is left to stand so that solids can sink to the bottom and oil and grease can rise to the surface. The solids are scraped off the bottom and the scum is washed off with water jets. These two substances are combined to form sludge.

Secondary treatment: The sludge is further treated in 'sludge digesters': large heated tanks in which its chemical decomposition is catalyzed by microorganisms. The sludge is largely converted to 'biogas', a mixture of CH_4 and CO_2, which is used to generate electricity for the plant. The liquid is treated by bacteria which break down the organic matter remaining in solution. It is then sent to oxidation ponds where heterotrophic bacteria continue the breakdown of the organics and solar UV light destroys the harmful bacteria.

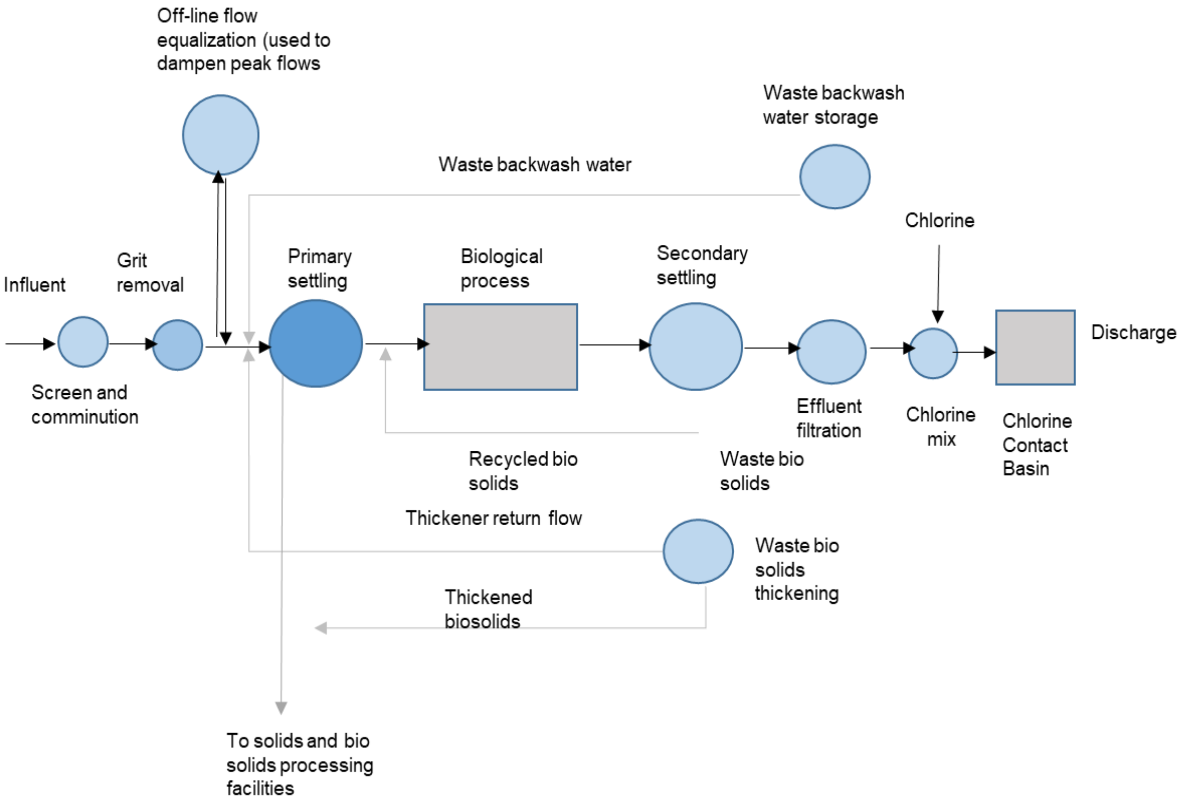

Figure 2.8 Schematic of a typical sewage treatment plant

Stand-alone technologies

Moving bed bioreactor (MBBR) technology combines the benefits of both activated sludge process and the fixed film process. It is a continuous flow process that uses media carrier, which yields the site for attachment of active bacteria in a suspended medium which can be used for wastewater treatment.The MBBR process uses carrier elements (plastic carriers, PVA Gel beads) to provide sites for bacteria attachment in a suspended growth medium. The carrier elements allow a higher biomass concentration to be maintained in the reactor compared to a suspended growth process, such as activated sludge. The biomass grows on small carrier elements that move along with the water in the reactor. The movement is caused by aeration in the aerobic version of the reactor and by a mechanical stirrer in the anoxic/anaerobic version.

Advantages of MBBR

- Compact units with small size.
- Increased treatment capacity.
- Complete solids removal.
- Improved settling characteristics.
- Operation at higher suspended biomass.
- Concentrations resulting in long sludge retention times.
- Enhanced process stability.
- Low head loss.
- No filter channeling.
- No need of periodic backwashing.
- Reduced sludge production.
- Low maintenance compared to other sophisticated technologies.

Disadvantages of MBBR

- Problems due to long start-up times due to bio layer formation on the carrier.
- Difficulties due to control of bio layer thickness.
- High energy consumption due to very high liquid recirculation ratio.
- High investment cost for liquid distribution to obtain uniform fluidization, especially in a large scale plant.
- The quality of plastic of media varies.
- The verification of whether the media is moving about the entire volume of the tank or merely clumping at the top layers and if so the method of mixing it up through the tank

volume without shearing of the biomass on it are issues of infirmity and which may need gentle movers of the media through the volume of the tank.

- Furthermore, the media is a patented product.
- Higher energy input

Activated sludge process: In activated sludge process, wastewater containing organic matter is aerated in an aeration basin in which micro-organisms metabolize the suspended and soluble organic matter. Part of organic matter is synthesized into new cells and part is oxidized to CO_2 and water to derive energy. In activated sludge systems the new cells formed in the reaction are removed from the liquid stream in the form of a flocculent sludge in settling tanks. A part of this settled biomass, described as activated sludge is returned to the aeration tank and the remaining forms waste or excess sludge.

Advantages of ASP

- Capable of removing 97% of suspended solids
- Biological nitrification without adding chemicals
- Oxidation and nitration achieved
- Biological phosphorous removal
- Solids and liquids separation
- Removes organics
- Cost effective
- Easily maintained mechanical work
- Self-sustaining system

Disadvantages of ASP

- Cleaning is a hassle
- Most plants need at least three tanks
- Temperature changes affect the tank greatly

Sequencing batch reactor: The Sequencing batch reactor (SBR) is an activated sludge process designed to operate under non-steady state conditions. An SBR operates in a true batch mode with aeration and sludge settlement both occurring in the same tank. The major differences between SBR and conventional continuous-flow, activated sludge system is that the SBR tank carries out the functions of equalization aeration and sedimentation in a time sequence rather than in the conventional space sequence of continuous-flow systems. In addition, the SBR system can be designed with the ability to treat a wide range of influent volumes whereas the continuous system is based upon a fixed influent flow rate. Thus, there is a degree of flexibility associated with working in a time rather than in a space sequence

Advantages of SBRs

- Equalization, primary clarification, biological treatment, and secondary clarification can be achieved in a single reactor vessel.
- Operating flexibility and control.
- Potential capital cost savings by eliminating clarifiers and other equipment.

Disadvantages of SBRs

- A higher level of sophistication is required especially for larger systems, of timing units and controls.
- Higher level of maintenance associated with more sophisticated controls, automated switches, and automated valves.
- Potential of discharging floating or settled sludge during the draw or decant phase with some SBR configurations.
- Potential plugging of aeration devices during selected operating cycles, depending on the aeration system used by the manufacturer.

- Potential requirement for equalization after the SBR, depending on the downstream processes.

Membrane bioreactor technology: Membrane bioreactor technology is based on biological treatment followed by membrane separation, system comprising of an intense activated sludge process with the biomass separation stage carried out by membrane cassettes located outside the aeration tank in separation membrane tank. The membrane replaces settlement stage in conventional activated sludge systems and effectively revolutionizes the process. The separation of biomass from treated water using membrane provides filtered quality final effluent, offering possibility of reuse. It allows very high biomass mixed liquor suspended solids (MLSS) concentrations to be developed in the bioreactor without the detrimental effects usually associated with traditional settlement technique.

Advantages of MBR

- MBR system is such that it effectively overcomes the limitations associated with poor settling of sludge in conventional sludge processes.
- It is also a cheaper source of water filtration being more rapidly used today.
- Filtering creates a disinfection barrier
- Produces less waste.
- Allows re-use of water.

Disadvantages of MBR

- Membrane modules are expensive and have to be replaced every 5 to 10 years.
- Cleaning solutions for the system can be considered hazardous waste.
- Requires skilled maintenance.

Upflow anaerobic sludge blanket: Upflow anaerobic sludge blanket (UASB) technology, normally referred to as UASB reactor, is a form of anaerobic digester that is used in the treatment of wastewater. The UASB reactor is a methanogenic (methane-producing) digester that evolved from the anaerobic clarigester. UASB uses an anaerobic process whilst forming a blanket of granular sludge which suspends in the tank. Wastewater flows upwards through the blanket and is processed (degraded) by the anaerobic microorganisms. The upward flow combined with the settling action of gravity suspends the blanket with the aid of flocculants.

The blanket begins to reach maturity at around 3 months. Small sludge granules begin to form whose surface area is covered in aggregations of bacteria. In the absence of any support matrix, the flow conditions create a selective environment in which only those microorganisms, capable of attaching to each other, survive and proliferate. Eventually the aggregates form into dense compact biofilms referred to as "granules". Biogas with a high concentration of methane is produced as a by-product, and this may be captured and used as an energy source, to generate electricity for export and to cover its own running power. The technology needs constant monitoring when put into use to ensure that the sludge blanket is maintained, and not washed out (thereby losing the effect). The heat produced as a by-product of electricity generation can be reused to heat the digestion tanks.

Advantages of UASB

- Low land demand.
- Reduction of CH_4 emissions from uncontrolled disposal/”open” treatment (ponds) due to enclosed treatment and gas collection.

- Reduction of CO_2 emissions due to low demand for foreign (fossil) energy and surplus energy production.
- Low odor emissions in case of optimum operation.
- Hygienic advantages in case of appropriate post-treatment.
- Low degree of mechanization.
- Few process steps (sludge and wastewater are treated jointly).
- Low sludge production, high sludge quality.
- Low demand for foreign exchange due to possible local production of construction material, plant components, spare parts.
- Low demand for operational means, control and maintenance.
- Correspondingly low investment and operational costs.

Disadvantages of UASB

- Insufficient standardization and adaptation for several implementation possibilities
- Methane and odor emissions (also of end-products) in case of inappropriate plant design or operation
- Insufficient pathogen removal without appropriate post-treatment
- Sensitivity towards toxic substances
- Long start-up phase before steady state operation, if activated sludge is not sufficiently available.
- Uncertainties concerning operation/ maintenance due to still low local availability of know-how and process knowledge.

Table 2.2: A brief comparison of the available technologies

	Moving Bed Bioreactor (MBBR)	Sequencing Batch Reactor (SBR)	Membrane Bio-reactor (MBR)
Removal efficiency (%)	> 90% -92%	95-98%	99%
Quality of treated effluent achieved	BOD< 20 mg/L and TSS < 30 mg/L	BOD< 10 mg/L and TSS < 10 mg/L	BOD< 1 mg/L and TSS < 1 mg/L
Hydraulic Retention Time (HRT, hrs)	3.5 - 4.5 hrs	Minimum 15 hrs	4-6 hrs
Solids Retention Time (SRT, days)	Minimum 6 days	Minimum 20 days	5- 20 days
MLSS (mg/l)	6000 - 9000 mg/l	2000 - 5000 mg/l	8000- 10000 mg/l
BOD Loading (kg/m^3.d)	1-1.4	0.1-0.3	COD Loading - 1.2 - 3.2 (kg/m^3.d)

Primary Clarifier	Required	Not Required	Not required
Extra provision for shock loading/Fluctuations	Equalization Tank must be provided before MBBR tank to handle shock loadings	No equalization tank is required before biological treatment. But Batch discharge may require equalization prior to disinfection	Not required
Process performance	Good, and it works well for low strength sewage.	Good. But process control is more complicated and high peak flows/ shock loadings can disrupt operation.	Excellent. Adaptable to many types of wastewater and it has large dilution capacity for shock and toxic loads. Organic matters (BOD) are well removed because of lower concentration of TSS compared with other process technologies.
Potential of re-use/ recycle	Additional tertiary treatment (micro-filtration/ ultra-filtration etc.)units required in order to make re-cycle quality effluent	Additional tertiary treatment (micro-filtration/ ultra-filtration etc.)units required in order to make re-cycle quality effluent	Treated water by MBR can be reused for various purposes such as toilet flushing, gardening, etc. without further additional treatment
Sludge production	Large quantity of sludge is produced which is undigested in nature and creates odor & nuisance	Lesser quantity of sludge is produced which is partially digested in nature.	Very less quantity of sludge produced, which is almost Nil during first year of operation.
Operation and Maintenance	O&M is cumbersome as the attached media needs to be replaced after suitable duration of time to ensure proper surface area is available for micro-organisms to grow (minimum 20-25% media needs to be replaced in every 3-4 yrs)	Requirement for more than one tank to accommodate cleaning schedules	1. Operation and maintenance works are easy and free from control of sludge bulking because final sedimentation tank is not required. 2. E-coli is blocked by MF membrane with pore size of less than 0.4 micro meters which is generally used for MBR system, hence, requirement of disinfection system is eliminated

Power consumption	Low power consumption	Higher Power consumption than extended aeration and MBBR	Comparatively higher power consumption as permeate produced from MBRs is transparent and fine containing almost no TSS, which is fit for re-use and re-cycle purposes. No further tertiary treatment is required.
Land Area requirement	Very low footprint among all.	Moderate	Least
Capital Cost	Lowest	High	Higher (justified where high quality treated water is required and land is a constraint)

2.3 Resource Recovery

The sustainability of the cradle-to-cradle approach is undeniable. It is in this approach wherein we regard each item – even if labelled as waste – as a potential resource or a raw material for generating something new. It is in contrast to the cradle-to-grave approach of the past, which was admittedly more wasteful.

Resource Recovery from waste is a prime example of the cradle-to-cradle approach.

Composting & bio-methanation:

Composting yields manure, which can serve as fertilizer as well as soil conditioner. In addition, it can be utilized in eco-restoration.

In contrast, bio-methanation yields two products – the methane generated can be used as fuel, while the slurry generated is rich in nutrient and serve as manure.

Dry Waste Reuse/Recycling

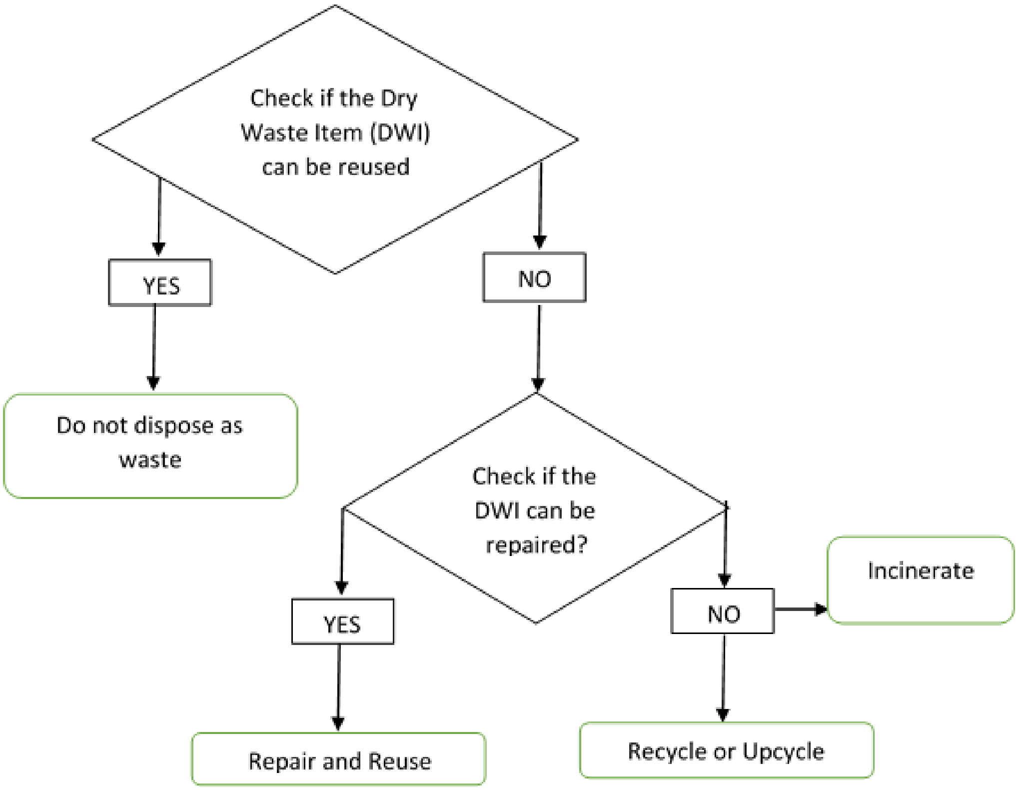

Figure 2.9: Flow-chart of dry waste management approach

Challenges of resource recovery from dry waste items –

- Poor segregation, which on one hand completely or partially destroys items such as paper and cloth, or soils them so badly that subsequent efforts at cleaning and disinfection become too costly to render resource recovery feasible.
- Complex dry waste items such as multi-layer packaging material, computer and electronic equipment require much effort in dismantling and separation into basic components. While in the case of the former, end products are not valuable enough to justify the labor cost, in the case of the latter, i.e., e-waste, the end products are valuable enough to justify the efforts at recycling.
- Even basic machinery such as shredder and compressor are hitherto unpopular in India

Potential fate of various dry waste items has been enlisted in the **Table 3** below:

Table 2.3: Potential fate of dry waste Items

Type of dry waste	Potential Fate
Paper	Paper bags, hand-made paper, tissue paper/toilet paper
Cloth	Cloth bags, fuel for boilers, fill for soft toys/pillows
Plastic	Pelletized, and the pellets sold to industries manufacturing items from it
Glass	New containers, bricks
Wood	Smaller articles of furniture, packaging, wooden flooring etc.
Metal	Formation of metal bars post its sorting, cleaning, melting and purification; bars sold

	to industries manufacturing items from it
C&D waste	Land-filling material, landscape material, base-filling of roads, bricks

In India, all dry waste management processes are manual with very little mechanization or automation. With insufficient segregation, the initial task of cleaning the items uses up labor and water.

To do Activity : Visit to nearest waste segregation and management centre

Material recovery facility:

MRF, pronounced as murfs, these are automated or semi-automated dry waste management units popular abroad where glass, metals, paper, and plastic are further separated to specific types as described below:

Metal – ferrous/non-ferrous

Paper – newspaper, magazine, cardboard boxes, office paper

Plastic – HDPE, PET

Items are sorted, baled, shredded, compacted and packed for supply to industries where these would be used as raw materials.

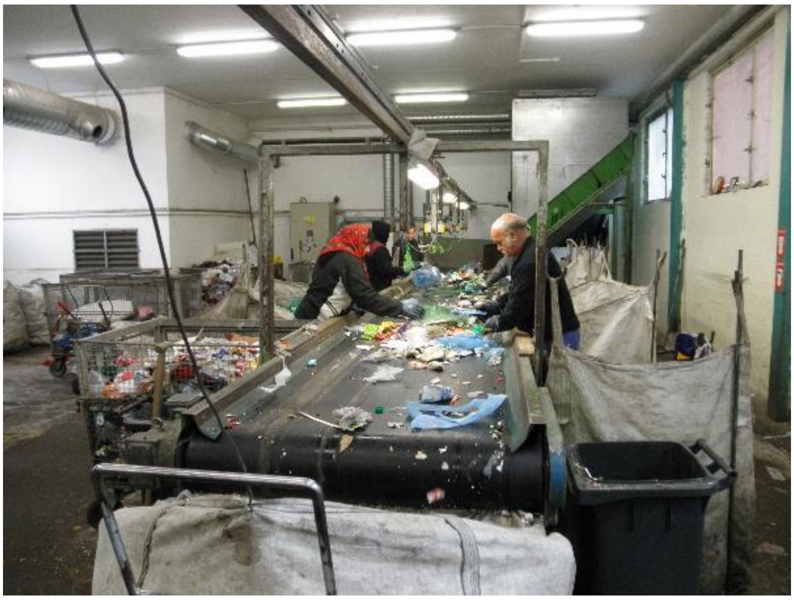

Figure 2.10: Material recovery facility photo for representation purposes

Landfill mining

Landfilling continues to be the waste disposal option for most Indian cities. Many landfills have been in use for several decades and contain waste dumps several hundred feet high. Some landfills (or landfill sections) have even been official closed as they cannot take the load of waste anymore. Importantly, given the poor rates of at-source waste segregation earlier, it is likely that several non-perishable dry waste items are still lying in the lower layers of a closed landfill. This concept forms the basis of landfill mining. Landfill mining is an excavation process like conventional mining, wherein tools similar to conventional mining are made use of to delve deep into closed landfills and excavate items of potential resale value, or of such hazard as to be deemed necessary to be removed. Benefits of landfill mining can be summarized below:

- Resource recovery
- A secondary benefit of the process is the release of landfill gas hitherto trapped within the waste piles.
- Another benefit is that the same landfill site, now that it has become partially empty, can begin to accept a fresh lot of waste; given that land is a scarce resource, this can be extremely beneficial

Waste-to-Energy (WtE)

These set of technologies attempt at recovery of energy from the waste, either in the form of electricity or heat. Refuse-derived fuel (RDF) is a broad term that applies to fuel obtained from waste, which replaces fossil fuels in residential as well as commercial units.

Several WtE processes and technologies are currently available, which have been summarized in the figure below:

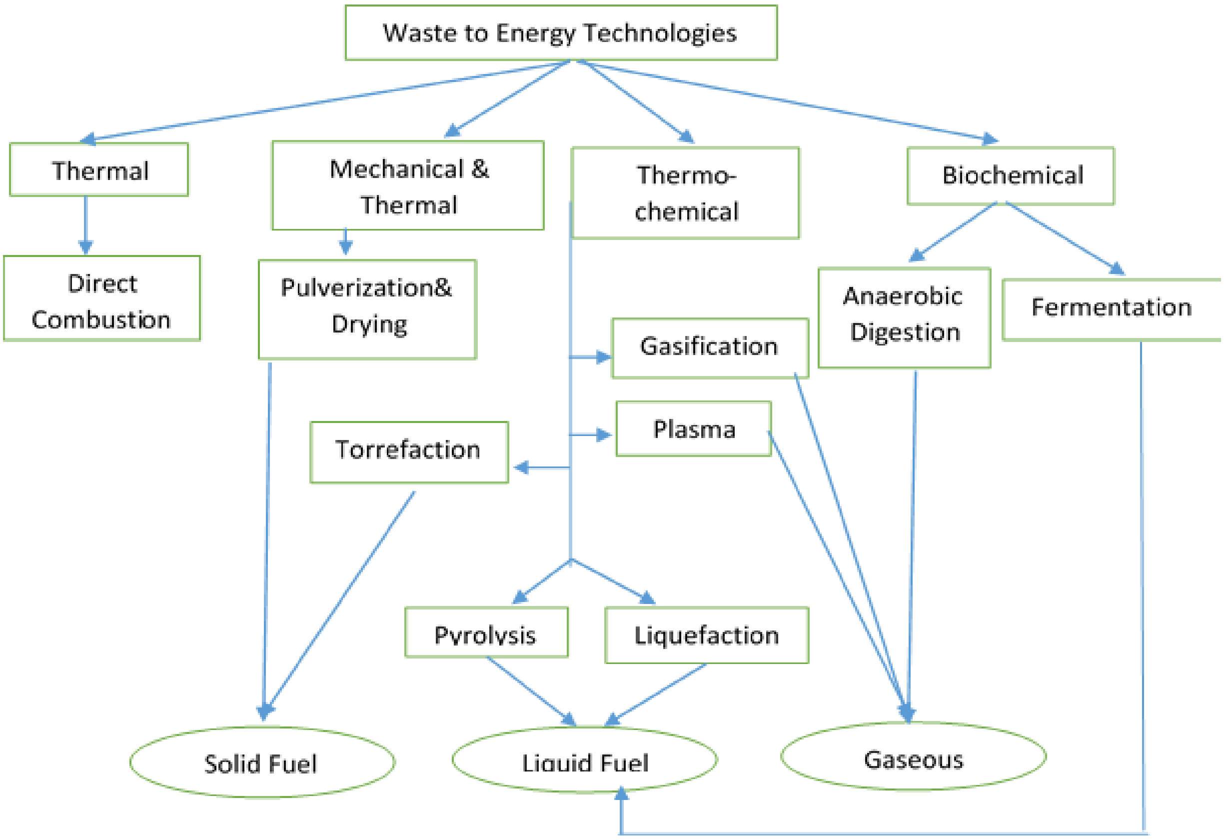

Figure 2.11: Overview of waste to energy technologies

Source: Gumisiriza R et al. (2017); Anaraki et al (2012)

- Pyrolysis – the thermal decomposition of matter at high temperatures, up to 700°C–800°C and under an inert atmosphere, i.e., in the absence of air/oxygen, is called Pyrolysis (pyro = fire, lysis = breaking down). Depending on the type of organic matter, the end-product can be oil, gas, carbon black or coke.
- Gasification – this is the conversion of organic material into gases such as carbon dioxide, carbon monoxide and hydrogen at temperatures higher than 700°C, in an atmosphere of controlled oxygen and/or steam and avoiding combustion.
- Torrefaction is a milder form of Pyrolysis wherein temperatures do not exceed 200-320 degrees C, and the end-product is brittle coal-like material with higher worth as fuel.
- Liquefaction is the direct conversion of biomass waste into liquid fuel. The reaction conditions (temperature, solvent, catalyst) will differ with different types of biomass.
- Plasma gasification is a high-end technology wherein plasma torch that has been powered by an electric arc ionizes and catalyzes organic waste (including hazardous waste) to yield slag and syngas.
- Briquette making – Briquettes are compressed blocks of biomass that can be used as fuel for domestic as well as industrial purposes.

Various Uses of Fly Ash and Bottom Ash

Fly ash is a coal combustion product. It is different from bottom ash, as it comes out of the emission stacks along with the flue gases while the bottom ash falls to the bottom. Bottom ash has been used as the alternate for construction material such as earth or sand, in road construction or in cement kilns for clinker production.

Various uses of Fly Ash have been outlined below:

- Cement clinker production
- Concrete production
- Slope/embankment stabilization
- Road sub-base formation
- Land filling material
- Fly ash bricks - Fly ash brick (FAB) is a building material, specifically masonry units, containing class C or class F fly ash and water. Compressed at 28 MPa and cured for 24 hours in a 66 °C steam bath, then toughened with an air entrainment agent, the bricks can last for more than 100 freeze-thaw cycles.

Resource recovery from human sewage

The most important resource to be recovered from sewage is water. While different technologies have different efficiency, treated sewage can be safely used for flushing and gardening purposes. In some cases, use of treated sewage for bathing has also been possible. In Singapore, treated sewage is even consumed as drinking water. Sewage sludge can be utilized as manure or soil conditioner.

To do Activity: Visit the sewage treatment plant of your city

Resource recovery from industrial effluent

While here, too, water forms one of the most significant resources obtained post the treatment, valuable inorganic and organic substances that can be recovered and reused in the same industrial processes are also valuable.

To do Activity: Visit the nearest industrial waste management plant and make a report on different categories of waste and process used for its treatment. Also, make a study of amount of waste recovered from the waste daily and it's commercial use and value.

2.4 Socio-Cultural Aspects

Most waste management technologies are technically sound, but may fail because of associated socio-cultural factors. Waste management is a highly complex process, and despite the centralized approach to its treatment, it actually requires active involvement of everyone who generates waste. While each individual household needs to segregate waste, bulk generators such as hotels, restaurants, shopping malls, cinema halls, hospitals, etc. need to treat their waste at source as well.

Hence, it is crucial to ensure that existing socio-cultural aspects are understood to the fullest extent and technologies suitable to the context are selected. The connotation of 'waste' in most societies is negative and those associated with waste handling or management are usually treated with disparagement and disrespect. Usually, it is those who are the most marginalized by the society, the unskilled and uneducated, who find their way into the solid waste management industry. The scenario is gradually changing, with resource recovery from waste and technical aspects of waste management attracting the educated and technically inclined towards this field.

Role of the rag-pickers & scrap-dealers

These form the lower-most rung of the SWM ladder, collecting items of potential recyclability from open dumpsites, secondary segregation sites and waste collection vehicles. Sometimes, they even find ways of illegal entry into city landfill sites. Uneducated, socially ostracized and often abused, the rag-pickers are parts of the informal waste handling sector in India and other developing countries. Earning as low as INR 100-150/- a day, rag-pickers are hardly able to get the education and health benefits they are entitled to. Recent study by Mondal et al (2017) roughly estimated the number of rag-pickers in India to be about a million, though the actual numbers may vary.

In several of the larger cities, though, the situation is changing for the better. Several Non-government organizations (NGOs) are coming forwards to organize the rag-pickers into a formal workforce and take up city waste management with aplomb. These are either functioning on corporate social responsibility (CSR) funds or becoming self-sustainable from the sale of resources from waste. However, this initiative needs to spread to smaller towns and villages that are more remote, and where CSR funds may not reach. Here, government financial aid must be utilized judiciously, and enthusiastic city volunteers must join hands to ensure that even the remote area waste handlers are given their due.

To do activity: Interaction with rag pickers and scrap dealers of your city to understand the commercial aspect of waste recycling and techniques to raise standards of living of them by making them skilled waste handlers.

Similar to the rag-pickers, while a small percentage of scrap-dealers are registered with their respective municipalities, most are functioning without a license. As a result, very little formal data is available as to the actual quantities of waste recycled and final fate of waste in most of the cities of India. Scrap-dealers purchase the dry recyclables from the rag-pickers, and compress package and transport it to the waste recycler.

In the next rung is the Waste Recycler, who purchases the scrap from the scrap-dealer. All waste recyclers need to be registered with their state's Pollution Control Board. However, an abysmally small number of waste recyclers are actually registered, as one of the chief criteria of owning a waste recycling facility is to show ownership of sufficient land. Hence, even several waste recyclers continue to operate without a license.

Given the vast number of livelihood options provided by the solid waste industry to the informal sector, the introduction of automated waste segregation has been looked upon with the fear of mass unemployment.

Challenges to waste segregation at-source

For an average household, the story of waste ends with the disposal of waste in the dustbin. The story of waste beyond the dustbin is something that only a handful know. More importantly, it is a story a very few are interested to know. Most people are completely unaware of –

- The potential resources that can be recovered from waste
- The injury and infection threats faced by other human beings in handling the hazardous waste discarded by them

This leads to an extremely low household segregation percentage. It has earlier been highlighted how critical waste segregation at source is, to ensure a high level of resource recovery. Clearly, it is important to raise the interest of each and every one in waste management activities. A very high level of awareness drive, making use of social media, print media, electronic media and other conventional approaches such as street plays, banners, posters, pamphlets, rallies and awareness lectures is strongly required. A step in this direction has been taken by the Swachh Bharat Abhiyan, wherein substantial sums have been earmarked for IEC (Information, Education, and Communication) activities.

However, waste segregation is more of a habit, and it will take time to coax people to break their old habits and take up new ones.

Another challenge to waste segregation are local grievances against local municipalities for

- Not providing one extra dustbin – in several small municipalities there are low income group dwellers who are not inclined to spend money on an extra dustbin required for segregation. Besides, even for those who are financially capable, getting an extra dustbin from the municipal authorities assures them of the seriousness with which their local government is approaching the solid waste management subject.
- Not collecting the segregated waste separately – For household owners who segregate waste, it is a serious let-downer to observe that it is getting mixed in the waste collection vehicle. Hence, waste collection vehicles with separate compartments for wet, dry and hazardous waste are essential.
- Associated grievances – sometimes the waste collection vehicle may skip a locality, or its timing or frequency of visit is not suitable for the residents. Dirty open gutters, incidents of waterborne diseases and malaria, flooding due to clogged drains etc. are common enough issues in small municipalities, and they end up aggravating residents who tend to retaliate by not segregating the waste deliberately.

Open defecation

Open defecation is a perpetual challenge in the Indian rural areas as well as among the urban slums. Open defecation is extremely unhealthy, widening the risk of fecal-oral route infections such as diarrhea, dysentery, typhoid etc. The indignity of squatting in the open and the safety risk run by the rural women who often go out after the dark or in very early hours are very serious social aspects of open defecation.

Despite all this, open defecation has deep roots in the Indian culture and personal habits, such that even financial incentives to build toilets are not ensuring that the newly constructed toilets are used! Indeed, as per Government of India’s Swachh Bharat Abhiyan portal, as of Oct 2018, 95% of Indian population had access to toilets, which is much higher than a 2011 census report that showed only 70% rural Indian households without a toilet; despite this, the status of Open Defecation Free (ODF) may rightly elude many a village. Insightful and aggressive awareness drives are crucial to ensure that this scenario changes as soon as possible.

In urban slums, the challenge of open defecation is not culture or habit-driven but is rather an outcome of fewer toilet seats than required. Besides, urban work routines being more strictly time-bound, there is a rush for toilet usage within a very short few hours in the early part of the day.

Urban slums are extremely densely populated, and are largely illegal wherein the actual ground conditions and exact facts and figures may be difficult to ascertain. Hence, exact number of toilets, how well-maintained they are, accessibility to their septic tanks etc. are the practical on-field challenges.

Commercial aspects of waste

Unless the commercial aspects of waste become apparent, it is difficult to maintain interest of the local public and ensure high segregation percentage at source. Hence, it is significant that local municipalities prepare a business model to make money out of waste, and finally, become capable of purchasing one type of waste from its residents. For instance, wet waste or kitchen waste is the type of waste generated in the largest quantity in any municipality, which can be converted to compost. This compost can replace the fertilizers used in municipality gardens, and sold to city nurseries, private gardens and also to the nearby farmers. Similarly, with greater attention to formalizing the workforce represented by rag-pickers and scrap-dealers and joining hands with local NGOs already working with them, dry waste management can be improved. More volume of dry waste can be recovered with intervention, and with the help of modern tools, compressed, shredded and baled more easily. By linking rag-pickers directly to waste recyclers, their income and social status can be augmented. Creating self-help groups out of rag pickers and training them to manually upcycle waste is another activity that can help uplift them and make dry waste management more profitable.

However, currently, segregation at source first, or municipality efforts at waste commercialization first – this has become a hen and egg problem. It is imperative that both activities are given due attention simultaneously.

Perception change towards recycled and upcycled products

An important aspect of commercializing waste is the average consumer’s attitude toward the products obtained from waste. Recycled or upcycled products may not find acceptance among customers given the common perception of waste as being dirty, unhygienic and unhealthy. In fact, given the poor level of waste segregation, and the use of post-consumer waste, these concerns are not wholly invalid either. Quality assurance is, thus, of the prime importance here to:

- Certify that the raw materials used were duly cleaned and disinfected
- The end-product is no less in quality than its counterpart made out of virgin products

In principle, it appears logical that with raw materials available almost for free, the upcycled products can be cheaper and hence, more competitive. However, the efforts in collecting, cleaning and disinfecting them are costly. Therefore, the aim here must be to ensure that as much as possible of the dry waste items must be prevented from entering the waste stream, i.e., prevented from getting soiled and sullied and infected, and collected directly from the waste generator.

Thus, to summarize, waste needs to be glamorized, its handlers need to be respected, and its commercialization should be worked out.

2.5 Eco-friendly innovative technologies and their mainstream use

Managing solid and liquid waste in itself is an eco-friendly activity given that it is aimed at reducing the pressure of natural regeneration on our various ecosystems.

Technologies less dependent on energy, making use of plants or microbial cultures or green chemistry were deemed to be eco-friendly. Simple, low maintenance and technically sound unique solutions that were effective, had a lower ecological footprint and enhanced human welfare were collated as being innovative.

Automatic segregation of dry waste

Manual segregation of waste is tiring and unhygienic, and can be at least partially replaced by technical intervention. While not popular in India, Automatic Sorting machines are in use elsewhere. To put simply, these are conveyor belts with moisture, laser, infra-red, weight and magnetic sensors that can automatically separate wet waste, paper, plastic and metal. Other technologies such as air shifting, dry density separators and spirals are also available.

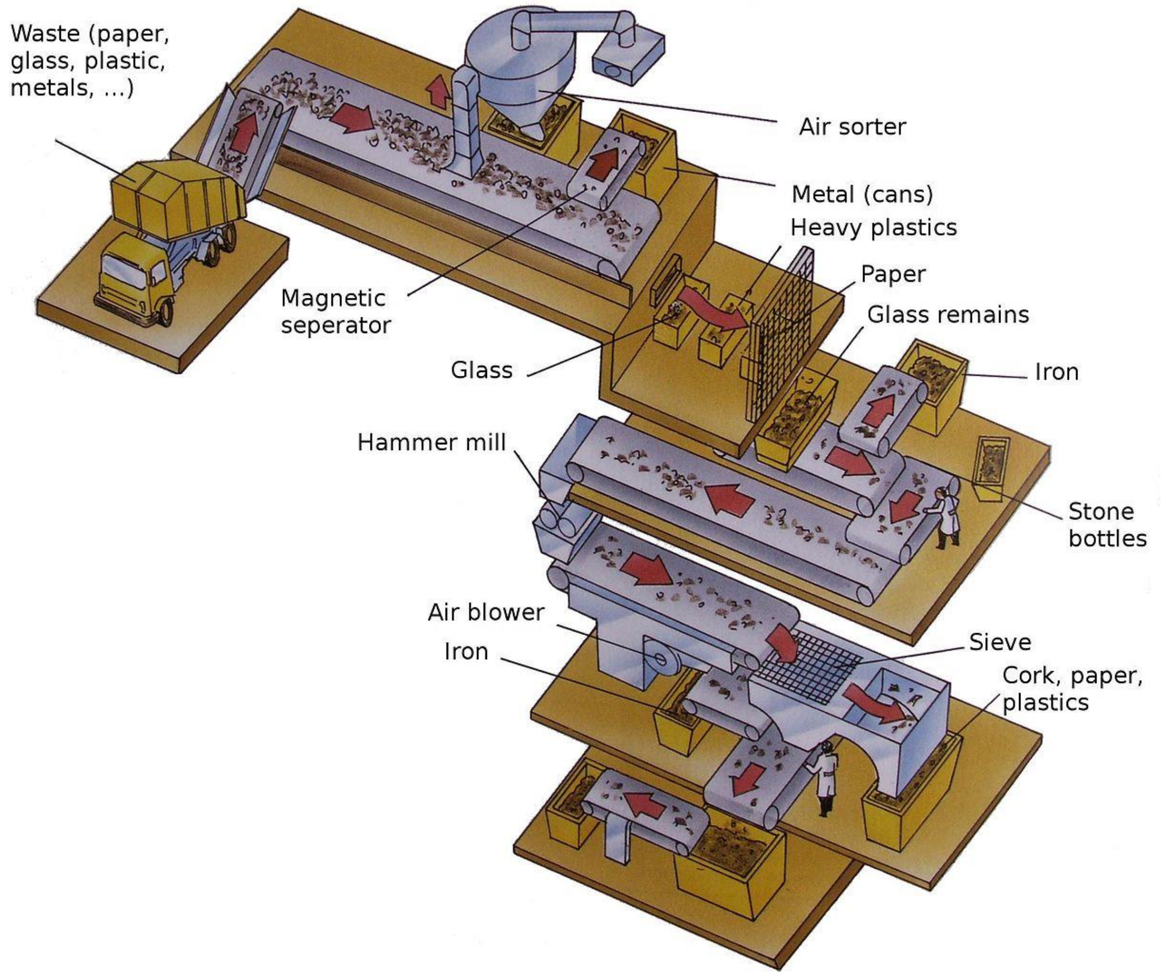

Figure 2.12: Automatic/Semi-automatic waste segregation – representative picture

Upcycling:

Upcycling may be defined as converting an article into another of greater value. Upcycling is largely manual, and requires artistic or mechanical skills. Few examples include –

- Conversion of PET bottles to t-shirts
- Conversion of used clothes/leather material to bags
- Upcycled clothing
- Furniture from PET bottles
- PET bottles filled with sand to serve as construction units to replace bricks
- Jewelry, toys, gift items, and home décor items fashioned from a variety of waste items

Co-incineration in cement kilns

Co-processing of plastic wastes in cement kilns is practiced substantially in different countries as an environmentally sound option for management of plastic wastes. In a cement kiln, different kinds of hazardous and non-hazardous wastes including plastic wastes get utilized as Alternative Fuel and

Raw materials (AFRs). During the usage of plastic wastes in cement kiln as AFRs, the material and energy value present in them gets fully utilized in the cement kiln as replacement to the fossil raw materials and fossil fuels that are conventionally utilized in the kiln. The performance evaluation of co-processing of plastic waste was carried out in ACC Limited, Kymore, Madhya Pradesh.

Plastic roads

The technology for this was developed by the 'Plastic Man' of India, Prof Rajagopalan Vasudevan, Professor of Chemistry at Thiagarajar College of Engineering, Madurai. A Government order in November 2015 has made it mandatory for all road developers in the country to use waste plastic, along with bituminous mixes, for roadconstruction. The entire process is very simple. The plastic waste material is first shredded to a particular size using a shredding machine. The aggregate mix is heated at 165°c and transferred to the mixing chamber, and the bitumen is heated to 160°c to result in good binding. It is important to monitor the temperature during heating. The shredded plastic waste is then added to the aggregate. It gets coated uniformly over the aggregate within 30 to 60 seconds, giving an oily look. The plastic waste coated aggregate is mixed with hot bitumen and the resulting mix is used for road construction. The road laying temperature is between 110°c to 120°c. The roller used has a capacity of 8 tons.

Sludge to bricks

Sludge mixed with clay (in proportions dependent on chemical properties of sludge) and co-fired in brick-making kilns can produce bricks with superior or at least same properties as conventional bricks. The advantages of using sludge –

- No need to add extra water, as sludge moisture content is sufficiently high
- Virgin clay input is reduced
- Sludge disposal cost is limited only to the transportation of sludge to the kiln site

Phytorid

Phytorid Technology is a self-sustaining technology developed by National Environmental Engineering Research Institute (NEERI), CSIR that works on the principles of natural wetland. It has been developed and patented by CSIR-National Environmental Engineering Research Institute (CSIR-NEERI). The PHYTORID system based on natural treatment method has distinct advantages over conventional treatment plant. The technology is recommended for decentralized plants with varying capacities of m3/day to MLD. In this technology, treatment occurs via natural methods such as filtration, sedimentation and nutrient uptake by plants and microbial action in a constructed system which is filled with gravel. Specifically identified different species of plants which are known to have good nutrient uptake rates are planted in the gravel bed. The system includes screen chamber, collection cum sedimentation, Phytorid bed and treated water tank.

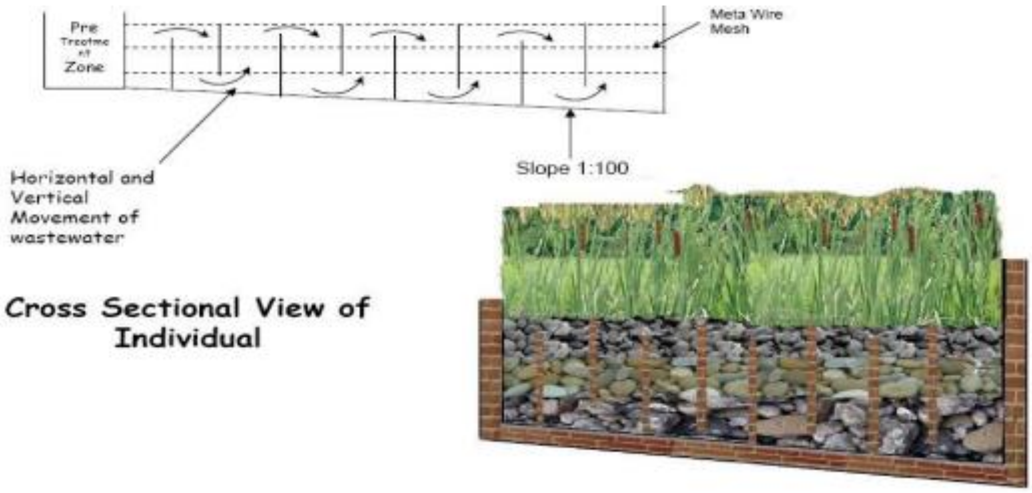

Figure 2.13: Phytorid technology for sewage treatment

Soil bio-technology

This is a terrestrial wastewater treatment technology designed by IIT Bombay. The underlying principle is that of trickling filter. Sediments and organic and inorganic pollutants are removed from wastewater with the basic processes of sedimentation, filtration and biochemistry. The technology requires no mechanical aeration or sludge removal.

Figure 2.14: Soil biotechnology at Lovegrove, Mumbai

Waterless toilets

Waterless toilets have emerged as the single answer to the dual problems of water availability and sewage treatment. EcoSan toilets work on a two-pit model requiring no flushing, wherein each pit is connected to a separate chamber. Usage needs to shift to the second pit once the first chamber is filled; by the time the second chamber has also filled up, contents of the first chamber have converted to manure during the ensuing months and can be used in the fields.

Figure 2.15: EcoSan waterless toilets

DRDO's anaerobic biotoilets

The fecal matter is digested in the absence of air with the help of a consortium of anaerobic bacteria. The design of the toilet can be modified to suit local conditions; indeed separate models have been designed for the Indian Army in snowbound areas, the Indian railways, for coastal regions, and even for houseboats.

Biodegradable sanitary napkins

Such sanitary napkins, fashioned out of cornstarch, bamboo fiber, banana fiber, pine fiber etc. are biodegradable unlike the popular commercial brands that use non-biodegradable, synthetic fibers.

The technologies listed above are assuredly newer than the conventional technologies, but have been tested under Indian conditions for a few years. Most of the above technologies are listed on the India Water Portal, and in some cases, appearing as an alternative to conventional options.

Hence, to conclude, a variety of solid and liquid waste management technologies are available for efficient solid and liquid waste management. Clearly, some technologies are well-established with plenty of case studies to validate their attributes, whereas some technologies are building their import, one case study at a time. Green technologies largely fall in the second category. It is important that more and more innovative and green technologies are tested on field and their suitability under different conditions is tested.

Summary

Thus, to summarize, firstly, the foundation was laid with the basics of solid and liquid waste management procedural overview.

Following this, conventional, well-established technologies were described with respect to their working principle and applicability.

Especial attention was paid to aspects of resource recovery, giving the overview of dry waste management and waste to energy technologies

Socio-cultural aspects strongly impact the successful waste management in a society - keeping this in mind, various such non-technological factors that could impact the application of waste management technologies were included in this Chapter.

Finally, the field of waste management is not untouched by innovation - several new technologies are jostling for space with the well-established conventional technologies. With their promise of lower environmental footprint, such green technologies require more and more field applications to establish their performance criteria.

There are business opportunities associated with both conventional and innovative technologies that need to be harnessed to create a win-win-win situation for the environment, society and the business owner as well. It is important that more and more innovative and green technologies are tested on field and their suitability under different conditions is tested.

Model questions

Q. A city with population 150,000 is divided into six zones with almost same number of people in each zone. Per capita waste generation in the city is about 260 gm and seven waste collection vehicles of capacity one tons are assigned in each zone. Using the available standards as to vehicle mileage, labor charges, loan rates, etc. calculate the various cost heads and per kg cost of waste collection

Q. What type of industrial waste items can be of disposed in sanitary landfills?

Q. How can one create a business model for uplifting rag pickers?

Q.From among Chemical fertilizers, paper and pulp, brewing and food processing sectors where Phytorid would be most suitable, how can one implement the technology in treatment of the waste water from such industries and create a plan for the utilization?

Q. A municipality of area 638 acre has 70% of its land under agricultural production and is in developing stage. How can one create a business model for solid waste management in the area?

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Chapter 3 Landfill Reclamation

Introduction

Landfilling continues to be the most common solid waste disposal method across the globe. The one reason to which its universal popularity can be attributed is its inherent simplicity. However, the earlier landfilling works were almost always unscientific dumping exercises, with little regard for leachate formation, groundwater pollution, landfill gas discharge, air pollution and climate change. With rising population and rising waste generation, most old landfills have no room for accommodating more waste. Besides, land as a resource is becoming scarcer and scarcer – hence, it makes little sense to spoil a precious resource such as this for waste disposal. In addition to these practical and environmental concerns, the regulatory framework in India has become conscious of resource recovery from landfill sites and its adequate capping.

Thus, effective landfill management, recovery of resources dumped there in the preceding years, capping it adequately and putting the land so recovered to other potential usage is the need of the day.

Objectives

With the above background, the objectives of this Chapter can be enlisted as:

- Understanding the dynamics of a landfill site – how leachate or landfill gas is formed and how a landfill 'settles.'
- Elucidating how an unscientific landfill site impacts the environment through groundwater and air pollution
- Comprehending the concept of landfill reclamation and landfill mining
- Enlisting what alternate uses a reclaimed landfill site can be put to
- Exploring the novel approach of Phyto-capping
- Comprehending the higher safety concerns associated with the landfilling of hazardous waste

3.1 Landfill Reclamation – An Overview

The necessity of landfill reclamation

Referred to by various names as ‘dumpsite’, ‘dumping ground’, ‘landfill site’ and ‘garbage dump’, municipal solid waste management (MSWM) in Indian cities and in other developing countries has largely centered around this piece of land where largely unsegregated, mixed type of waste is deposited on a daily basis. Prior to the scientific and technical considerations now being directed at solid waste management, MSWM in the earlier years happened without much planning. Dumpsites were largely selected for being sufficiently distant from human habitation and little or no consideration was spared for leachate percolation or methane generation. However, with rising populations and shrinking resources, land is becoming scarcer and scarcer. Old dumpsites once far away from human habitation are now in the middle of full-fledged urban areas; more importantly, most of these dumpsites are filled to capacity and cannot accommodate more waste. In addition to this, new government regulations make it mandatory for dumpsites to be capped scientifically so that the falling rain does not create more leachate. Retro-fitting of old landfills to convert them into sanitary, lined dumpsites is also encouraged. Clearly, dumping of waste has not remained the relatively simple, non-technical exercise it once was.

With land for dumping becoming scarcer, it is no wonder that some of the considerations for selecting the most scientifically sound landfill sites are flouted. For instance, the Kanjur Marg dumpsite in Mumbai is in close vicinity of the high value mangrove ecosystem while the Guwahati city dumpsite is on the banks of the internationally recognized Ramsar Wetland, DeeporBeel. The Mulund dumpsite of Mumbai is barely buffered from human habitation. Clearly, then, it is of paramount importance that landfills are either capped scientifically or reclaimed partially to create more airspace. Herein, the relatively novel concepts of ‘landfill reclamation’, ‘landfill mining’, ‘capping’ and alternate uses of reclaimed landfills have gained the attention of urban planners and researchers alike.

For municipal authorities in India and elsewhere, the approach towards dumpsite management may be summarized as in the figure below:

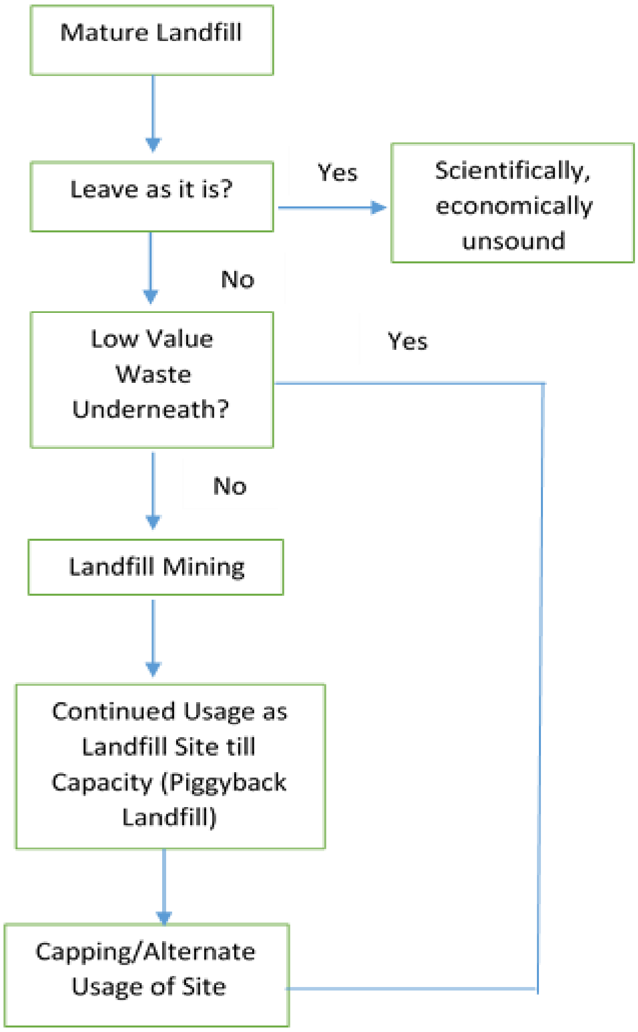


Figure 3.1: Overview of landfill management

Disclaimer: Above figure is a general overview; project-specific decisions need to be taken post detailed feasibility studies

Clearly then, if landfill footprint has to be reduced, landfill reclamation and capping are essential.

Landfill reclamation: definition

Landfill Reclamation may be defined as a set of procedures to ensure recovery of landfill space and articles of resale value from existing dumpsites. The entire landfill itself can be put up for alternative uses once through technological intervention it has been confirmed that no potential hazardous substances (such as methane and leachate) remain underneath, and items of potential reuse/resale value have been removed. Alternately, as more space is created post landfill reclamation, landfilling can continue in a dumpsite that had been filled to capacity.

Regulatory framework

Solid Waste Management Rules, 2016 [suppressing The Municipal Solid Wastes (Management and Handling) Rules, 2000] notified by Ministry of Environment, Forest and Climate Change, made by

Central Government in exercise of the powers conferred by the Environment (Protection) Act, 1986] applies to every municipal authority responsible for collection, segregation, storage, transportation, processing and disposal of municipal solid wastes.

The Solid Waste Management Rules 2016 encourage reclamation of dumpsites, following it up with capping.

Benefits of landfill reclamation

The potential benefits of landfill reclamation have been enlisted below:

- Sale of dry recyclables, manure, soil or waste that can be burned as fuel, which are obtained from landfill mining
- Avoiding the acquisition of additional sites for landfilling – by removing waste items of resale value, one is effectively reducing the volume of waste from the dumpsite and creating more airspace. Hence, this increases the life span of aging dumping grounds.
- Offsetting the cost of landfill closure – regulations make landfill closure mandatory, which entails a cost (cost of capping material such as clay, geotextile membrane or PVC etc. itself can be high). However, with landfill reclamation, this cost can be partially or totally offset.
- Landfill site land may partially become available for resale for other purposes
- At least partial retro-fitting an old, unsanitary landfill site can become possible, as after excavation, geotextile membranes and leachate pumping system can be laid.

Piggyback landfilling

The concept of continuing to use an existing dumpsite post partial landfill reclamation for fresh waste dumping has been extended to and named as the Piggyback Landfilling approach – this implies the construction of a new landfill site on the top of an existing dumpsite or along its side that has closed or is scheduled to be closed. Hence, it is the vertical or horizontal extension of an existing dumpsite that has closed or is about to be closed (Stulgis et al. 1996).

The capping of the old dumpsite also serves as the liner of the new piggybacking dumpsite. Suitable engineering interventions must ensure that the base of the piggyback dumpsite is stable, and is not disturbed by the natural waste decomposition processes going on in the old dumpsite.

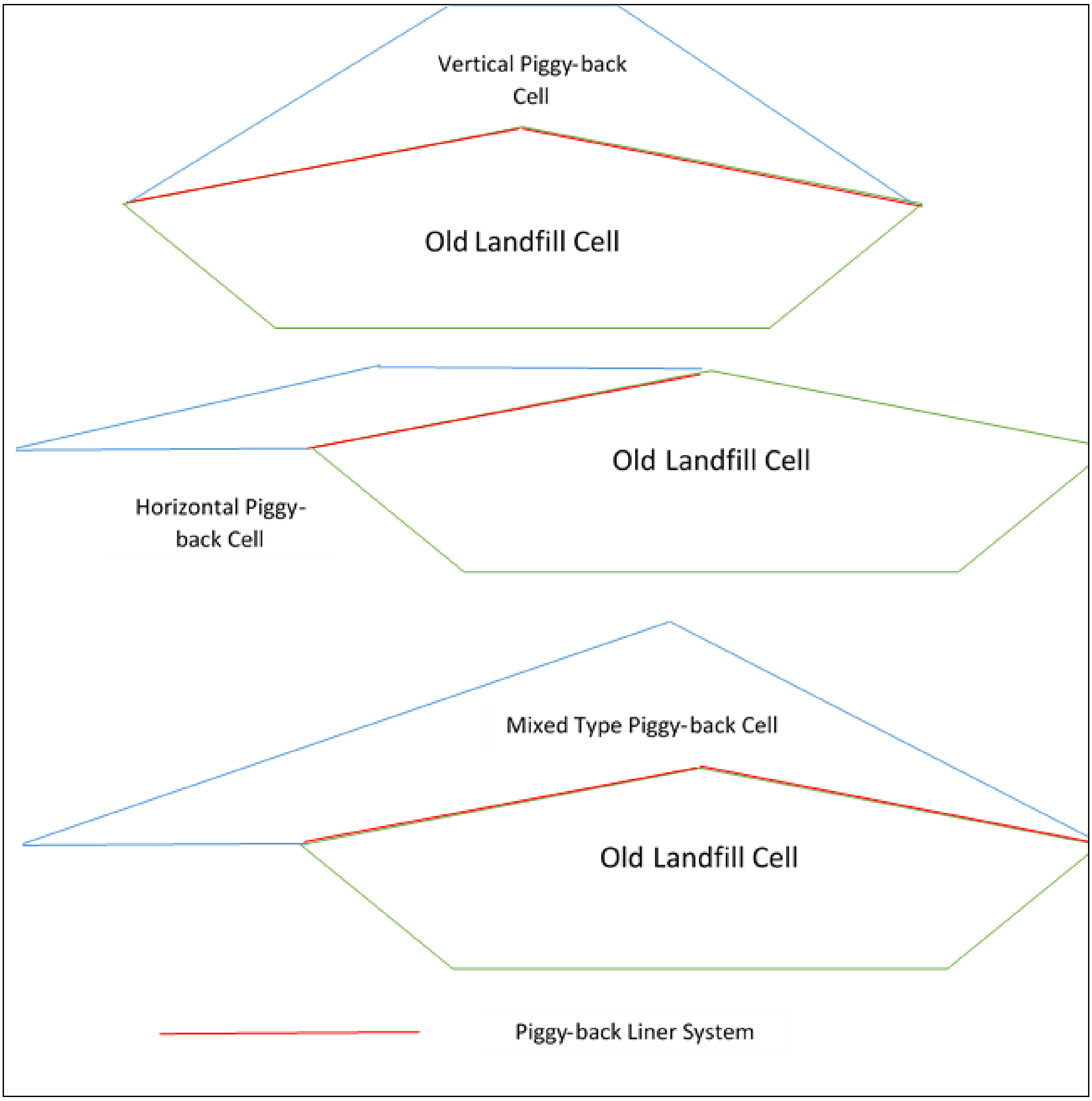


Figure 3.2: Overview of piggyback landfilling

Methane gas management, landfill lining & leachate management

With increased attention towards landfill management, landfill reclamation, landfill mining, and putting reclaimed landfill sites to alternate uses, the methane gas and leachate generation are challenges that must be understood and addressed.

Methane Gas Management – Methane gas generated from the anaerobic decomposition of wet waste in unregulated landfill sites is a serious environmental problem, contributing to global warming and climate change. Methane is often referred to as landfill gas, though landfill gas also includes carbon dioxide in some proportion. Methane collection from dumpsites and its potential use as a renewable energy source is a sustainable option with clear environmental benefits.

Collection of methane gas is by installing vertical or horizontal wells in the landfill mass. As per the USEPA, one vertical well per acre has been recommended while horizontal wells are 50-200 feet apart. Methane so collected is piped to a collection header with the help of a blower, from which it is either flared off or used for energy generation.

Landfill Lining & Leachate Management – Landfill leachate is the water that upon percolating down through the mass of waste in a dumpsite, dissolves soluble components of the waste and becomes highly concentrated. Source of this water is largely the local precipitation as well as water from the waste itself that is squeezed out under self-weight of the waste. Leachate is often black or brown in color and particularly difficult to treat. Leachate management is crucial as the case of unlined landfills, it percolates through the soil, finally polluting the groundwater. Hence, leachate management has two major components –

- Ensuring that landfills are lined with HDPE geo-membrane and clay to prevent the leakage of leachate into the groundwater below. These are called composite liners.
- Collection of the leachate through a network of perforated pipes, collecting the same in a sump and pumping it out, either vertically or along the slopes of the landfill, to treat it.

Landfill Capping – Once a landfill site has been deemed to be closed, it needs to be 'capped', i.e., adequately covered with clay/geotextile membrane/vegetation to ensure that the rainfall does not percolate through the waste, forming leachate. Another purpose served by landfill capping is the prevention of erosion of the waste mound.

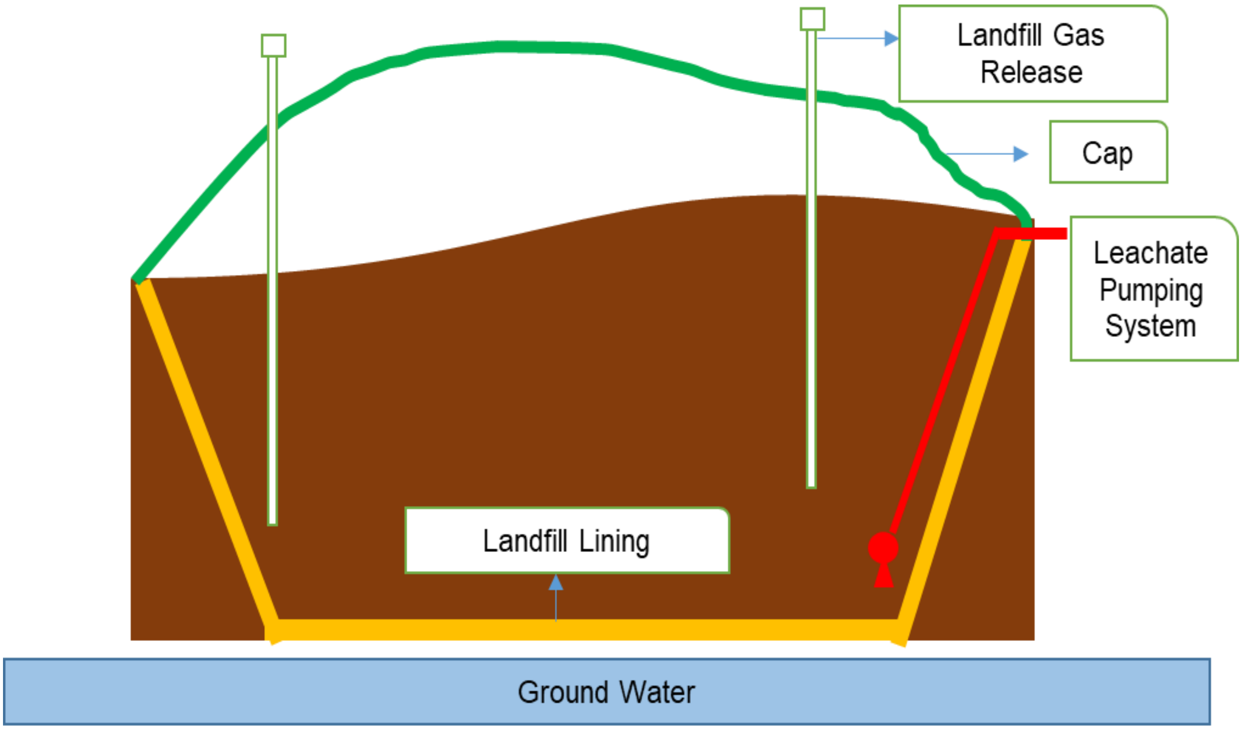


Figure 3.3: Cross-section of a sanitary landfill

Concept of landfill settlement

Landfill settlement is the phenomenon of lowering of the surface of a dumpsite over time. Landfill settlement is a complicated process, depending on several variables, including waste composition, local precipitation and time. In fact, the degree of complexity may be imagined that apart from varying between different dumpsites, the rate of settlement may vary widely even within the same landfill. This makes landfill settlement rate prediction a challenging exercise.

Landfill settlement that occurs immediately is related to the load, occurring due to air-void compression and pressing of compressible waste items. This occurs almost as soon as sufficient weight is laid atop and depends upon the compressibility of the waste. A slower settlement occurs when water is expelled from the waste. Clearly then, this type of settlement depends on the permeability of the waste. In the next stages, waste is subsequently bio-degraded through microbial activity – which essentially liquidates or gasifies the waste; in addition, mechanical creep (mechanical distortion, bending, crushing and re-orientation) and raveling (migration of smaller particles into voids among larger particles) contribute to the mechanical settlement of waste. External factors such as local climatic conditions, filling sequence, waste composition and drainage etc. also control landfill settlement rate. As per DEFRA guidelines (2004), maximum settlement occurs in the first 5 years in a landfill largely accepting putrescible waste.

The above processes have been delineated through Table 3.1:

Table 3.1: Factors involved in landfill settlement

Stage of Landfill Settlement	Processes Involved	Description	Controlling Factors
Immediate	Loading	Air-void compression and pressing of compressible waste	Compressibility of the waste, fill height, density
Primary	Water loss	Expulsion of water from the waste	Permeability of the waste
Secondary	Biodegradation	Degradation of organic waste by microbial action	Biodegradability of the waste (waste composition), moisture, temperature, pH
	Mechanical creep	Mechanical distortion, bending, crushing and re-orientation	Particle stiffness
	Raveling	Migration of smaller particles into voids among larger particles	

3.2 Landfill Mining

Overview

Landfill mining is fast emerging as a sustainable landfill reclamation option, with the help of which resale-worthy material as well as free airspace for further landfilling are obtained. It is an approach similar to conventional mining, wherein equipment similar to those used in mining are made use of.

Figure 3.4: File photos of landfill mining

Benefits

- Dry recyclables of resale value can be obtained from closed landfills. For instance plastic items, metals and glass can remain unsullied in the landfill environment for long periods and still have resale value.
- Through the natural process of composting, wet waste deposited in the earlier phase of the life cycle of the dumpsite has already converted to rich manure. Even if it is impractical to separate this manure from the mixed low quality dry waste (earlier, waste must have been dumped unsegregated), it can be used as land filling material for new infrastructural constructions.
- Moisture loss from the wet waste will be almost complete over the years; hence, the mixed waste can be converted to briquettes or pelletized and used as fuel

Caution

- Excavation at one site may lead to adjacent areas sinking or collapsing – most landfill sites are partially reclaimed. Hence, it is possible that excavation at one site causes instability in other sites; even collapses have been reported. Hence, site characterization study primarily for safety is a must.

- Release of odor - this may become unpleasant for the workers on site and nearby residents (if any).
- Release of methane gas– in most of the landfill dumpsites, waste – largely wet waste – has been in the process of deposition for several years. Under anaerobic conditions, this decomposition yields methane gas. Methane is an extremely potent greenhouse gas, the release of which in the atmosphere is harmful.
- Unearthing of hazardous waste dumped earlier – if initial test pit content analysis or information from landfill operators reveals this to be the case, adequate precautions must be taken for the safety of the workers, subsequent handling of the hazardous waste, and its final disposal.
- Wear-and-tear of excavation equipment may be a serious implication
- Cost of processing of the recovered material may outweigh the benefits – hence, initial studies must include careful economic consideration.

Spurs to planning

- Ascertaining the policy framework/existing regulations
- Conducting a site characterization study to ascertain composition of material in the landfill, which will be a function of variables such as local climate, age of the dumpsite, and land use features nearby
- Assessing the economic benefits likely to ensue from the exercise, and weighing it against the project costs
- Putting in place a workers' safety plan
- Management of reclaimed materials from the dumpsite

Procedural overview

Initial data collection to understand the operation history, types of waste dumped earlier, dimensions of the landfill site, topography of the area and demographic and social features are important. Such information is collected from the secondary data available with the municipal authorities and/or through personal interviews and discussion sessions.

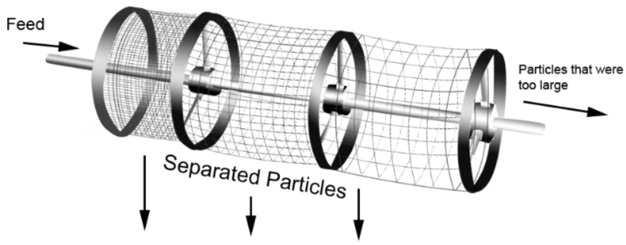
A site characterization study is essential to ensure that the site is structurally stable and can offer products of resale value. Structural stability analysis will also help create working zones in the area to be excavated.

Test pit digging and physico-chemical analysis of the underlying material gives a view of the type of products likely to be obtained from the excavation, and helps confirm the economic feasibility of the entire operation.

Market survey to confirm best venue of sale of the excavated material, and analysis to ascertain the most economical mode of transport of the material to be sold are also recommended.

Actual number of test pits, equipment selection, mode of material processing, and manpower organization are all significant aspects of planning for the actual excavation phase. Judicious usage of the correct equipment to ensure minimal site disturbance is important. Hogland et al (2014) in his studies reported that actual excavation will involve equipment such as Wheeled front-loader, excavator and Trommel sieve 40 mm and 80 mm.

Personnel protection equipment will include safety goggles, reflector jackets, headgear, gloves, masks and boots; portable methane detectors are recommended as the leakage of this so-called landfill gas is almost inevitable.



Trommel Screen

Wheeled Front-loader

Excavator

Figure 3.5: Various Equipment for Landfill Mining

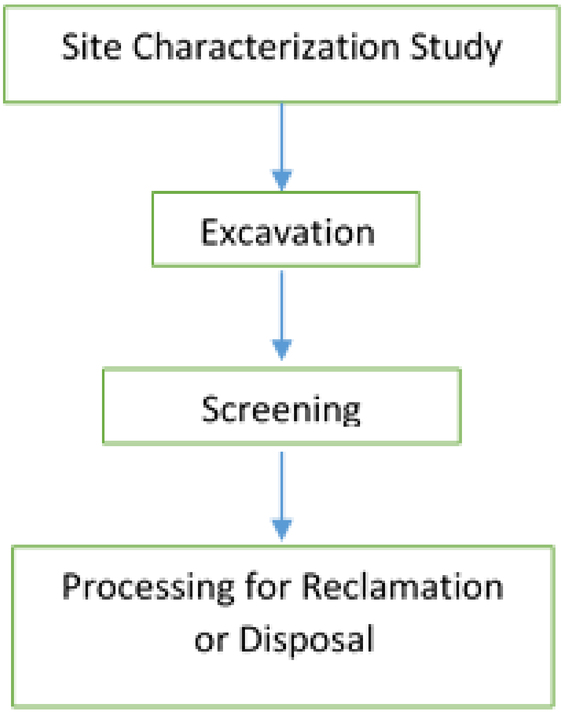


Figure 3.6: Overview of landfill mining procedure

Economic Considerations

While economic considerations will largely be project-specific, few broad outlines remain generic. They have been depicted in Table 3.2 below:

Table 3.2: Landfill mining – economic considerations

Stage of Activity	**Cost-Heads**
Pre-excavation	Secondary data collection
	Test-pit digging
	Laboratory-based chemical analysis of the sample to understand waste composition and its worth
	Structural stability testing
	Market survey for the sale of excavated materials
	Prior training to workers in the basics of landfill mining
During excavation	Excavation equipment
	Labor
	Excavated material temporary storage
	Protective equipment for health & safety of workers
Post-excavation	Equipment &labor for screening/sieving
	Equipment &labor for material processing
	Transport
	Cost of landfill lining, leachate management

Costs associated with landfill reclamation will be project-specific and include miscellaneous costs associated with the project. The costs for excavating and screening materials include equipment, labor and O&M costs.

Case studies

Although in its nascent stage in India, landfill mining in the USA and European countries is a well-established procedure with several case studies documented in peer-reviewed publications. Few such case studies have been described below:

Guerriero (1996) reported that in 1989, the Town of Thompson, Connecticut, USA initiated landfill reclamation, with the primary goal of enhancing the life of their landfill. The Connecticut Department of Environmental Protection allowed landfill mining in one acre area of the oldest part of the landfill. Test pits were dug to ascertain the content of the waste below, and it was found that it mostly contained ash from the burning of waste. It was deemed that reclamation would be easier here as most of the reclaimed material was reusable soil. The project was found to be cost-effective as compared to simple incineration. Most importantly, the life of the landfill was extended by 18 months.

Guerriero (1996) also mentioned that The Lancaster County Solid Waste Management Authority in Pennsylvania, USA took up landfill mining and burning the refuse as fuel, with the primary aim of enhancing landfill capacity, energy production and soil and ferrous metal recovery. The remnant ash and other waste items that could not be recycled were disposed of in a sanitary landfill nearby. In the year 1992, about 765 m^3 of cover soil and 1530 m^3 refuse for fuel had been reclaimed each week.

Jain et al. (2012) described the landfill reclamation at a Florida landfill site wherein 6.8 ha of unlined dumpsite was reclaimed. The recovered soil was sold and used as landfill cover.

Hogland et al. (2014) and Bhatnagar et al. (2017) described a landfill mining project in the Baltic Sea area, namely the Estonian Kudjape Landfill. The Kudjape Landfill site was 5.16 ha in area, with an estimated 193,000 cubic meter of waste volume. Of this only 57,777 cubic meter was the excavation volume. The mining continued from May 2012 till 2013. The uppermost 10-year deposition layer was targeted. Soil recovery and methane degradation were the objectives. The recovered soil fractions of <10mm particle size showed promise of recovery of metals such as Cr, Cu, Ni, Pb, and Zn.

Hogland et al. (2014) also described landfill mining operations at a Swedish landfill. Spread across 30 ha, the Ragn-Sells AB landfill site at Högbytorp, Sweden had an operational history of municipal as well as industrial waste disposal. About 150,000-200,000 tons waste was excavated.

To-Do Activity : Visit to the nearest dumping ground and study its shelf life and also prepare a closure plan for future that will generate commercial importance.

3.3 Alternate Uses of Closed Landfills

Once the landfill has reached its full capacity and decision has been taken to close it after scientifically capping it, it becomes a piece of land that can be put to multiple uses. In this unit, few such alternate uses have been collated, based on case studies published in peer-reviewed journals. Here, too, most of the case studies have been documented from countries other than India – however, they are comparable and may be emulated under Indian conditions after due diligence on technical, regulatory and social aspects.

Converted to real estate

The remedial investigations that have to be undertaken for converting a disused landfill to real estate are much more stringent than for usual landfill remediation projects, given that the human contact in this case is to be much more than in other projects. Thus, health and safety of the human occupants acquires paramount importance. This also enhances the financial investment for landfill reclamation.

Onsite contaminant characterization through chemical and physical tests are recommended, with especial stress on hazardous waste, presence of landfill gas, concentration of landfill leachate, impact on nearby ecological features (if any), and finally, structural stability. The concept of landfill settlement is of paramount consideration here, as differential settlement may negatively impact the foundations of civil structures set atop a closed landfill. The engineering approach towards building on a reclaimed dumpsite is comparable to that when constructing over marshy lands and other.

Wiley and Asadi (2002) describe several landfill redevelopment projects wherein real estate projects were constructed over reclaimed landfills in New Jersey. One community college (Passaic County Community College, 12 acres), the largest mall in the region (Jersey Gardens Mall, 166 acres), an office development (Federal Business Centre, 38 acres), and two housing developments (Seaboard Point Resort and Ashbrook Farm of 12 and 30 acres, respectively) were the five projects. The aspect most commonly discussed with these case studies was the impact on the nearby wetlands, and the project proponents' positive steps towards maintaining and/or remediating the same.

Converted to regions of high ecological value

The conversion of disused dumping ground into areas of high ecological value, such as urban jungles or biodiversity parks is also gaining merit in urban areas where green space is scarce but valuable. However, Rawlinson et al (2004) in his study indicated that several constraints to tree growth on landfill sites have been enumerated (soil depth, site exposure, soil compaction, waterlogging and low soil oxygen. Wind-throw of trees is a challenge, too, in the absence of adequate soil depth, for which Dobson and Mofat (1995) recommend a root depth of 1.5 m.

A notable such case study is the Mahim Nature Park or Maharashtra Nature Park, was set up as an eco-restoration attempt for the erstwhile Dharavi garbage dumping ground. Spread across 37 acres, the park is in close vicinity to the Mahim Creek and is a much-needed green lung of Mumbai.

Vaverkova and Adamcova (2018) report the planned forestry reclamation of a dumpsite in Czechoslovakia that was started in 2009, with the aim to study species survivability. Authors observed 90% survival over the years.

Converted for recreational purposes

The Freshkills landfill in New York was formally closed down in 2001, post which it is now under process of reclamation. Reclaimed wetlands, recreational facilities and a public parkland are planned herein, covering an area of 2200 acres.

Shoreline Park, Mountain View, California (USA) includes an 18-hole golf course, an amphitheater, a clubhouse and a restaurant – all these facilities have been built over a waste dumpsite. Interestingly, these recreational features had been planned for this site prior to its operation as a dumping ground, as early as in 1967. Being a low-lying area, it was required to import earth and raise the ground level by 20 feet to reduce the risk of flooding. However, these costs being prohibitive, it was decided that the site be operated as a dumping ground for the garbage from San Francisco city. In the year 1983, this park was opened to the public. As per local newspaper records, a few incidents of methane-related fires were reported in the park.

A study conducted by Wiley and Asadi (2002) mentioned an example in which 18-hole golf course (Bayonne Golf Course 120 acres) was designed over a reclaimed landfill in New Jersey.

Converted for renewable energy production

The major impact of setting up solar panels, be it financial, environmental or social is the land requirement. Clearly, then, lower the value of land, more suitable it is. Reclaimed landfills, as discussed above, can be converted to real estate or for recreational purposes – however, it is possible that the social acceptability of the same can be low. Additionally, it is more suitable that solar panels are set on reclaimed landfills instead of occupying land of higher environmental or social value. The United States Environmental Protection Agency (USEPA) has put together a set of best practices for siting solar photovoltaics on municipal solid waste landfills. An overview of the procedure has been provided in **Figure** below.

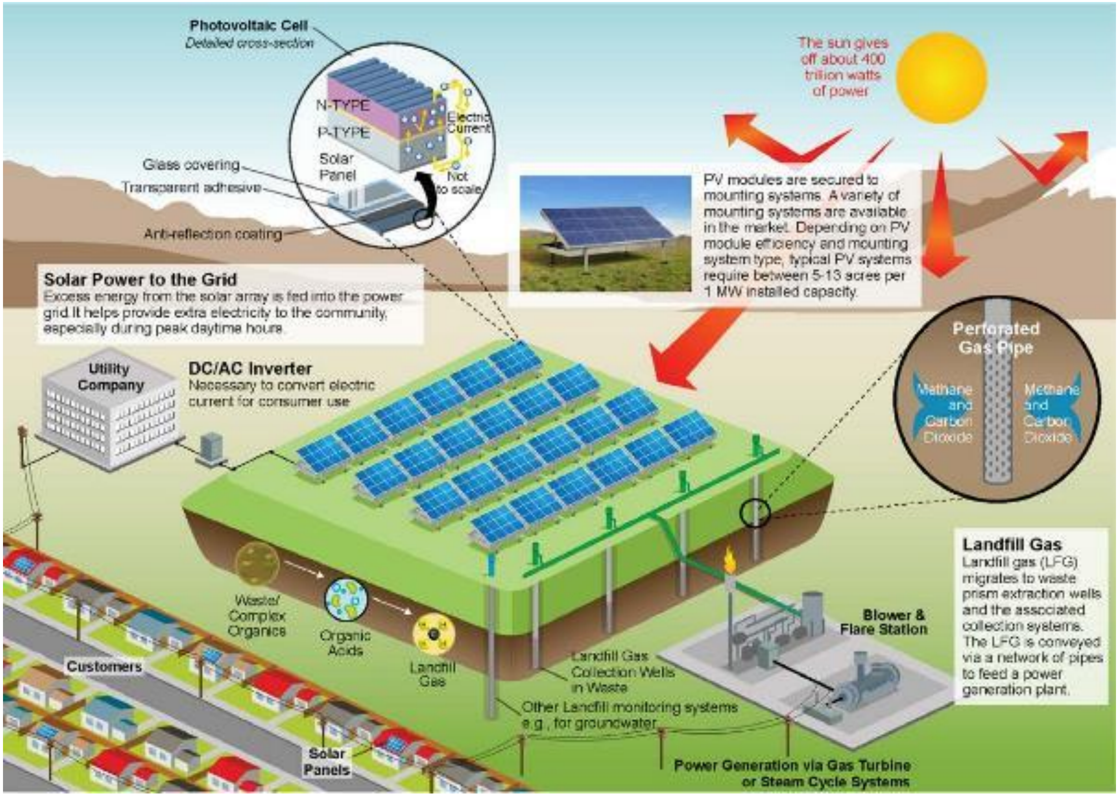


Figure 3.7: Overview of setting up solar panels on reclaimed landfills (Source: USEPA)

Although the land area required for a given solar power generation system size is dependent on individual module efficiency and mounting system, a minimum area of 2 acres has been recommended by the US EPA. Reclaimed landfills with sections of contiguous lands are preferable. Other landfill characteristics such as initial waste composition, landfill settlement, engineered/vegetated capping, topography and demographical features have a role to play in deciding whether a reclaimed landfill site is suitable for setting up solar panels.

In Table below, the completed solar power projects in MSW landfills in USA have been delineated:

Table 3.3: Landfill reclamation with solar panels: Sites in the USA

Project	Location	Siz	Completio	PVTechnology
BeeRidge Landfill/Rothenbach Park	Sarasota,FL	250 kW	200	Crystalline
Camp Pendleton	SanDiego,CA	1.4 MW	201	Crystalline
EastHampton Landfill	Easthampton, MA	2.2 MW	201	Crystalline
Evergreen Landfill	Canton,NC	550 kW	201	Crystalline
FortCarson AFB Landfill	FtCollins,CO	2 MW	200	ThinFilm
Greenfield Solar Farm	Greenfield, MA	2 MW	201	Crystalline

GROWSLandfill38	BucksCo, PA	3 MW	201	Crystalline
HickoryRidge	Atlanta,GA	1 MW	2011	ThinFilm
Islip/Blydenburg	Hauppauge/Islip,NY	50 kW	201	Crystalline
MadisonCounty	Lincoln,NY	50 kW	201	ThinFilm
NC StateUniversity–Agricultural PesticideLandfills	Raleigh,NC	76.5 kW	200 7	Crystalline
NellisAirForceBase	Las Vegas,NV	14.2 MW	200	Crystalline
PaulsboroTerminal–Gypsum Landfill	Paulsboro,NJ	276 kW	200	Crystalline
Pennsauken Landfill	Pennsauken,NJ	2.1 MW	200	Crystalline
TessmanRoad*	San Antonio,TX	135 kW	200	ThinFilm

*In the Tessman Road landfill, capping was done with a photo-voltaic cell-integrated geomembrane.

Agriculture/livestock grazing

Agriculture can be taken up on capped landfills provided that adequate arability is provided. For this the DEFRA guidelines (2004) recommend –

- 1m of soil profile (topsoil and subsoil) where possible
- 1.2m of soil profile in drier areas
- Arable land must drain well and normally needs a remedial drainage system with a minimum of 60cm of soil cover over the drainage pipes
- Adequate considerations have been taken for landfill settlement, which can damage the drainage system

Alternately, livestock grazing can be taken up on the grasses that have been encouraged to grow on the capped landfill. Grassland is less demanding on soil than arable crops. As per DEFRA guidelines (2004), goat, sheep and young stock are suitable animals to be taken up for grazing on reclaimed landfills.

However, care should be taken that

- Animals grazing and trampling on newly-sown grass and fragile soils can cause damage
- There should be a contingency plan to move livestock if there is signs of damage
- There should be fencing and water supply for stock

Under the following conditions, it is not recommended to plan agriculture/grazing on reclaimed landfills –

- Sites where there is risk of contamination, disease or vermin

- Sites that are too remote, or physically inaccessible
- Sites where plot size is too small to ensure economic feasibility of the agriculture/grazing activity

Hence, to summarize, depending on social, topographical, financial and landfill history-specific factors, a reclaimed landfill can be put to several alternative uses, ranging from direct human use (real estate, grazing & agriculture, recreation) to indirect human use (alternative energy generation) and ecological purposes (forestry, wildlife corridors).

To do Activity: A visit to the Mahim Nature Park, Mumbai

3.4 Phyto-Capping

Explaining the Concept

Landfill capping is a technology by which a physical barrier is created between the waste collected in the landfill and the outside environment. The purpose served is the prevention of precipitation from infiltrating into the waste layers below and forming leachate. The Central Pollution Control Board (CPCB) of India provides the following guidelines for landfill capping –

"After completion of landfill, a final capping shall be provided with (i) a barrier of soil cover of 60 cm of clay or amended soil with permeability of $1X10^{-7}$ cm/sec, (ii) on top of the barrier soil layer, there shall be a drainage layer of 15 cm and (iii) on top of the drainage layer, there shall be vegetation layer of 45 cm to support natural plant growth to minimize soil erosion."

An alternative to conventional capping may be the technology of Phyto-capping.

Lamb et al. (2014) defined phyto-capping may be defined as the dumpsite capping technology that uses plants and unconsolidated soil to control and limit entry of water into waste.

Phyto-capping is an approach towards landfill remediation and not just capping it off to prevent rainfall percolation and subsequent leachate generation. The three purposes served through Phyto-capping may be outlined as –

- Effective interception of rainwater, preventing it from washing off the waste
- Effective control of erosion
- Oxidation of methane gas from the depths of the dumpsite through root zone oxygen diffusion in the planted species

Venkatraman and Ashwath (2008) in their study mentioned that phyto-capping is composed of two elements - soils, and trees. Together, the phyto-cap serves the twin purpose of a 'bio-pump' that extracts the water from the dumpsite, and 'rain interceptor' that prevents the rainfall from percolating into the landfill below and leaching away the soluble pollutants. In addition, the methane inside the layers of waste is oxidizedthrough root zone oxygen diffusion. Small to medium sites are more suitable for phyto-capping.

The rainfall interception by phyto-capping is in turn managed with the help of three phenomena –

- Canopy interception
- Evapo-transpiration of stored water (in which the roots suck in the water trapped in the dumpsite like a conventional hydraulic pump)
- Storage of moisture in soil layers

Similarly, the oxidation of methane through plants is with the help of two phenomena –

- Some plants create channels for oxygen diffusion via roots
- Provide shelter to methane-oxidizing bacteria in their root zones (Ding et al. 2005)

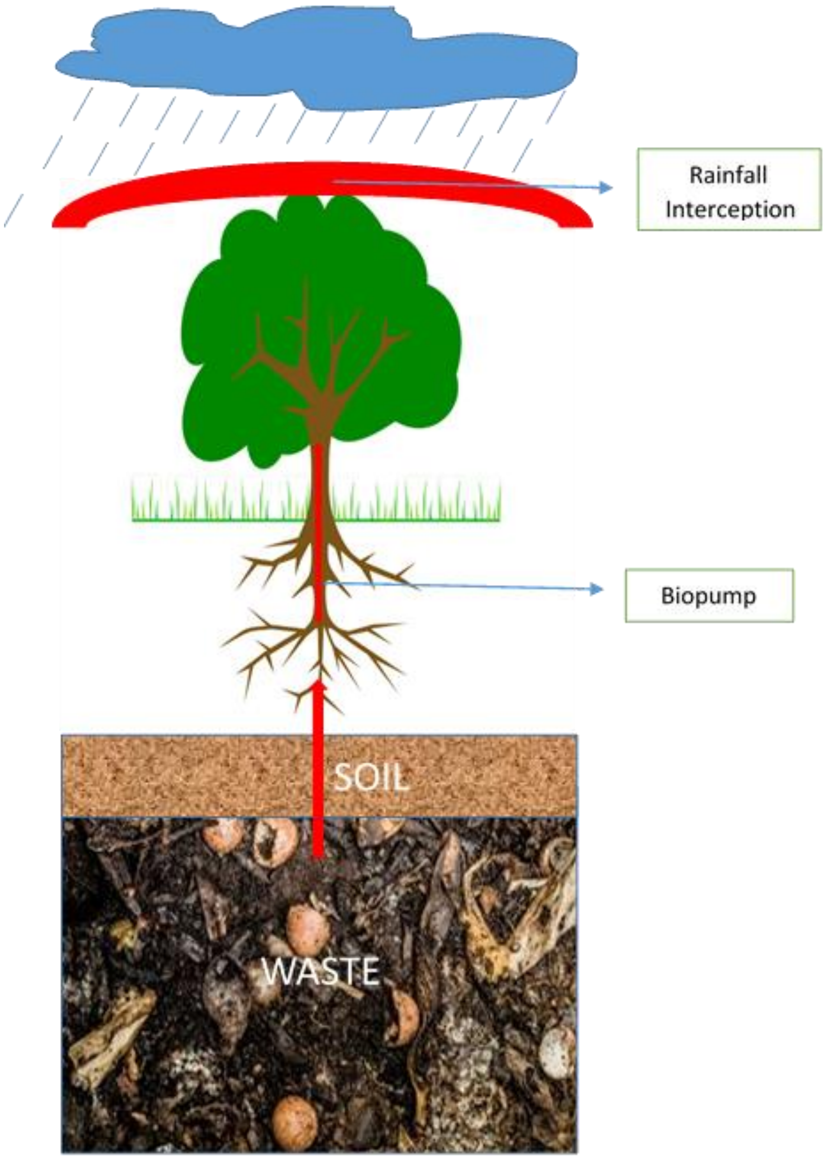


Figure 3.8: Conceptual overview of the phyto-capping technology

Landfill Factors Affecting Growth of Trees

An array of physical, chemical, topographical and edaphic factors affect the growth of trees in landfills.

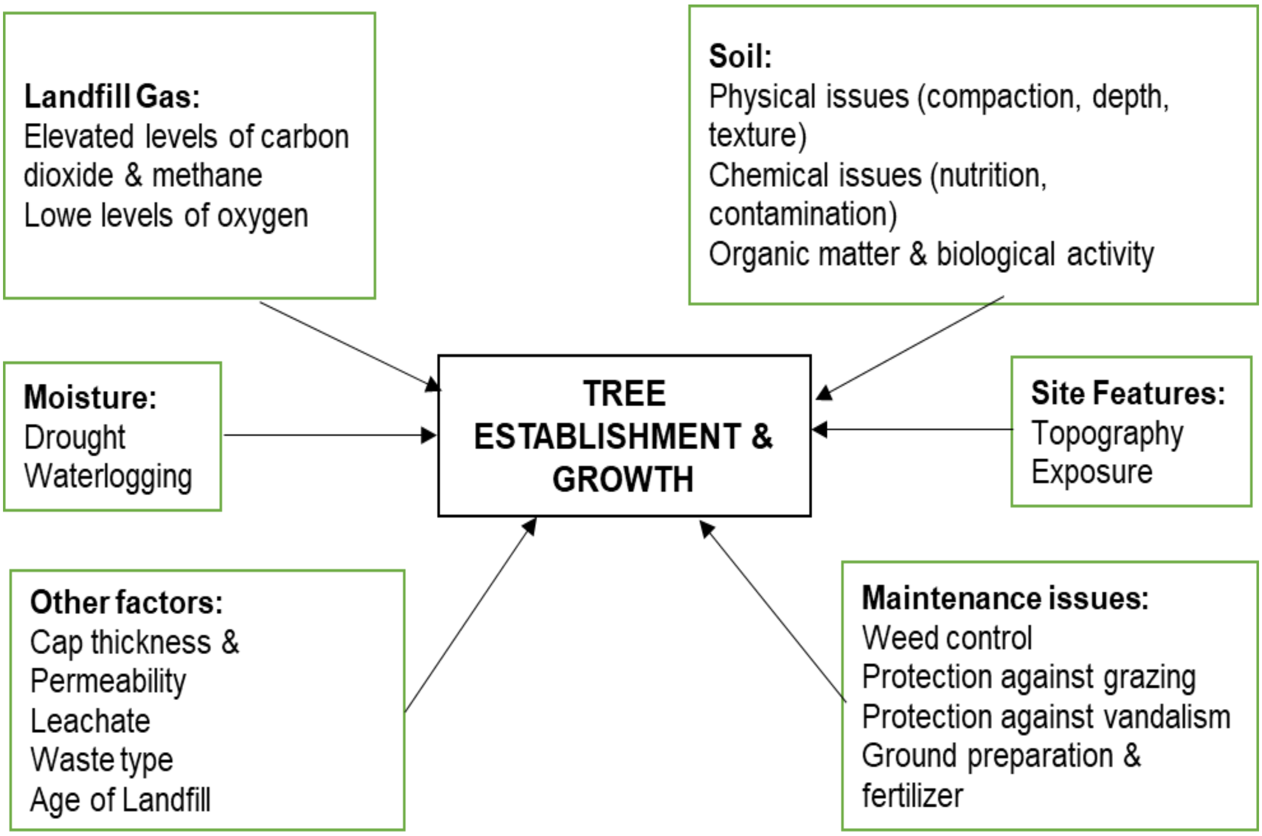


Figure 3.9: Factors affecting tree establishment & growth in landfill sites
Source: Rawlinson et al. (2004)

History

Phyto-capping was first introduced in 1991 by the Idaho National Engineering and Environmental Laboratory. It was presented as an alternative to conventional capping. The tree species used were Salix and Populus, apart from a few shrubs and grasses. Post this, in 1997, the technology was trialed by the US EPA under different agro-climatic zones. Since then, this capping system has been approved by the US EPA to be used on a full scale.

Benefits of Phyto-capping

As per Venkatraman and Ashwath (2008), and Yuen et al (2010), phyto-capping was found to be superior to conventional capping in that it

- Served the second purpose of methane is oxidation through root-zone oxygen diffusion
- Was found to be less expensive

- Required little skilled engineering intervention and was hence suitable for remote locations
- Prevented erosion of the soil cap
- Reduced wind-blown dust
- Served as a green cover/afforestation project, providing the additional benefits of
    - Enhanced biodiversity
    - Carbon sequestration
    - Opportunity to plant species of commercial importance
- Was suitable even for semi-arid regions where suitable species selection could still ensure capping, while conventional clay caps dried up and cracked, letting precipitation in
- Provided a physical barrier to prevent vermin access to the waste
- Did not crack due to landfill settlement
- Was aesthetically more pleasing

To compare the phyto-capping procedure with conventional clay caps and geo-membrane cover, the following table has been prepared:

Table 3.4: Comparison of Phyto-capping, Clay capping and Geo-membrane Cover

Criteria	Clay Cap	Geo-membrane	Phyto-cap
Use of locally available material	Clay may not be the locally available soil and may have to be transported from elsewhere	Will have to be purchased, hence not suitable for remote locations	Local soil and plant species strongly recommended
Longevity	Can crack or erode, especially under arid conditions	Can get torn	Top soil with suitable vegetation layer resists erosion and cracking
Efficiency at preventing percolation	High (if not eroded/cracked)	High (if not torn)	Comparable to clay, at times better
Methane oxidation	Not possible	Not possible	Added benefit
Ecological gains	Not possible	Not possible	Added benefit

Design Criteria

- Selection of species – Salix and Populus were the two tree species used in the first phyto-capping study, in addition to a few shrubs and grasses. Venkatraman and Ashwath (2009) made a detailed study of 19 species and found that among these, 10 species were quite suitable for the Central Queensland region, Australia. These included Melaleuca leucadendra, which is known to diffuse oxygen into its root zone, Ficusmacrocarpavar. hillii and Dendrocalamuslatiflorus that showed the maximum methane oxidation. Eucalyptus grandis, Glochidionlobocarpum, Hibiscus tiliaceus, and Lophostemonconfertus showed the highest root depth.

- Rawlinson et al. (2004) studied 11 unsanitary landfills in England with the purpose of ascertaining tree growth factors and concluded that native species (vs. exotics), shrubs (vs. trees) and broad-leaved trees (vs. conifers) survived better when planted over dumpsites.
- Optimum depth of soil atop the waste is also a significant design criteria. Venkatraman and Ashwath (2009) determined the impact of soil depth and arrived at the conclusion that methane concentrations were higher in thin soil caps. An unconsolidated soil cap of 1400 mm thickness reduced surface methane emissions 45% more than a cap half as thick. Also, Bogner and Matthews (1999) in their study mentioned that varying soil depth also impacts methane emission.
- Selection of appropriate soil amendments – Lamb et al. (2014) suggest biosolids, biochar, compost, or other materials as soil amendments to improve moisture retention in phyto-capping.
- Porosity of soil –oxidation of methane will depend upon the diffusion of oxygen gas from the root zone, and the rate of diffusion will, in turn, depend upon the soil porosity (Venkatraman and Ashwath 2009).

Case Studies of Phyto-capping

The phyto-capping technology was trialed at the Lakes Creek landfill in Rockhampton, Australia (Venkatraman and Ashwath 2010). The study reported superior performance of the Phyto-cap in slowing water percolation into the dumpsite as compared to compacted clay. Substantial reduction in methane emission was also reported.

Karaca et al. (2018) describe the use of Phyto-capping to remediate mine tailing disposal sites. The authors stressed the importance of soil amendments to help establish the first vegetal layer, and the right selection of native species to tolerate the bio-toxicity of the underlying waste.

Yuen et al. (2010) describe the outcome of 5 sites in Australia (Lyndhurst, Victoria, McLaren Vale, South Australia, Henderson, Western Australia, Townsville, Queensland and Lismore, New South Wales) where phyto-capping was trialed. The most obvious observation was reduction in drainage over time in all sites but 1.

Albright et al. (2004) report the findings of a study conducted by the US Alternative Covers Assessment Program wherein phyto-capping efficiency at preventing water percolation was studied at 12 sites, wherein the alternative of vegetal cover was found to be effective.

Similarly, Preston and McBride (2004) studied the role of poplar trees in reducing seepage of precipitation in a decommissioned landfill in southern Ontario, Canada, and found the poplar tree system to be efficient.

3.5 Hazardous Waste Landfill Remediation

Hazardous Waste – Definition, Identification, Impacts

As per the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016
'"Hazardous waste" means any waste which by reason of characteristics such as physical, chemical, biological, reactive, toxic, flammable, explosive or corrosive, causes danger or is likely to cause danger to health or environment, whether alone or in contact with other wastes or substances.' Hazardous waste is any substance that can directly harm human beings or the environment, or come in contact with other components and get converted into potentially harmful products or get bio-magnified by getting ingested by living organisms and entering the food chain.

As per (Devi et al. 2018), around 4.4 million tons hazardous waste is generated in India per annum. 13 Indian states contribute 97% of the hazardous waste generated annually in the country – these states are: Maharashtra, Gujarat, Tamil Nadu, Orissa, Madhya Pradesh, Assam, Uttar Pradesh, West Bengal, Kerala, Andhra Pradesh, Telangana, Karnataka and Rajasthan.

The Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 include Schedules I, II and III wherein is included a detailed list of hazardous chemicals as well as the concentrations beyond which some chemicals can be harmful.

As per US EPA, hazardous wastes have been divided into four categories called the F, K, P and U categories. F list - hazardous waste from non-specific sources, which may have originated from a number of industrial processes common across industries. In contrast is the K list waste that can be specifically traced to a particular industry. P and U lists contain chemicals that were commercially produced but have to be disposed of due to non-use and subsequent end of shelf life. Such chemicals are either 100% pure or are sole ingredients of a commercial product. Thus, source of the hazardous waste is an important managerial aspect.

Hazardous Waste Management – Current Practices in India

The Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 provide a detailed plan for hazardous waste management, which has to be followed by those who generate, store, transport, treat or dispose hazardous waste. The considerations significant for municipal solid waste also pertain to hazardous waste, which include reduction in waste generation at source, prevention of recyclable waste entry into the waste stream, scientific efforts at resource recovery and safe disposal. However, the recycling and resource recovery options with this type of waste may be limited, and its disposal attracts much more stringent criteria given its hazardous nature.

Treatment, Storage and Disposal Facilities (TSDF) have been designed to accept hazardous waste and provide a centralized facility for multiple generators. Here at the TSDFs, depending on the available facilities, resource recovery can be attempted prior to disposal.

From source to the TSDF, the significant link in the chain is an effective hazardous waste transport system that can ensure zero spillage. Given that spillage is quite probable during loading, transport and unloading, each step of hazardous waste transport needs to be regulated. In this regard, following are the major considerations:

- Leak-proof containers of sufficient strength
- Containers to be sealed shut to prevent spillage during transport
- Containers to be made of a non-reactive material so as to negate the possibility of cross-reaction with the hazardous waste
- Potential of gas generation during transport, due to cross-reaction, can be a challenge leading to distortion or bloating of the container and increased risk of leakage and spillage. Hence, prevention of gas generation is of paramount importance
- Labeling on the container describing the nature and potential toxicity of the waste being transported
- Similar label on the transport vehicle, with the addition of first-aid instructions and an emergency number in case of spillage and exposure
- Vehicle to be well-maintained and in excellent working condition
- Manpower to be well-trained, and with sufficient technical experience in guiding proceedings post an accidental spillage

Unfortunately, legal hazardous waste management facilities in India are less than required, which translates into illegal dumping and multifold damages to human health and the environment. The challenge associated with proper hazardous waste management is its cost, which industries in the medium, small and micro (MSME) category fail to afford.

Hazardous Waste Landfill Management

The CPCB has outlined a detailed plan for designing a hazardous waste landfill. The purpose of designing such a landfill is to ensure minimum environmental impact. Guidelines ensure that the hazardous waste landfill is located at a safe distance from water bodies and its associated ecosystems, as well as human habitation. Locations with low alternative use value, groundwater level at more than 2m depth of the landfill base, and with high clay content in the sub-soil are preferred. Following are the essential components of a hazardous waste landfill site –

- A liner system for the bottom and sides of the landfill
- A leachate collection and treatment system
- A gas collection facility
- A final cover system as well as intermediate covers (daily or weekly, depending on waste type)
- A surface water drainage system
- A fence and greenbelt around the landfill site
- An access road

Also required are: a contingency plan for emergency management and safe exit for all in case of accidents, an environmental monitoring plan along with monitoring facilities, and a closure and post-closure plan (with especial stress on capping and vegetation layer to ensure no erosion and surface water drainage) for the hazardous waste landfill site.

In addition to these, management of hazardous waste site will require office space, space to store liner and cover material (purchased in bulk), equipment shelter, and storage site for special waste.

The life of a hazardous waste landfill can range from 40-65 years, of which 10-25 years are the active period while next 30 years are the closure and post-closure period, during which the environmental monitoring (for landfill cover, leachate quality, gas quality, groundwater and air quality) has to be carried out.

Given the highly reactive nature of hazardous waste items, the hazardous waste landfill site must be divided into units or cells, and only compatible waste items should be dumped together to avoid the risk of cross-reaction. Table 1 of the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 provide a detailed list of compatible wastes.

It is strongly recommended that hazardous waste landfills are operated in phases, with each phase being in a different stage of operation. Phase-wise operation leads to better over-all management of the hazardous waste and helps set site-specific protocols.

Liner and capping material should be of such a chemical nature that they do not react with the chemical elements in the hazardous waste pile. Composite liners of geo-textile and clay are recommended.

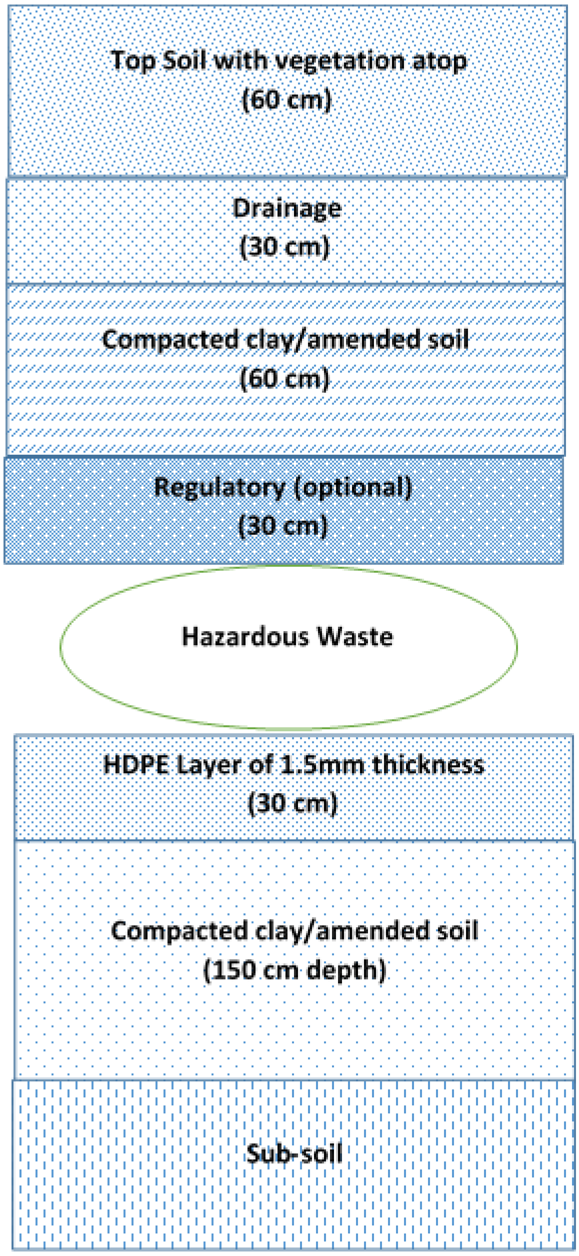


Figure 3.10: Overview of Hazardous Waste Landfill Liner and Cover

Liquid Hazardous Waste Management

Further, it must be envisaged that hazardous waste is not always in the solid state – there are free liquids, industrial sludge and slurries, which require to be de-watered before being dumped in the landfill. For such waste, a special hazardous waste impoundment needs to be designed in the vicinity of the landfill site.

Alternately, research has been on-going for chemical fixation and solidification of liquid hazardous waste. For instance, Vacenovska and Drochytka (2012) report the use of fly ash to stabilize hazardous solid waste (industrial sludge from rubber manufacturing plant).

Resource Recovery from Hazardous Waste

Importantly, there are incinerable and/or compostable elements even in hazardous wastes, which can be separated and used for energy or material recovery. Co-processing of hazardous waste is also a viable option. Interestingly, the state of Gujarat reported co-processing of hazardous waste as fuel in cement kilns to the tune of 600,000 tons per annum in 2013-14, a 35-times increase with respect to 2009-10 figures (Karthikeyan et al. 2018).

In addition, most of the hazardous wastes are rich in chemicals, which can be re-used after isolation or recovered from the waste through processing. Such resource recovery boosts the cradle-to-cradle approach towards sustainable manufacturing. For instance, spent solvents and metals can be recovered and reused.

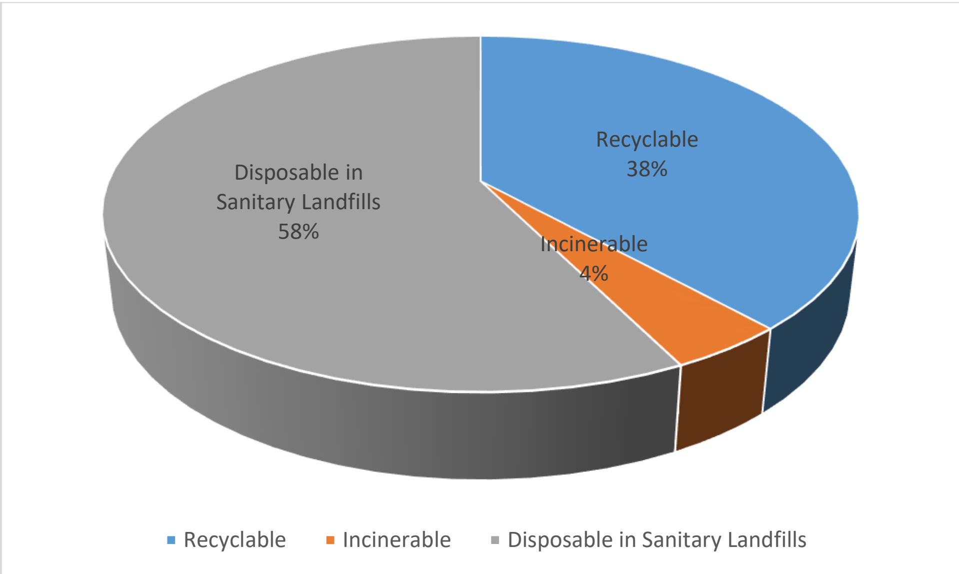


Figure 3.11: Fate of Hazardous Waste (Above % is an estimate presented by Devi et al. (2018))

Suggested To-do Activity: Visit to a hazardous waste management facility in Gujarat

Thus, to conclude, landfill management is a critical area of applied research today, and not without opportunities. Ensuring maximal resource recovery from a landfill, using the most suitable landfill closure technologies and ensuring the best possible alternate usage of reclaimed landfills are the critical requirements for almost every municipality in India today.

Summary

To summarize, landfill management is a critical part of waste management, given how it is connected with the valuable resource of land. Ensuring maximal resource recovery from a landfill, using the most suitable landfill closure technologies and ensuring the best possible alternate usage of reclaimed landfills are the critical requirements for almost every municipality in India today.

Landfill reclamation and landfill mining open up immense business opportunities, both from resource recovery from waste as well as from the different alternate uses that reclaimed landfill sites can be put to - ranging from real estate to eco-parks and solar energy parks.

Efficient landfill management through innovative technologies such as Phyto-capping offer the advantage of novelty and larger environmental benefits.

Hazardous waste management, being in its early stages in India, need to be explored for business opportunities, given that the current volume of available treatment and disposal facilities are much less than required.

Model questions

Q1 A small town in the heart of an agricultural district has a thirty-year old landfill site which it now plans to close. What action plan would you suggest to this municipality?

Q2 An old dumpsite had been receiving mixed waste from households as well as a nearby chemical industry for several years. It was observed over the years that the hand pumps and wells in the area near the dumpsite began to yield dark-coloured water. What do you think must have happened, and what managerial suggestions would you give to the a) chemical industry b) local municipality c) local residents?

Q3 How would your closed landfill after-use management decision differ for a) a city like Mumbai (climatologically wet, real estate hub, surrounded by industries) and b) a city like Aurangabad (climatologically dry, surrounded by agricultural fields)?

Q4 Which types of business activities are likely to gain from a municipal solid waste (non-hazardous) landfill reclamation project if an ecologically beneficial after-use has been planned?

Q5 What business model can you envisage with reference to phyto-capping of landfills?

Q6 What business model can you envisage for hazardous waste management by a group of MSME (medium, small and micro enterprises)?

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Chapter 4 Bioremediation

Introduction

Pollution amelioration using living organisms (bacteria, fungi and plants) has immense scope in waste management. Each living cell is a tiny factory, with its own unique naturally-formed machinery with a variety of biochemicals to help tackle pollution.

Living cells require a source of energy and a source of carbon – there is immense diversity among different taxonomic groups with respect to the different sources of these two critical factors. In addition to this, different species are exposed to adverse environmental conditions (less or no oxygen, carbon sources other than glucose, acidic or alkaline pH, high pressure, high radioactivity or very high or very low temperatures). These organisms have successfully adapted to extreme environmental conditions – by successful adaptation it is implied that they have in place a specific machinery of biochemicals that helps them combat the adversities and continue with their basic life processes of respiration, ingestion, excretion and reproduction.

To link diverse physiologies of different types of living cells with waste management, it may be understood that what appears as waste for us may actually be the natural living condition for a bacteria or a fungal cell!

In fact, if it is attempted to synthetically design a chemical reaction for pollution remediation it is possible that the attempt fails, or becomes too complex or too costly for practical purposes – in contrast, it can be a one-step reaction for a bacterial or fungal cell. In other cases, even if a pollution remediation is chemically feasible, using living cells can reduce operation or maintenance costs.

Objectives

The objectives of this Chapter can be summarized as:

- To understand the underlying physiological mechanisms that make it possible for living organisms to take up seemingly harmful pollutants.
- To understand how natural processes occurring in the living cells be designed to fit into various pollution amelioration technologies
- To understand the basics of ex-situ and in-situ approaches to pollution amelioration
- To understand how technologies need to be designed differently for treating polluted soil or polluted water

4.1 Overview of Processes Involved in Bioremediation and Phytoremediation

History

The concept of using batch-reactor type jars to bio-remediate wastewater was practically tried out in the early 1960s, and the technology of bioremediation was born (Agnihotri 2017). However, it took nearly a decade for the technology to come out of the laboratory and be applied on-field. Also, Chapelle (1999) in his studies mentioned that in the early 1970s, bioremediation efforts were extended toward hydrocarbon-contaminated groundwater (Chapelle 1999). From then onwards, there has been no looking back, with more and more natural as well as genetically modified microbes being discovered or designed to make bioremediation the sophisticated technology it is today.

Bioremediation

The process of pollution remediation involving microorganisms or their purified enzymes is called bioremediation. Microorganisms or microbes are extremely tiny organisms, not visible to the naked eye. While in classic microbiology (the branch of life science that studies microorganisms) virus, bacteria, algae, fungi and Protista are included, from bioremediation perspective, research is largely focused on bacteria and fungi (myco-remediation), which have acquired much significance.

The beauty of microorganisms lies in the fact that their natural metabolism processes are unique and they can grow and reproduce using inputs far different from those required by plants, animals or human beings. For instance, glucose is the most significant source of energy for all – plants make it by themselves while animals get it from plants (herbivores), other animals (carnivores) or both (omnivores). However, microbes are not limited to accepting glucose. For them, the source of energy can be several, some of them extremely complex compounds.

In addition to this, in some cases, several microorganism species called extremophiles can exist in environments where other organisms can never survive – for example, under extreme heat (thermophiles), extreme cold (psychrophiles), pH extremes (acidophiles and alkaliphiles), extremely high pressure (barophiles), high radioactivity (radiation-resistant) and even the absence of oxygen (anaerobic).

Thus, given their extreme sturdiness and flexibility with using different sources of energy and tolerating extreme conditions, microorganisms become ideal candidates for pollution remediation. Not only can they tolerate the adverse environment created by the pollutant, they can use the pollutant as a source of energy! In fact, the conditions deemed adverse for us are actually ideal and optimum for a microorganism.

To better understand the diversity of metabolic processes microorganisms can display, a few details must necessarily be comprehended:

All life on earth can largely be categorized into Autotrophic and Heterotrophic. While autotrophs prepare their own food and are not dependent on other organisms, heterotrophs are dependent on other organisms.

Among autotrophs, there is a sub-division, depending on the source of energy – Photoautotrophs (algae, photosynthetic bacteria) use light as the source of energy, while Chemoautotrophs (like chemoautotrophic bacteria) harness the energy from inorganic chemical reactions. Both use carbon dioxide as a carbon source.

The same sub-division heterotrophs – while Photoheterotrophs use light as the source of energy, they are dependent on carbon compounds other than carbon dioxide. Similarly, chemoheterotrophs can obtain energy from inorganic chemical reactions but cannot fix carbon dioxide and will require other sources of carbon.

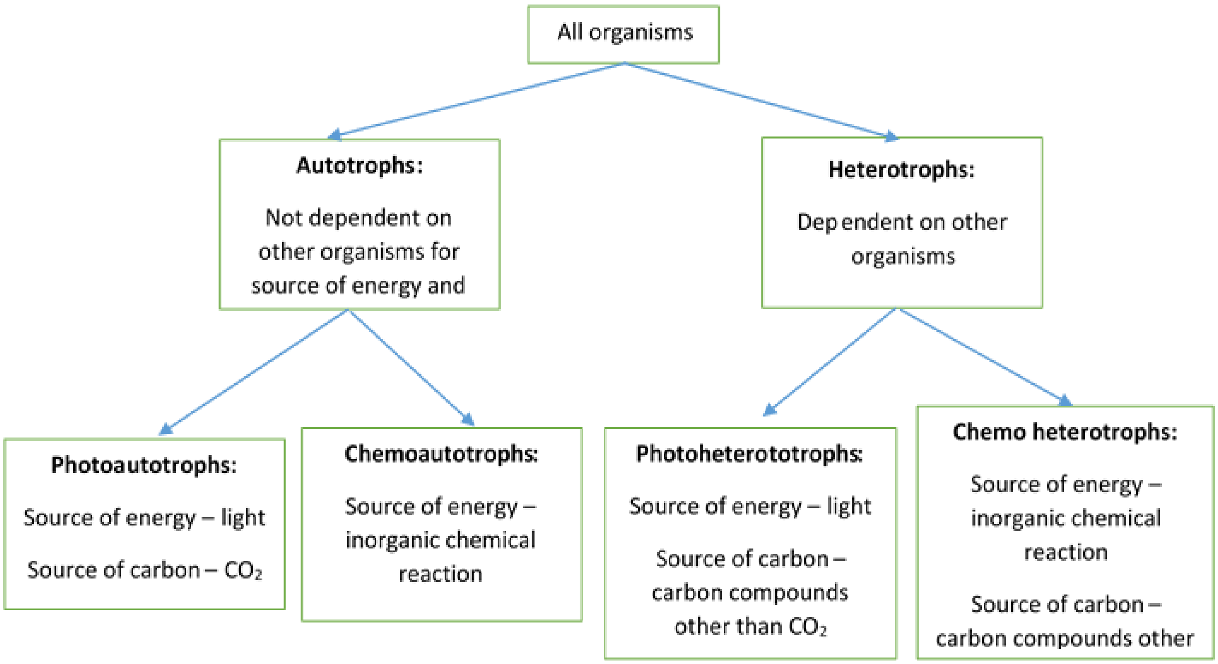

Figure 4.1: Basics of Microbial Metabolism

Thus, based on the wealth of microbial research, if such information emerges that bacteria X can metabolize organic compound C (which happens to have contaminated a given site), a bioremediation procedure can be designed and executed.

Interestingly, use as a source of energy or carbon is not the only mechanism by which a microorganism may help remediate a contaminated site. There are a host of other processes by which microorganisms take up pollutants. Some such processes are:

- Biosorption: a property of certain types of inactive, dead, microbial biomass to bind and concentrate heavy metals from even very dilute aqueous solutions. Biomass exhibits this property, acting just as a chemical substance, as an ion exchanger of biological origin.
- Bioaccumulation: a property by which certain elements are accumulated within the microbial cell – not getting excreted or catabolized at the rate at which it is getting ingested.
- Bioleaching: extraction of metal from its compounds with the help of enzymatic processes within a living cell

- Biotransformation: it is the conversion of a compound into another with the help of enzymatic processes within a living cell
- Biomineralization: it is, in principle, a process opposite to that of bioleaching, in which living organisms produce minerals to stiffen or harden their tissues

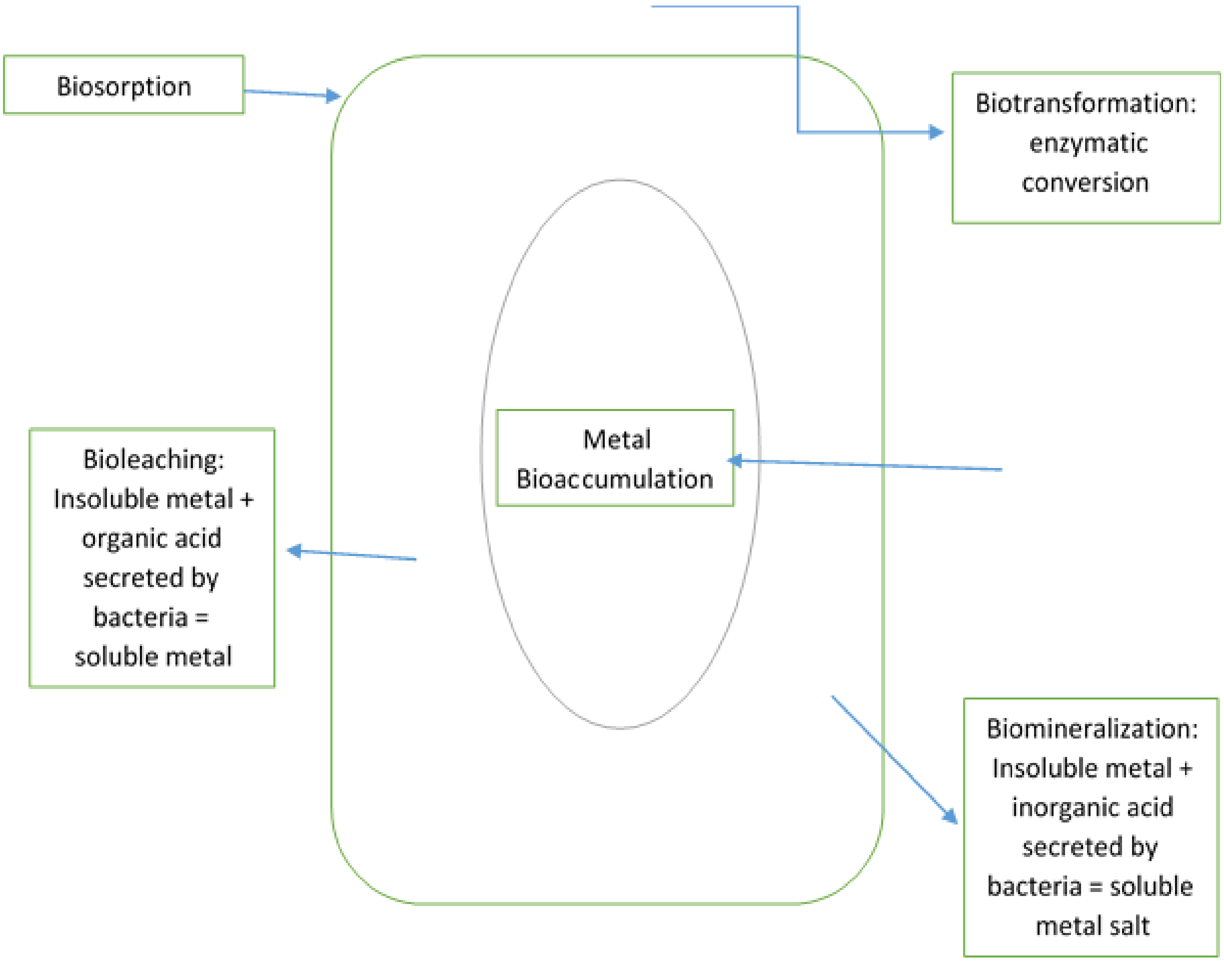

Figure 4.2: Underlying Mechanisms of Bioremediation

Phytoremediation

The various processes of phytoremediation have been outlined below, and in Figure 4.3.

- Phyto-extraction - Phytoextraction is the extraction of pollutant from the contaminated soil or wastewater through its root system.
- Phyto-degradation – Phytodegradation, which is also termed phyto-transformation involves the induction of chemical changes in the pollutant molecule through plant enzymes. This transformation can occur after the plant has absorbed the pollutant molecule through one of its nutrient uptake pathway (mistaking the pollutant molecule for something else!) or it can occur outside through exo-enzyme secretion.

- Phyto-stimulation – Bacteria inhabiting the root zone of plants are stimulated by the plant atmosphere such that they together assist in contamination removal. It may also be referred to as plant-assisted bioremediation.
- Phyto-volatilization – Conversion of contaminants to the gaseous form after undergoing phyto-transformation. Volatile organic compounds may be volatilized from stems or leaves (direct) or from soil due to plant root activities (indirect).
- Rhizo-filtration – suitable plant species with stabilized root systems can absorb, concentrate, and precipitate toxic metals when irrigated with contaminated water, or if growing in soil with contaminated groundwater.
- Hyperaccumulation - Hyperaccumulator plants have the capacity to accumulate a substantial amount of pollutant, usually heavy metals or metalloids, in their plant body. Sites of accumulation are cell vacuoles, cell walls of roots, and bundle sheath of leaves.
- Hydraulic containment – Pollutant dissolved in groundwater can spread to an unprecedented degree if left unchecked. Hydraulic containment is the activity of preventing contaminated groundwater from spreading. This may be achieved with the help of deep-rooted trees such as poplar.
- Phyto-capping - Phyto-capping may be defined as the dumpsite capping technology that uses plants and unconsolidated soil to control and limit entry of water into waste (Lamb et al. 2014).
- Phyto-desalination – Phytodesalination is the process of using halophytes (i.e., plants that flourish on saline soil) to remove salt from the soil and make it more amenable for cultivation.

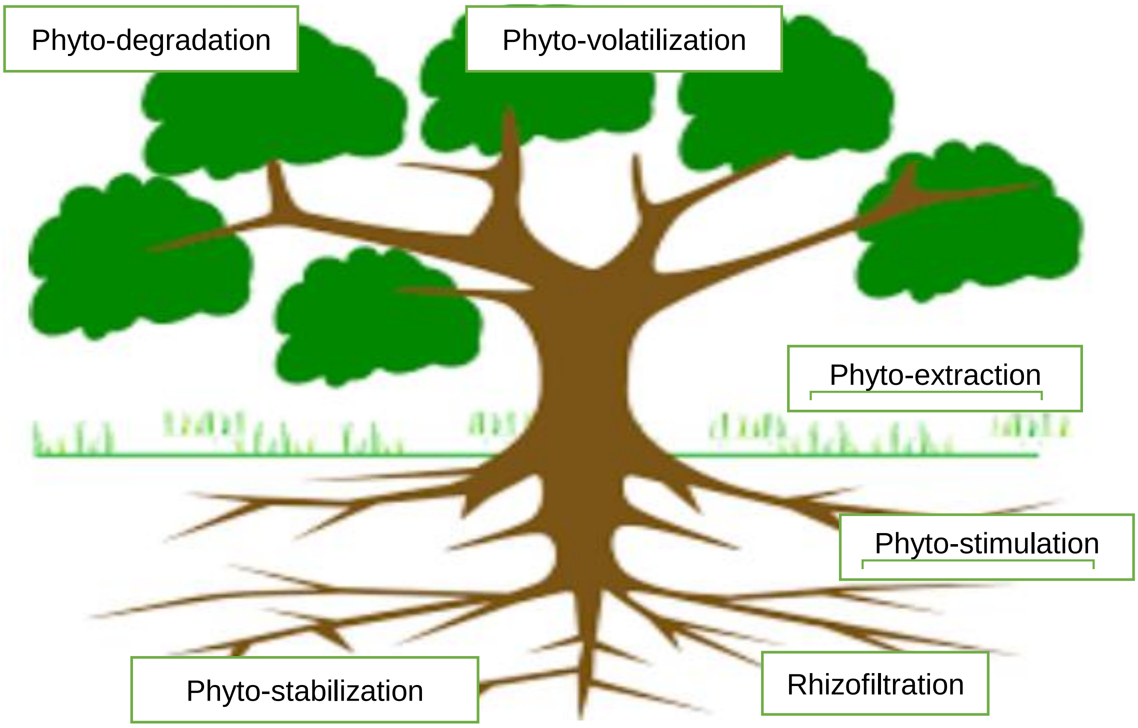

Figure: 4.3: Underlying Mechanisms of Phytoremediation

4.2 Bioremediation

Bioremediation technologies shall differ with:

- Type of waste – heavy metals, hydrocarbons, are the types of pollutants that can be efficiently tackled with the help of bioremediation.
- Site where remediation is required

In general, in-situ (i.e., at the site itself) technologies are preferred over ex-situ ones wherein it is necessary to physically remove the polluted component and transport it to site where remediation efforts will be initiated. Usually, the ex-situ approach can be justified only if the site in question is under threat, or the remediation process entails heavy machinery that cannot translocate onsite.

In-situ bioremediation technologies

In-situ soil bioremediation technologies have been described later in this unit (section 4.5). To summarize here, a suitable microbial consortium or culture is sparged into the contaminated soil layers and given additional dosages of required nutrients to help it grow. Additionally, oxygen or ozone is also sparged into the contaminated soil layers if the microbial flora of interest is aerobic in nature.

In-situ water bioremediation technologies have been established by various studies. One such technology is that of Microbial Dosing, wherein a suitable microbial consortium or culture is added to the water body in question. The natural microbial flora of the water body is augmented and pollution is gradually remediated.

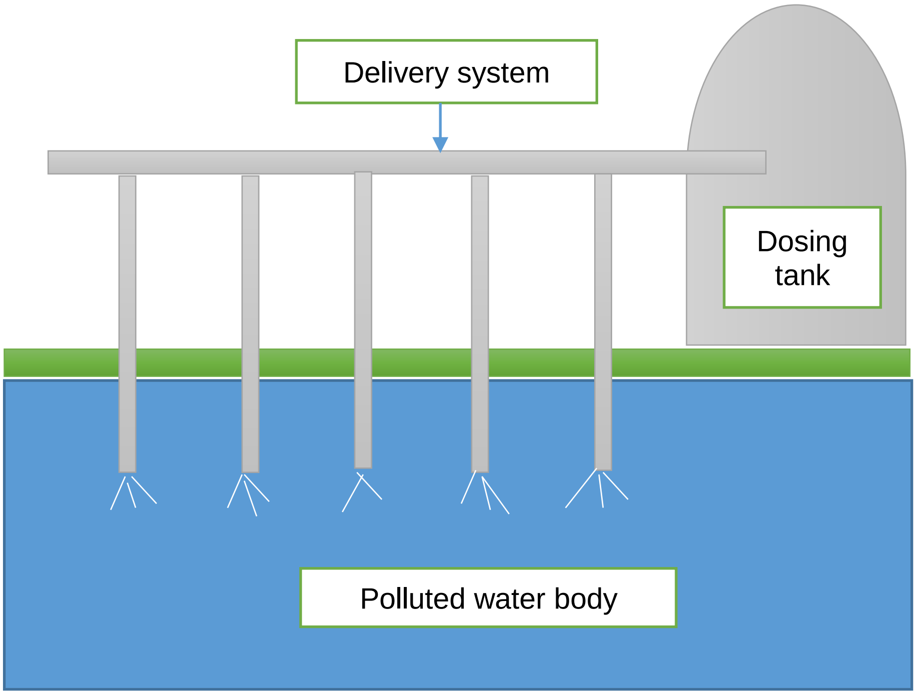

Figure 4.4: In situ microbial dosing system

Bio-film formation is another in-situ water bioremediation. The bio-film technology mimics the natural bio-film forming property of various microorganisms with the help of processes such as adsorption, degradation and filtration. The nutrients required to assist microbial growth are externally provided.

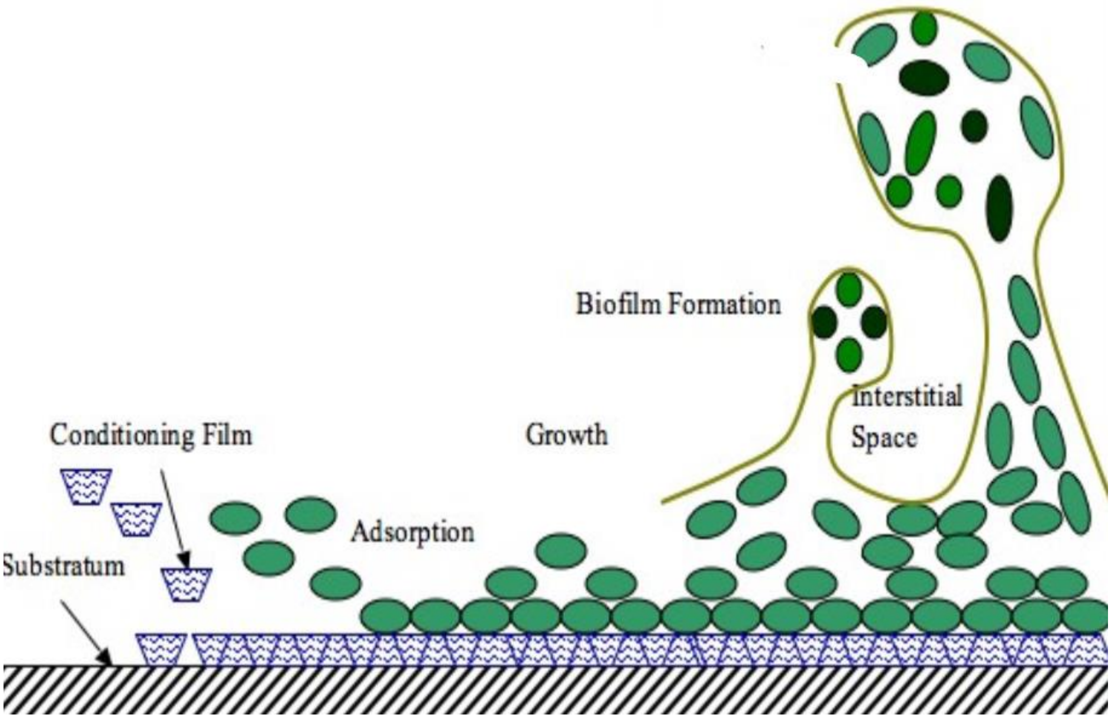

Figure 4.5 Biofilm formation

Ex-situ bioremediation technologies

Invariably, ex-situ or offsite bioremediation technologies will be conducted in the liquid or slurry phase within a bioreactor, or, if the physical state of the waste permits, then in the solid phase.

Ex-situ liquid or slurry-phase bioremediation is typically carried out in a bioreactor. A bioreactor is an apparatus wherein a biological reaction or process is encouraged to take place, maintaining optimum conditions for the growth of the microorganism within. A bioreactor typically operates at the industrial scale and for profitable operations, though it can be scaled down to the pilot or laboratory levels for research and development activities. A bioreactor may also be referred to as a fermenter. Bacterial and fungal cultures as well as plant and animal cells can be cultivated in bioreactors. In the context of bioremediation, though, we are restricting ourselves to bacterial and fungal cultures. A typical bioreactor has been described below:

- Material used to make a bioreactor –
  - It is most commonly fashioned out of stainless steel (for industrial and pilot scales), though at the laboratory scale, glass may be preferred
  - While the bioreactor vessel can take any shape and size depending on project-specific requirements, it is essential that the vessel withstand sterilization - given that it is a microbial process where contamination can reduce process efficiency, the bioreactor vessel needs to be sterilized before the cocktail of growth media + microbial culture + pollutant to be remediated is introduced into it
  - In addition, it is significant that the bioreactor vessel is so constructed that there is no scope of entry of non-sterile air /media/ water or any other substance during the period (of a few hours to a few days) in which the microbial process is going on.
- A growth medium feeding pump – through this, a pre-determined optimal growth medium rich in sufficient nutrients, is pumped into the bioreactor.
- Autoclave – to steam-sterilize the growth medium (steam sterilization is the most preferred method for microbial growth media sterilization)
- An air feeding pump – for aerobic microbial systems, sterilized/filtered air that is free of cross-contaminating microbes is introduced into the bioreactor.
- An air sparging system/ aerator – for efficient bubbling of air through the growth medium
- A stirrer/agitation system – a stirrer ensures that the air and nutrients are evenly distributed within the bioreactor vessel, and none of the microbial cell is deprived of these growth essentials. This enhances speed and efficiency of the bioremediation process
- Sensor probes – sensors of pH, temperature, pressure etc. yield real-time outputs of these microbial growth-affecting parameters; they are indicators of whether the microbial growth

is following its usual trajectory, and whether the bioremediation process is proceeding with its predicted efficiency

Contrastingly, in an anaerobic bioreactor, the stress is on

- Stress on maintaining oxygen-free conditions within the bioreactor, as anaerobic microbes perish upon exposure to air
- Absence of air pumping and sparging system
- Release mechanism for the gases that will be inevitably generated

In Figures 4.5 and 4.6 below, a typical aerobic and anaerobic reactor system has been depicted, respectively.

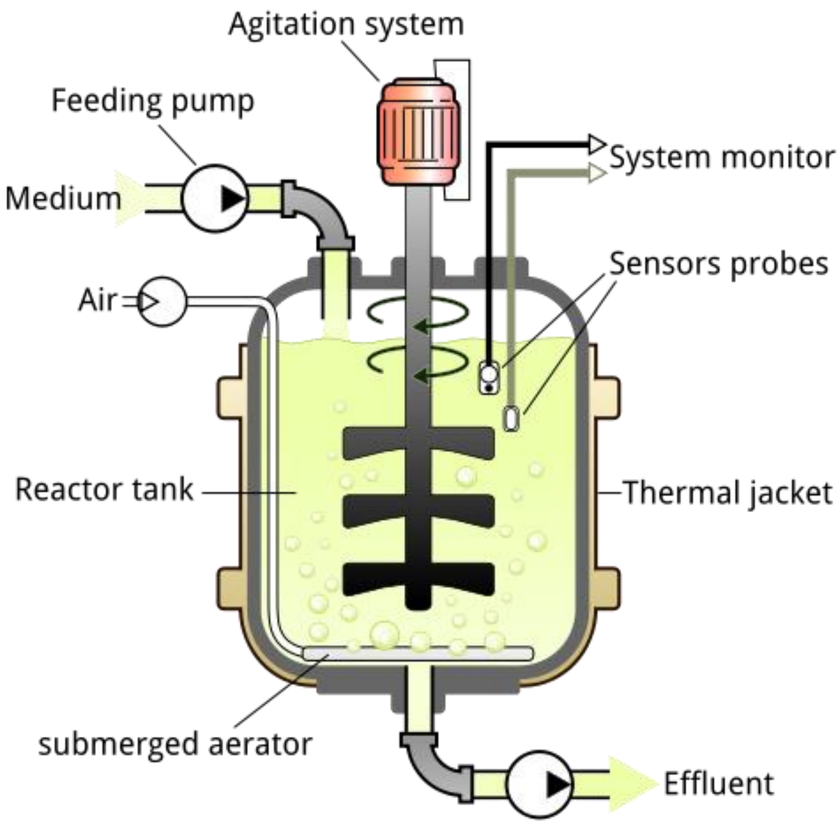

Figure 4.6: A Typical Aerobic Bioreactor

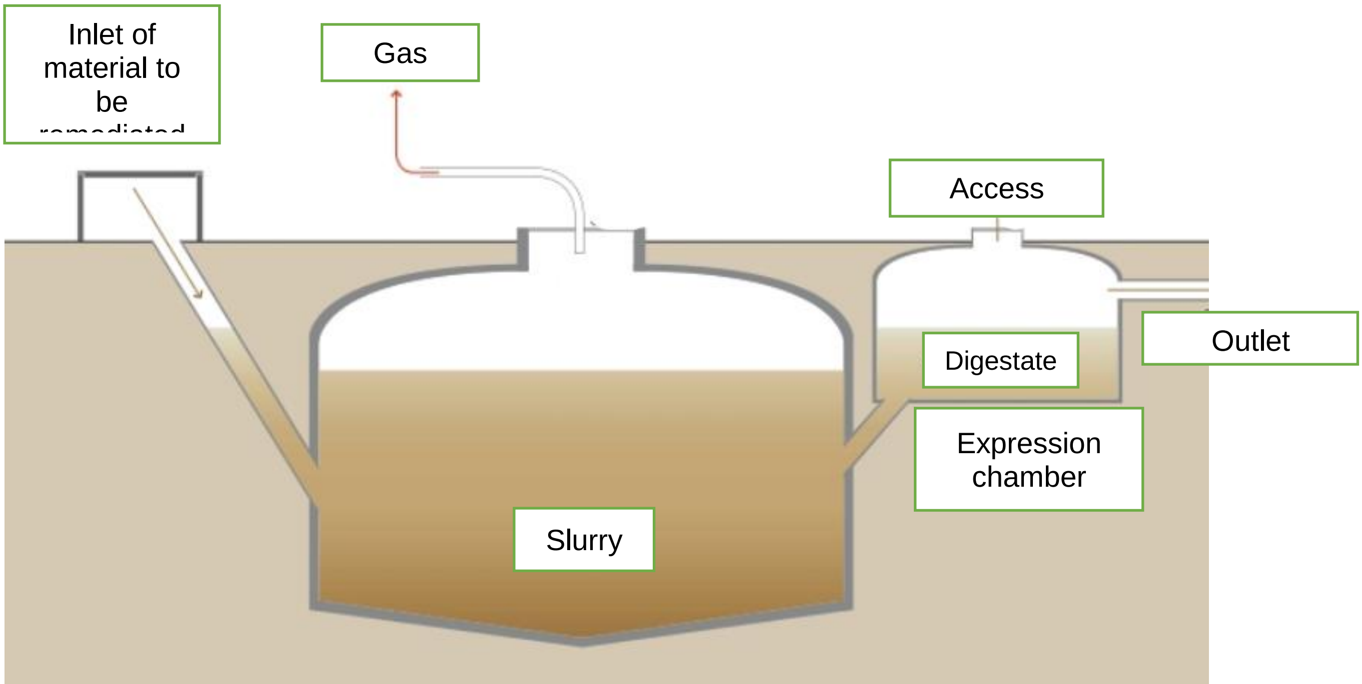

Figure 4.7: A typical anaerobic reactor system

Sterilization protocol

Steam Sterilization – an autoclave is an apparatus used commonly for steam sterilization. As per microbiology standards, an autoclave regime of 15 minutes sterilization at 15 pounds per square inch (psi) pressure at a temperature of 120°C is considered sufficient to destroy even thermophilic microbes and their spores.

Filtration – media components that are heat-labile (i.e. will degrade under high temperature) can be filter-sterilized, using a filter of 0.2 micron or smaller pore size.

Radiation – ultraviolet rays in the laminar air flow units are commonly used for surface sterilization of the working surface

Chemical disinfection for glassware is also a part of the standard procedures.

Disadvantages of bioremediation

- Requirement of acclimatization
- Risk of contamination
- If optimum growth conditions are not met, process becomes inefficient
- Inability to perform in wastewater streams with widely fluctuating chemical constitution
- Not an instantaneous solution

Case studies

Mandal et al. (2012) prepared a consortium of four bacterial species, selecting their isolates from crude oil-contaminated soil samples from various oil refineries and oil exploration sites of India. As per their report, the consortium could efficiently remediate crude oil-contaminated soil.

Istok et al. (2004) reported the in situ bioreduction of technetium and uranium in a nitrate-contaminated aquifer; they concluded that the natural bio-reduction of Uranium (VI) and Technetium (VII) mixtures at high-nitrate concentrations could be stimulated by the addition of organic compounds such as ethanol or acetate, which served as electron donors.

Algae can be also used for the removal of nonconventional pollutants such as uranium from wastewater (Kalin et al. 2004).

Mingjun et al. (2009) described the in-situ bioremediation of a eutrophic lake, namely Yingze Lake in Anshan, China for four months. Microbial consortium was prepared from the bacterial species screened from the lake waters and sediment.

To-do activity: Visit to a biomethanation or biogas plant near you; both are examples of anaerobic reactions. Prepare a plan for establishing a biomethanation plan for your city/ bulk generators.

4.3 Phytoremediation

Phytoremediation can be defined as "the efficient use of plants to remove, detoxify or immobilize environmental contaminants in a growth matrix (soil, water or sediments) through the natural biological, chemical or physical activities and processes of the plants".

In situ technologies

Floating treatment wetlands (FTWs) are currently gaining popularity as an in-situ phytoremediation technology for water-based ecosystems. Despite the inherent difficulties in providing the necessary hydraulic retention time (HRT), variants of this technology continue to be used. FTWs mimic nature's floating wetlands, and employ emergent aquatic plants such as Canna, Typha sp., Scripus, etc. Not only do the FTWs serve as a contaminant removal system but serve the ecological role of bird perches and fish egg-laying sites.

Figure 4.8: Initial Prototype of CSIR-NEERI's Floraft Technology

In situ soil phytoremediation is a popular approach for pollution amelioration. The use of plants to 'cap' landfills (Phyto-capping), as described in Unit 3, may be observed as an in-situ phytoremediation approach for landfill sites.

Depending on how deep the contaminant has penetrated the soil layers, the decision to use deep-rooted trees or shoots with shorter root depths can be selected.

Ex-situ technologies

Constructed Wetland technology has been a popular ex-situ phytoremediation technology of choice.

Constructed wetland technology

The constructed wetland is an artificial wetland, constructed of suitable locally available construction material, which is used to mimic natural ecosystems using soil and local vegetation, and aimed at the remediation of polluted water, sewage, or industrial effluent. Constructed wetlands are engineered to suit local conditions and are designed for treating specific types of pollutants. Constructed wetland has been discussed here as an off-site or ex-situ remediation technology. However, constructed wetlands are simple enough to be constructed on-site; the wastewater stream to be treated can be pumped into it, given the adequate hydraulic retention time, and then pumped back.

Typha and Phragmites are two emergent macrophytes that are used most frequently in constructed wetland systems.

Constructed wetland technology is often used after primary and secondary treatments, as a polishing tertiary treatment.

Depending on the direction of flow of the effluent through the constructed wetland, the CW design can be segregated into horizontal and vertical flow systems. While in the horizontal flow system the inlet and outlet are at the two ends, in the vertical flow vertical flow constructed wetland system, the effluent is drained from the bottom of the bed and loaded on the top with pipes.

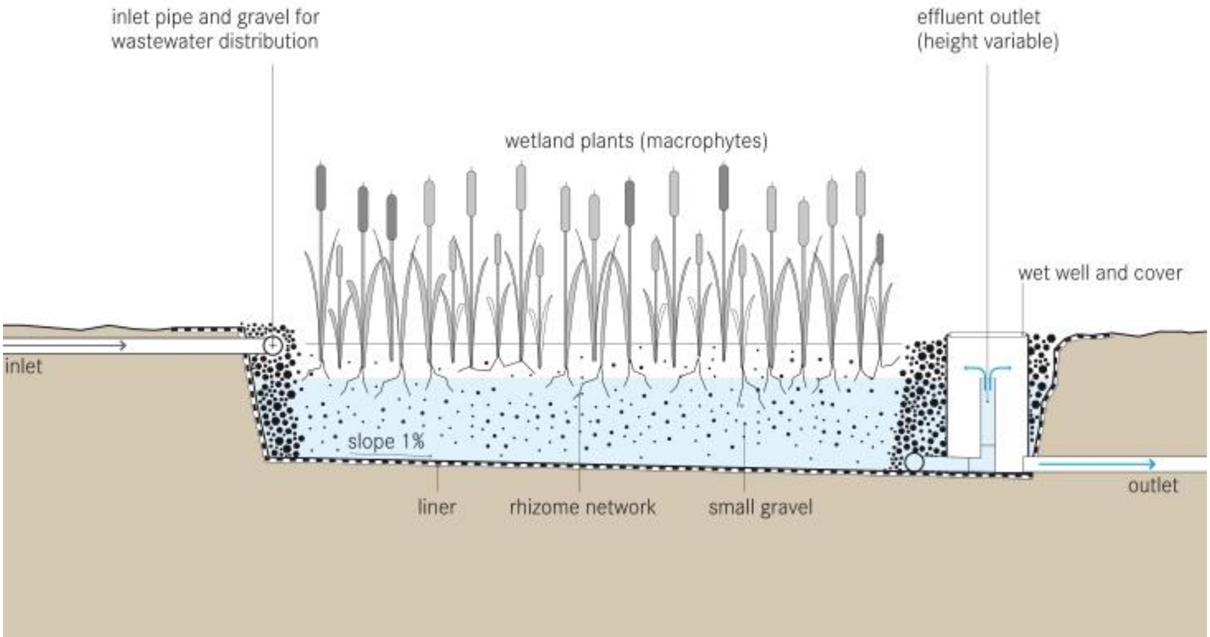

Figure 4.9: Representation of Horizontal Flow Constructed Wetland (Source: Tilley et al. 2014)

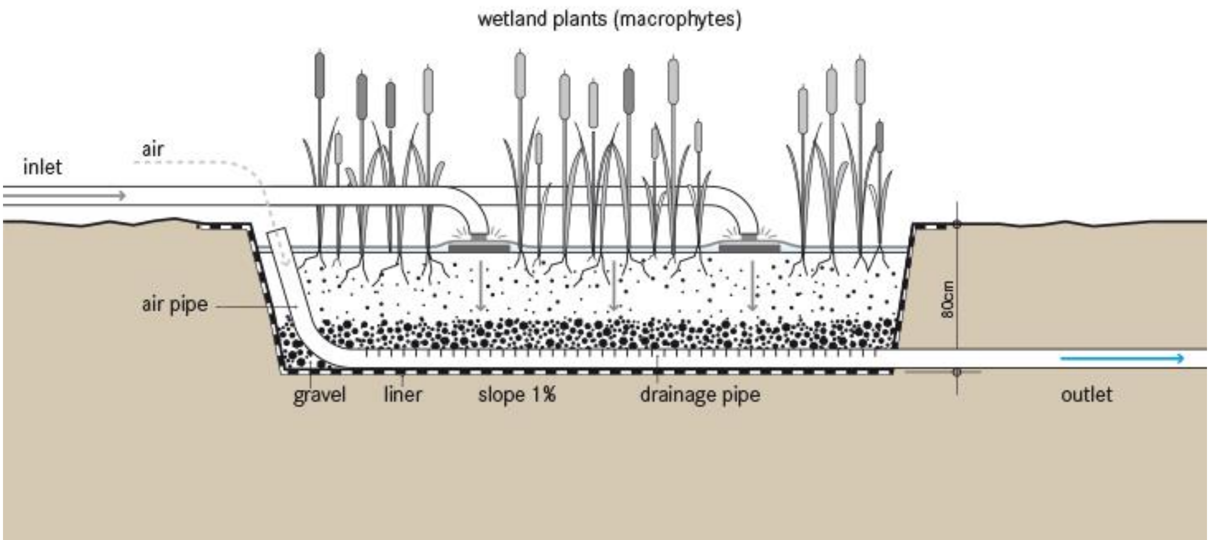

Figure 4.10: Representation of Vertical Flow Constructed Wetland (Source: Tilley et al. 2014)

The scientific community stands divided as to whether the vertical flow CW is more efficient than the horizontal one. Few authors report nearly equal performance (Luederitz et al. 2001), whereas other studies indicate that while the vertical system is more efficient at removing some pollutants, the horizontal system displays its higher efficiency with other pollutants (Yalcuk and Urgulu 2009). Hence, hybrid systems, as in, a combination of horizontal and vertical constructed wetlands have also been engineered and reported to show good efficiency.

Case studies

- Selvaraj et al. (2013) in his recent studies reported that Brassica junceato be an efficient species for arsenic phytoremediation
- Banach et al. (2012) concluded that Azolla sp. was capable of accumulating significant quantities of mercury, cadmium, lead, chromium, arsenic, silver, platinum and gold.
- In a study by Arora et al (2009) a pot trial was set up in order to evaluate bioremediation efficiency of Panicum virgatum (switchgrass) in association with PAMs (Plant Associated Microbes). Growth parameters and bioremediation potential of endomycorrhizal fungi (AMF) and Azospirillum against different concentrations of lead and cadmium were compared.
- Barac et al. (2009) in his studies reported that the hydraulic containment of a BTEX plume in groundwater was reported by poplar tree plantations near a car factory. 275 poplar trees took about 5 years to grow down to the groundwater level and then significantly reduced the spread of the BTEX plume.
- Hadad et al. (2006) demonstrated the phytoremediation of industrial wastewater using macrophytes such as Typha domingensis in a pilot-scale constructed wetland. The highly alkaline wastewater was also rich in nickel, zinc and chromium; T. dominngensis was found to effectively phyto-remediate the wastewater.
- Zimmels et al. (2008) reported the use of floating aquatic plants water hyacinth and water cabbage (also known as water lettuce) for sewage treatment.
- Francis et al. (2017) in his recent study reported that in-situ soil phytoremediation for an arsenic-contaminated site was carried out in a location in China. The arsenic hyperaccumulating plant Pteris vittata was grown in the contaminated soils amended with citric acid and EDTA. The results showed a positive impact on the contaminated soil.
- Pongwichian et al. (2014) describe the phytoremediation of salinity-infused soils in the coastal areas of Petchabauri in Thailand. The species used were Sporobolusvirginicus, Distichlis spicata, and Spartina patens.

4.4 Bio-mining of Waste

Popular connotation

Bio-mining of waste should not be confused with the more popular connotation of the term Bio-mining. Bio-mining popularly refers to the extraction of metals of economic interest from rock ores or mine and industrial wastes using microorganisms. Understandably, bio-mining has been considered a greener technology than conventional mining that relies heavily on environmentally-harmful chemicals.

Industrial and mine waste management through bio-mining

Various anthropogenic activities such as mining, metallurgy, leather tanning, electroplating and industries manufacturing paints, dyes, batteries, photovoltaic cells etc. can generate wastewater streams rich in metals. Bio-mining can be offered as a green solution herein, aiding recovery of metals that are scarce and valuable; in addition, this reduces pressure on natural mine resources if taken up on full scale.

As outlined above, microbes are capable of multiple metabolic pathways that are far removed from modern life forms. The extremophiles and metal-metabolizing microbes can carry out bio-leaching and remove metals from their ores. Unlike chemical processes, even low-yielding ores can be utilized. This bio-leaching can be carried out under controlled environments in bioreactors, and the metal of interest can then be extracted from the microbial biomass in a two-step reaction.

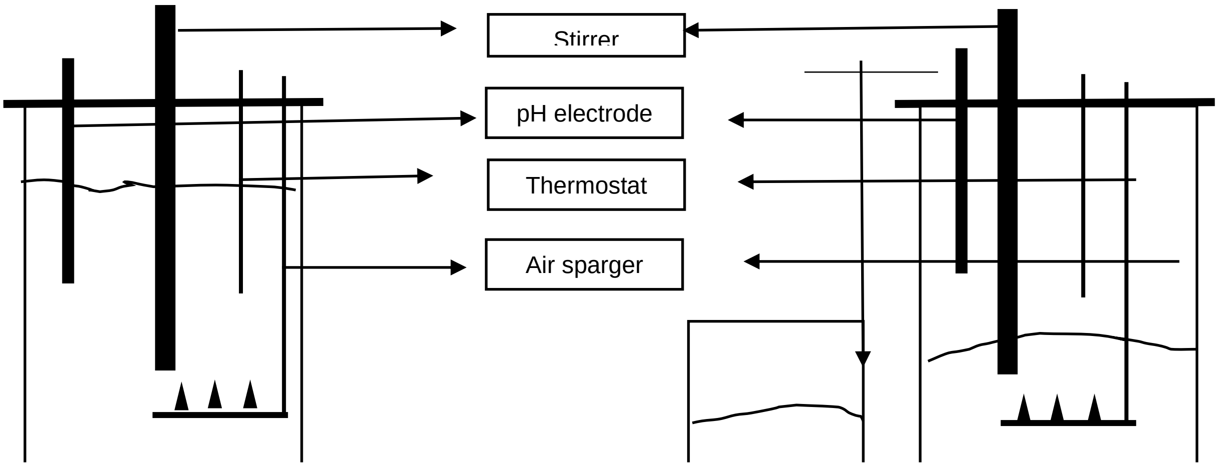

Figure 4.11: Bio-mining of mine tailings for metal concentration; Bioreactor 1 (step 1): Bio-leaching of tailings; Bioreactor 2 (step 2): Selective precipitation of metal

In a novel attempt, Hong and Valix (2014) reported the use of acidophilus sulfur-oxidizing bacteria for bio-leaching of electronic waste. They used Acidithiobacillusthiooxidans on Cu-rich electronic waste and found that e-waste toxicity did not deter bacterial growth.

Hoque and Philip (2011) enlist several case studies wherein bio-hydrometallurgical processes were employed to recover heavy metals from a variety of secondary sources including low grade ores, wastewater streams, river sediments and electronic waste ashes.

Mishra and Rhee (2014) described the bio-leaching of metals from industrial solid waste. They emphasized the conversion of insoluble sulfide ores to their corresponding soluble sulfate forms under acidic conditions, with the help of acidophilus bacteria such as Acidithiobacillusferrooxidans, Acidithiobacillusthiooxidans, Leptospirillumferrooxidans and Sulfolobus spp.

In Table 4.1 below, bio-leaching efficiency of different metals from different waste streams has been outlined:

Table 4.1: Bio-leaching efficiency of different metals from different waste streams

Type of waste	Bioleaching efficiency	Microorganism	Reference
Fly ash	Al:97%; Zn:98%; Fe:56%	Aspergillus niger	Xu and Ting (2009)
Sewage sludge	Cu:64%; Zn:76%; Ni:58%; Cr:52%	Acidithiobacillusthiooxidans	Pathak et al. (2009)
	Zn:89%; Cu:80%; Pb:50%; Cr:32%	Iron-oxidizing bacteria	Wen et al. (2013)
Electronic scrap	Cu:90%; Al:80%; Ni:82%; Zn:80%	Thermoplasmaacidophilum&Sulfobacillusthermosulfidooxidans	Ilyas et al. (2013)
	Cu & Sn:65%; Al, Ni, Pb& Zn:>95%	Aspergillus niger& Penicillium simplicissimum	Brandl et al. (2001)
	Cu:71%	Acidithiobacillusferrooxidans	Yang et al. (2009)
	Au:68.5%	Chromobacteriumviolaceum	Brandl et al. (2008)
Spent battery	Co:99.9%	Acidithiobacillusferrooxidans	Zeng et al. (2012)
	Co:100%	Acidithiobacillusferrooxidans	Velgosova et al. (2013)
	Co:>90;	Acidithiobacillus spp.	Xin et al.

	Ni:>80%		(2009)
	Co:65%	Acidithiobacillusferrooxidans	Mishra et al. (2008)
Spent petroleum catalyst	Fe, Ni & Mo:100%; Al:67%	Acidianusbrierleyi	Bharadwaj and Ting (2013)
	Al:35%; Mo:83%; Ni:69%	Acidianusbrierleyi	Gerayeli et al. (2013)
	Al:63%; Co:96%; Mo:84%; Ni:99%	Acidihtiobacillus spp.	Gholami et al. (2011)
	Ni:88%; Mo:46%; V:95%	Acidithiobacillusthiooxidans	Mishra et al. (2008)
Spent fluid cracking catalyst	Al:54.5%; Ni:58.2%;	Aspergillus niger	Saanthiya and Ting (2005)
	Mo:82.3% Mo:99.5%; Ni:45.8%; Al:13.9%	Aspergillus niger	Amiri et al. (2012)
	W:100%; Mo:92.7%; Ni:66.4%; Al:25%	Penicillium simplicissimum	Amiri et al. (2011)
Waste electronic device	Au:11.3%	Chromobacteriumviolaceum	Chi et al. (2011)
Jewelry waste	Ag:5%	Pseudomonas plecoglossicida	Brandl et al. (2008)
Spent automobile catalytic converter	Pt:0.2%	Pseudomonas plecoglossicida	Brandl et al. (2008)

Reproduced from Mishra and Rhee (2014)

Bio-mining of waste: the context in India

Now, in the Indian context, Bio-mining of waste refers to the reduction in volume of garbage in landfill sites through –

- Physically mining for recoverable waste portions using appropriate machinery (detailed in Unit 3)
- Use of bio-culture to reduce garbage volume
- Transfer of the non-biodegradable portion of the waste for energy recovery

The terminology became popular since its mention in the Solid Waste Management Rules, 2016, post which, several municipal tenders were published. Currently, few such projects are underway while some are slated to be started in the near-future.

In the Mulund dumping ground in Mumbai, a bio-mining project has been proposed. While that is a large dumpsite with associated complexities, South Kannanaur town panchayat in Tamil Nadu reported a successful case study of the same. With about 3400 households, the waste generated is. With the help of a microbial culture, nearly 70 tons organic manure was formed over a period of 45 days, which was later distributed to local farmers. Thus, to summarize the process in Figure 4.11 below:

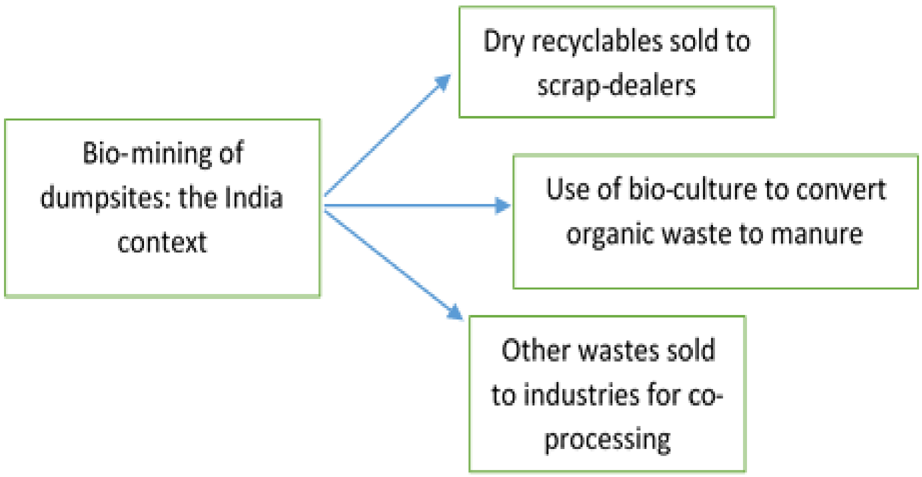

Figure 4.12: Overview of the Dumpsite Bio-mining Process in the context of India

4.5 Soil-related aspects

Importance of soil resources

Blanco and Lal (2010) describe soil as the "most fundamental and basic resource". Human survival owes aplenty to soil, given that all terrestrial vegetation (our source of oxygen, food, medicines, fiber etc.) grows in soil. Without a doubt, human food security is dependent on soil.

However, soil is much at risk today, depleting under the twin stressors of erosion and pollution. Juxtaposed with the fact that soil is a non-renewable source (over the human timeline), it becomes crucial to conserve and remediate soil.

Soil monitoring parameters

Physical and chemical parameters of soil need to be monitored to –

- Understand the baseline environmental status
- For agricultural purposes
- For risk assessment in contaminated areas or in areas at risk of contamination (i.e., areas near a nuclear power facility, or hazardous waste treatment facility etc.)

The physical parameters of soil that must be monitored include –

Soil color – soil color indicates the mineral content of soil.

Soil texture – i.e., whether soil is clayey, sandy or silty or a combination. Soil texture may be determined as per the Soil Texture Triangle given in Figure--- below.

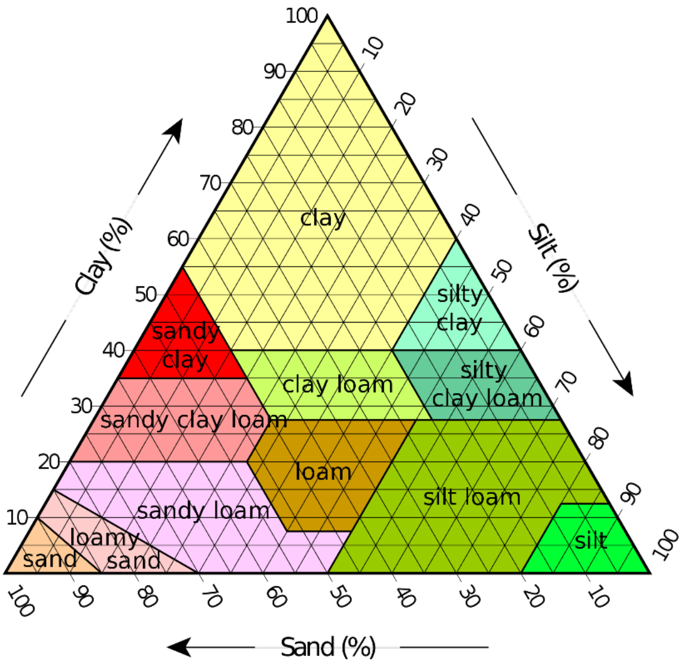

Figure 4.13: Soil Texture Triangle

Other important physical parameters are – bulk density, particle density, pore space, moisture holding capacity and Attenberg limits. Phogat et al. (2015) in his studies mentioned that physical characteristics of soil are important as they help decide how much water the soil can hold, the movement and retention of nutrients in its pores, its microbial life supporting ability, air and heat flow, or how easy or difficult it will be for plant roots to penetrate the soil.

Important chemical properties of soil include its pH (which helps decide whether soil is acidic/ alkaline/ neutral), conductivity (which indicates how), and its nutrient (nitrogen- N, phosphorus- P and potassium- K content) content (which helps decide the fertilization regimen).

Sensor-based soil monitoring

Badhe et al (2018) worked on sensors that could estimate atmospheric temperature & humidity, soil pH, soil moisture, and NPK (nitrogen, phosphorus, potassium) sensors.

Dhivya et al (2015) reported a smart sensor-based soil monitoring system wherein moisture, light and temperature were measured using sensors and could give output in an Android smart phone.

Soil contamination

Soil remediation technologies- in-situ versus ex-situ approaches

In-situ remediation approaches may come across as –

- More efficient, as it negates the possibility of residual contamination
- Negates the risk of cross-contamination during transport
- Less disruptive

Soil remediation technologies – Bio-remediation vs. physico-chemical approaches

While bioremediation processes involve living organisms (largely microbes) to metabolize the pollutants and ameliorate contamination, in physico-chemical processes, it is done so through engineering and the use of chemicals. However, in several technologies, these boundaries are difficult to demarcate and a combination of approaches is required to ensure efficiency.

Advantages of bio-remediation

- Bio-remediation, when compared with the corresponding physic-chemical process may come across as economical
- As an in-situ approach, it creates relatively less environmental disruption in contaminated sites
- In some cases, it may be the only feasible solution, as the microbial systems may possess an entire metabolic process to digest some pollutant naturally

Soil bio-remediation

Bio-venting – Bioventing is an in-situ remediation technology wherein injection wells are used to force air or oxygen or ozone, along with other nutrients, into the layers of contaminated soil with the aim of encouraging the local soil micro-flora to flourish and bio-remediate the soil.

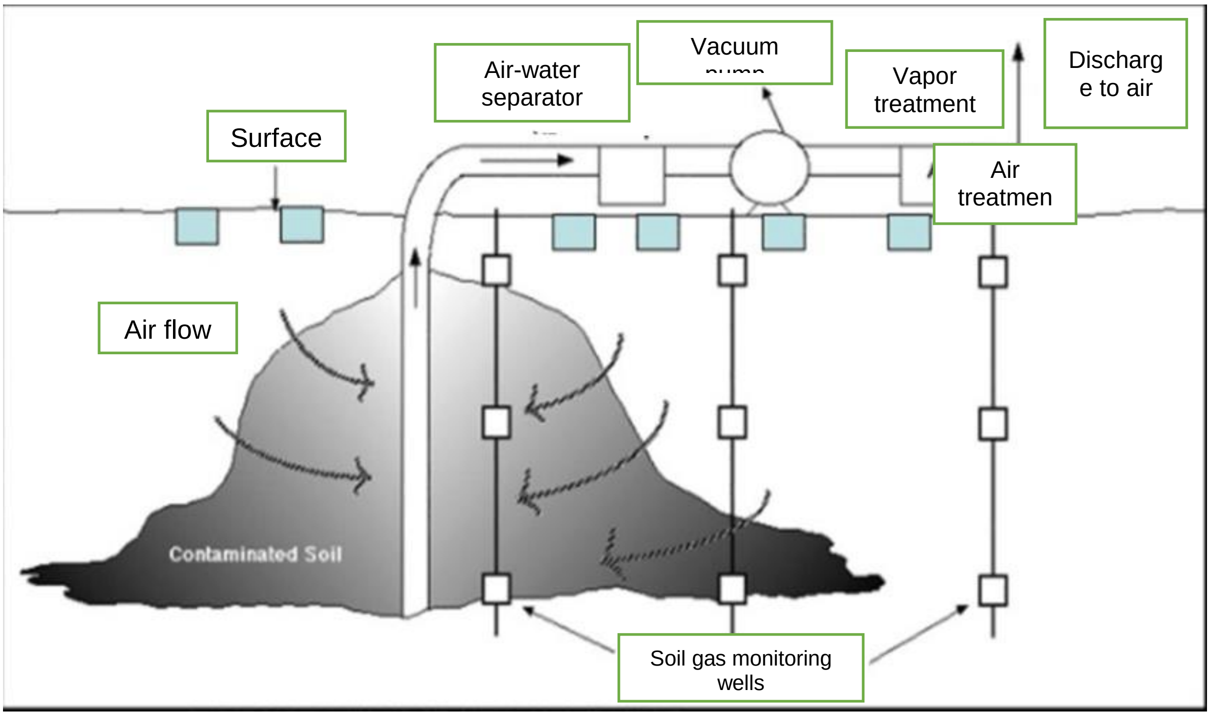

Figure 4.14: Illustration of Bioventing

In contrast, on several occasions, anaerobic microorganisms fare better than their aerobic counterparts, in which case, no oxygen /air /ozone is sent into the contaminated soil pile; instead, the anaerobic microbial culture /consortium and the substrates likely to serve as electron acceptors to them to aid their respiration and metabolism are injected.

It must be understood that in the immediate wake of soil contamination, urgent and active efforts to ameliorate the situation must be taken. However, more often than not, complete remediation will take a long period of time. During this period, it is the native soil micro-flora that gradually ensures that the soil environment returns to normalcy. During this period, minimal human intervention is required – to the extent of periodically monitoring the necessary parameters to ascertain that natural bioremediation is in progress. This process has been termed as Monitored Natural Attenuation.

Ex-situ bioremediation of soil

Bio-remediation processes that are conducted off-site (that is, contaminated soil is removed and carried over to the site where remediation facilities have been housed) are called ex-situ processes.

The bioremediation process may be conducted in a slurry phase (after mixing soil with water) or solid phase.

In the slurry phase, the soil-water suspension is infused with the relevant microbial culture or consortium and other necessary nutrients in a bio-reactor or fermenter. To maintain ideal growth conditions, temperature, pressure and other environmental parameters are maintained in the optimum ranged. Also, the slurry is stirred continuously to ensure that oxygen and nutrients are available to the microbes. During the bio-remediation process, samples are regularly withdrawn from the bio-reactor and tested to ascertain the rate at which the contaminant is getting metabolized. Once the remediation process is deemed complete, the soil is dewatered and returned to the site. Robles-González et al. (2008) give a detailed description of slurry bioreactors for soil/ sediment treatment.

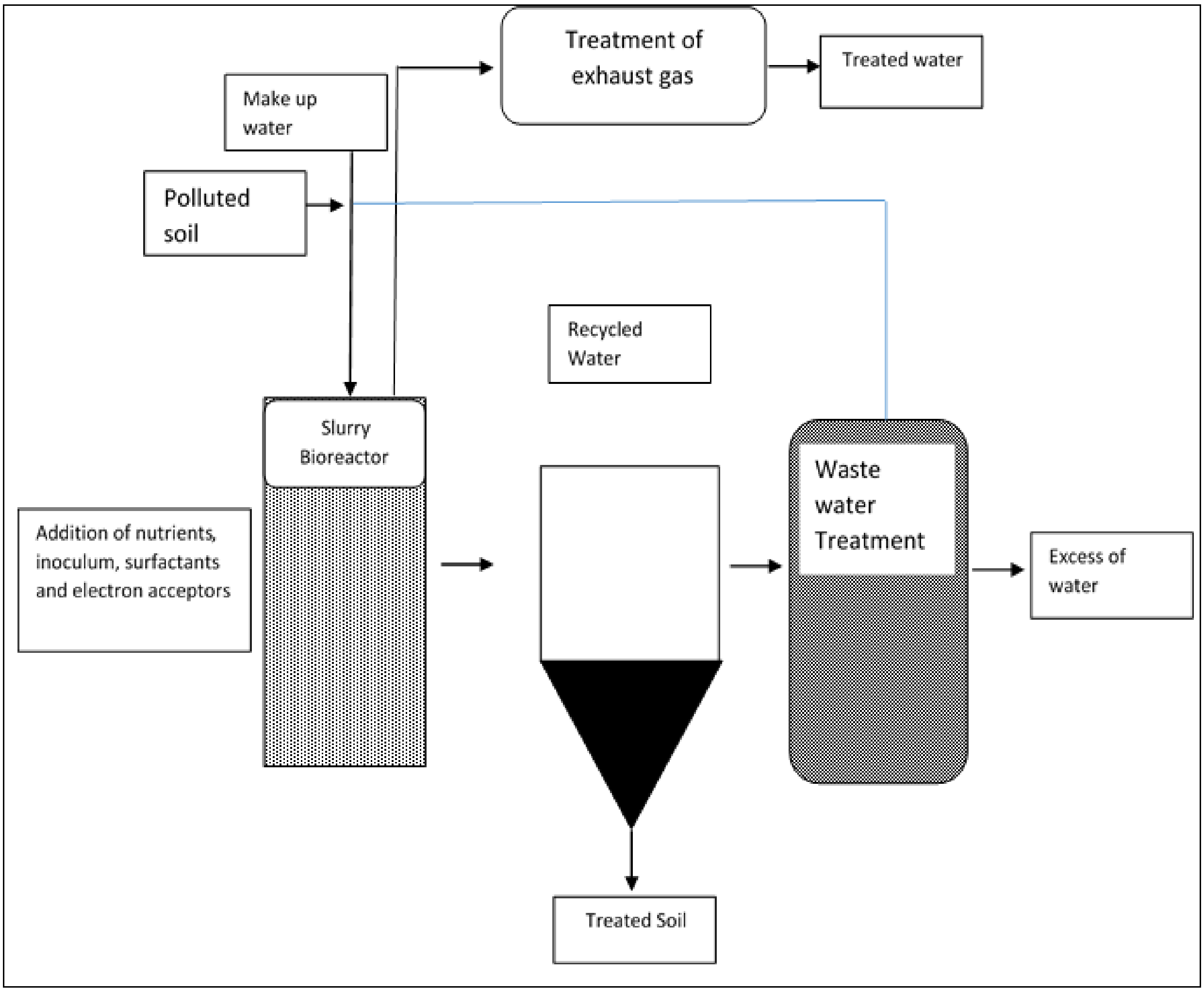

Figure 4.15: Illustration of Slurry-phase Soil Bioremediation

In Solid-phase soil bioremediation, the process is above-ground, and as indicated, occurs in the solid phase with water inputs reduced to a minimum. Just as in a bio-reactor, for solid-phase bio-remediation as well growth conditions for the microbe need to be maintained at the optimum level. Though requiring lower maintenance than slurry-phase bioremediation, solid-phase bioremediation requires ample land space and is a relatively slower process. Processes involved are: land-farming, soil bio-piles, and composting.

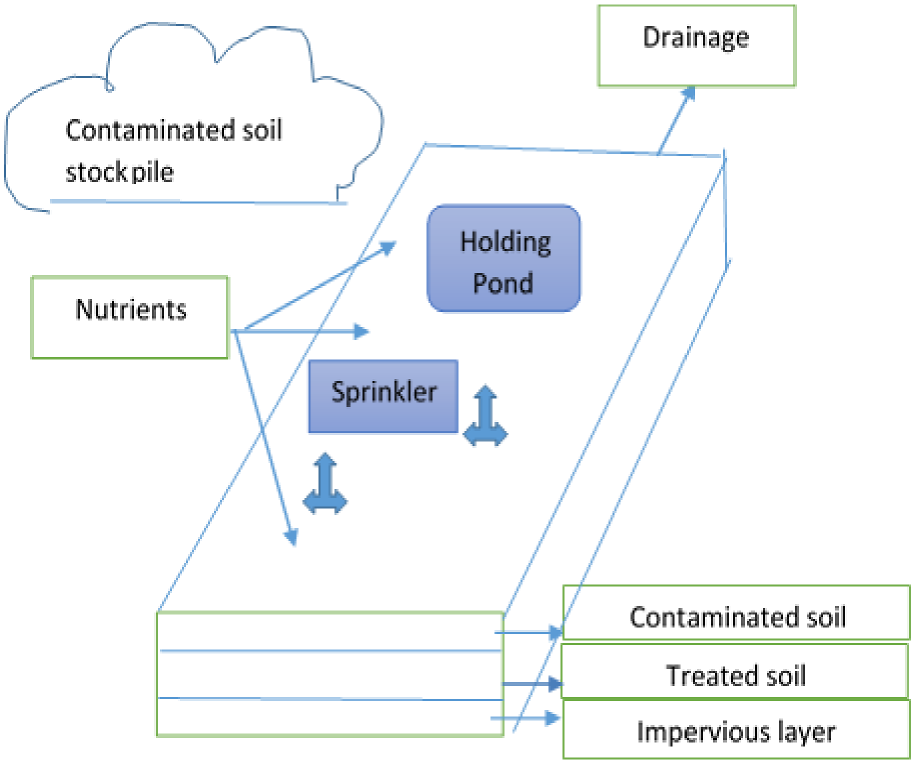

Figure 4.16: Illustration of Solid-phase Soil Bioremediation

Physico-chemical approaches

For soil polluted by volatile organic compounds (VOCs) – which are compounds present in petroleum products – it poses a serious threat to the soil and groundwater. As their name itself suggests, VOCs are volatile or unstable, and can be vaporize easily. By injecting air into contaminated soil or water, the VOCs are ejected and trapped for further treatment.

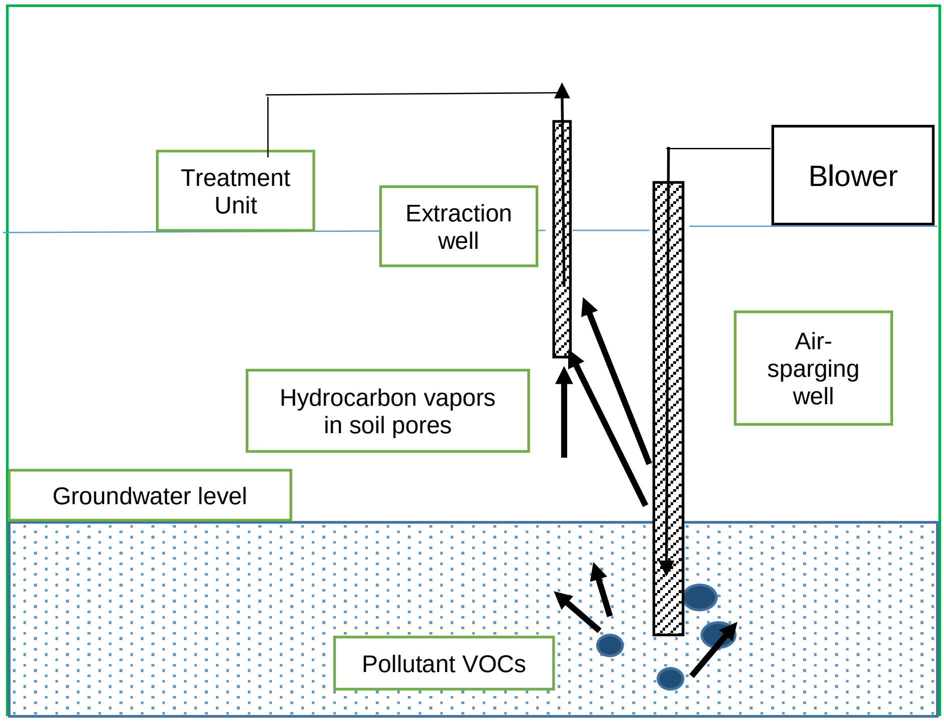

Figure 4.17: Illustration of Air-sparging for in-situ soil remediation

Night-soil management

Night soil refers to human excreta obtained from cesspools, pit latrines, and septic tanks, etc. It is an obsolete term, now largely replaced by the term 'fecal sludge'. The approach to fecal sludge management varies with the nature of human habitation, being more technology-driven in urban areas and relying on manual and non-technical approaches in rural regions.

Challenges of night soil management are:

- While now the age-old practice of manual scavenging has been illegalized and is largely forgone, it still persists in remote rural pockets
- Also, a pervasive human reluctance to think of fecal sludge as useful often leads to this valuable resource getting wasted
- Worse still, due to irresponsible, non-technical disposal in many areas, it can actually harm human health and the environment

In urban areas, most of the households are a part of the sewerage grid, where sewage is collected in sumps, pumped out into pipelines and from there, disposed of into the nearest water body (sea or river) with or without treatment.

However, in urban areas the challenge persists in urban slums that are off the sewerage network. The septic tanks of many densely-populated slums are inaccessible. Hence, here too, the approach to fecal sludge management is manual, with some technical assistance.

In rural areas, where it is difficult for technologies to be set up and maintained – given the high costs associated with skilled manpower, energy and chemical inputs – it makes more sense to employ green technologies.

Outline of a typical sludge management plan has been provided in Figure 4.17 below:

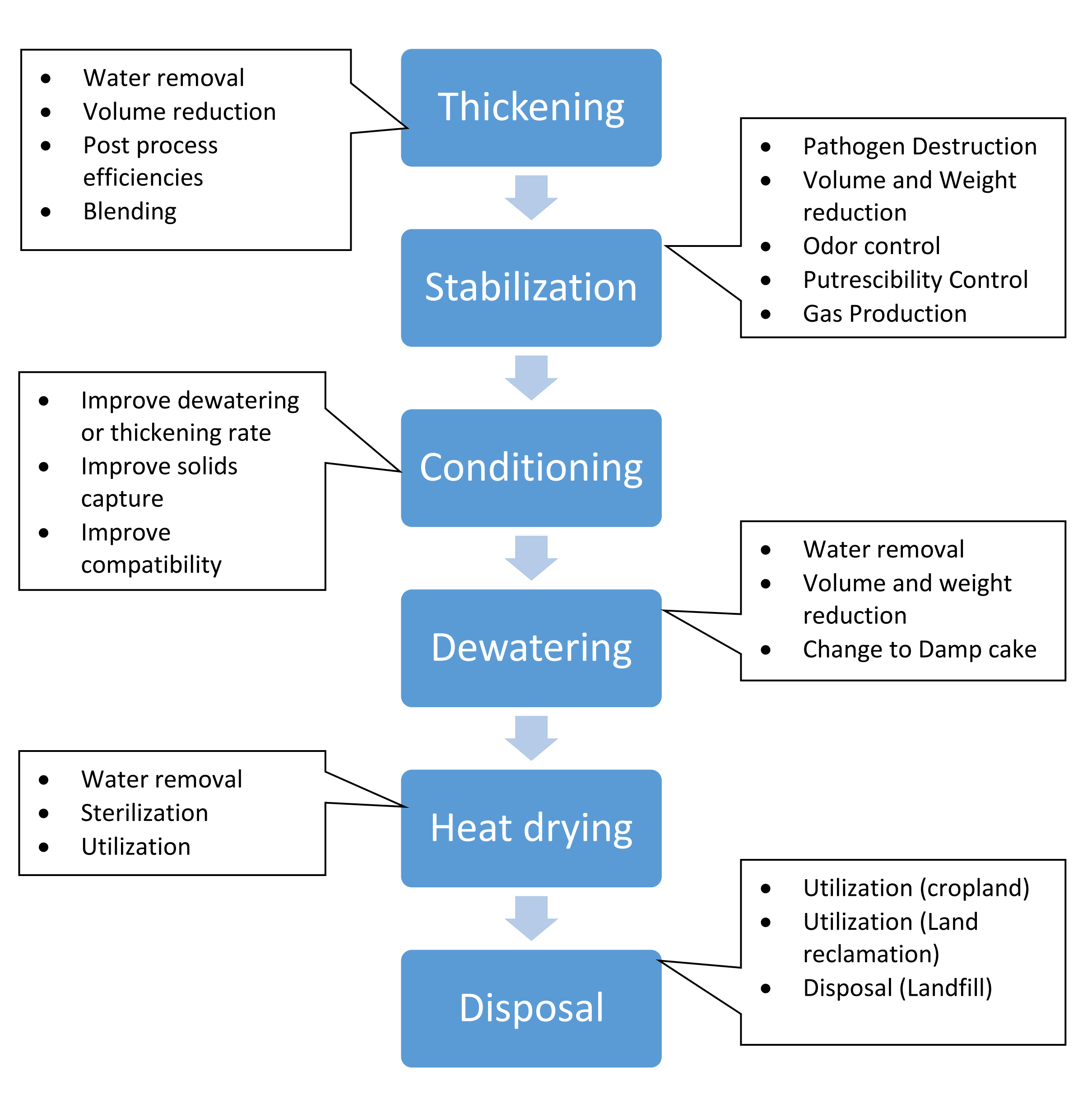

Fig.4.18: Flow Diagram of steps in sludge management

However, the most significant aspect of night soil management is to change the average individual's perception about it, recognizing it as the resource that it is:

- Night soil /fecal sludge makes excellent manure
- It can also be used as a soil-conditioner
- Alternately, it can be used for landfilling

In Table 4.2 below, the equipment utilized in different stages of sludge management have been enlisted:

Table 4.2: Equipment used in different stages of sludge management

Process	Equipment/Procedure
Sludge Thickening	Gravity Thickener
	Centrifuge
Sludge Stabilization	Lime addition
Sludge Conditioning	Charge neutralization
	Polymer bridge formation
Sludge Dewatering	Belt Filter Press
Heat Drying	Direct/indirect dryers

Summary

Thus, to summarize, by a number of natural processes, bacteria, fungi, algae and plants can either passively trap pollutants onto their surfaces, or take them inside their cells, where they either accumulate them within or metabolize them into less harmful or harmless end-products.

Several technologies have been envisaged to ensure that these natural processes become quantifiable, replicable and scalable - and hence, practically usable for actual pollution remediation. In-situ technologies are applied on the site, while ex-situ technologies require off-site transport of the polluted material. The selection of the most suitable technology depends on actual site conditions, available skill-set and available technologies.

Bioremediation and phytoremediation technologies are central to the vision of sustainability, given their low dependence on energy, chemical and manpower with comparable efficiency to conventional technologies in several cases. These green technologies need to be explored further with respect to their applicability in different scenarios, and present ample business opportunity given their attractive features.

Model questions

Q. Explain clearly how in some cases microbial treatment of waste is the only feasible solution.

Q. In what cases it would not be possible to employ a Bioremediation approach to waste treatment?

Q. Outline an innovative business plan with the following inputs – Gram Panchayat, Swachh Bharat Abhiyan, a green category manufacturing industrial plant in the vicinity, Phytoremediation approach.

Q. What is bio-mining of industrial waste? How can you prepare a business case around it, with the understanding that it is a new field with few set protocols?

Q. Despite the associated social challenges, can you envisage night soil as a resource and prepare a business case for its multifarious uses?

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Chapter 5 Multi-Criteria Decision Analysis (MCDA)

Introduction

Public decision-making is a challenging task given that any social subject has multiple facets, multiple criteria and sub-criteria with varying weights and multiple viewpoints and preferences. In this light, making the correct or most suitable decision is a tough responsibility. Be it philosophy or the more prosaic concerns of welfare economics or utility theory, decision-making is a central concern.

A decision-maker often questions –

- What alternative or choices are available?
- What are the criteria to be considered for making the right selection?
- Which criteria directly impact the decision-making and which do so indirectly?
- Does each criterion have equal importance?
- If not, which is the most important criterion?

Such questions cannot be answered randomly, or on the basis of subjective, individual viewpoints. Mathematical data analysis comes to the aid in such circumstances.

Objectives

The objective of this unit is to:

- Understand the fundamentals of the MCDA approach
- Elucidate the working principle of popular MCDA tools such as AHP, TOPSIS and ELECTRE
- Enlist the software packages that can be used to process raw data using one or more of the MCDA tools
- Comprehend how MCDA tools can be applied to decision-making challenges in waste management by understanding the drivers and challenges, and studying relevant case studies

5.1 MCDA – Overview, History and Current Trends

Even the simplest of decisions in one's day-to-day life depends on multiple criteria. For instance, the purchase of a car is a serious decision for a middle-class family who would base its final judgment on criteria such as –

- Size and style of the vehicle
- Cost
- Fuel economy
- Safety features
- Comfort

Now under each criterion, it is possible to have a set of sub-criteria. For instance, a few sub-criteria for the simplified example of car purchase have been provided:

- Size and style of the vehicle
    - Sedan / Multi-utility vehicle/ Minimum-budget car
    - Over-all look
- Cost
    - Minimum down payment
    - Easy EMI options
- Fuel economy
    - Type of fuel used (CNG/ petrol/ diesel)
    - Mileage
- Safety features
    - Power brakes
    - Seat belts
    - Air bags
    - Reverse sensing system
    - Head injury protection
- Comfort features
    - Leg-space
    - Seat breadth
    - Seat cushion covers

Now, it is necessary to understand if the decision-makers given equal importance to each criterion. For instance, the cost becomes a critical criterion for a middle-class family. Similarly, comfort-related aspects would score lower than safety features. Next, the decision-maker would draw up a list of options – what the market has to offer in terms of four-wheelers. Following this, a score from 0-1 can be assigned to each sub-criterion for each alternative, which can then be summed up to arrive at the highest-scoring alternative. Thus, to summarize, the components of an MCDA activity are:

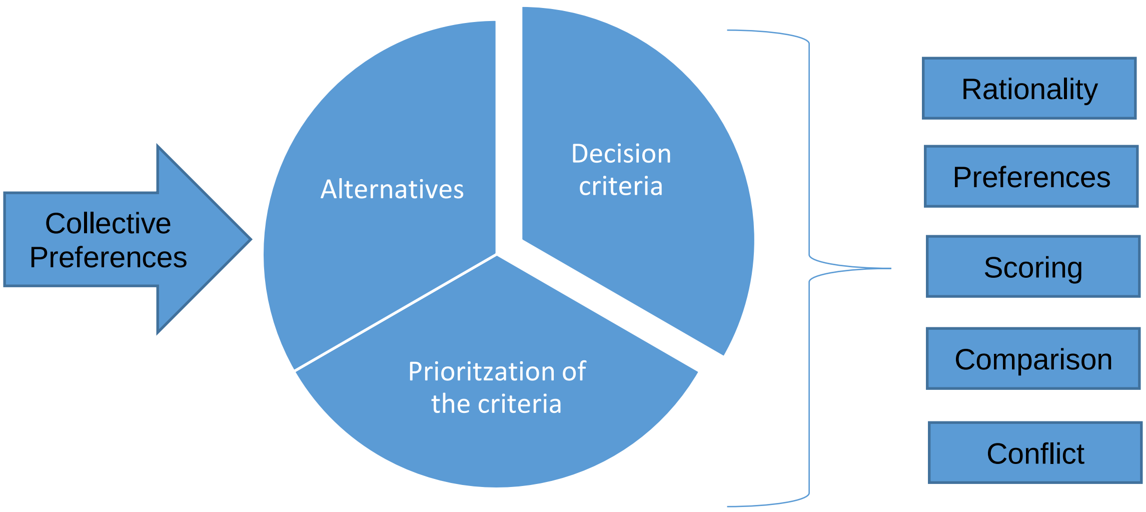

Figure 5.1: Components of an MCDA Activity

The problem discussed above is, of course, an over-simplified example intended to introduce the reader to the concept of MCDA. However, the importance of rationality, existence of preferences, ability of comparison, and resolution of conflict are features that lie central to an MCDA exercise at any level.

In real-life problems, several other considerations emerge. For instance, the criteria and sub-criteria selection cannot be random – it has to be justified with a detailed and informed literature review or on the basis of the judgment of experts or stakeholders. Similarly, adequate research must back the weights assigned to a sub-criterion. Selection of alternatives differs on a case-to-case basis.

Thus, to define, MCDA is a facet of operational research and management science that is aimed at easing a decision-making process when it is dependent on several, often conflicting criteria.

The purposes of MCDA can be outlined as:

- To break a decision into smaller units for better comprehension
- Deep analysis of each unit
- Integrating the units to produce a meaningful whole

The overview of an MCDA process can be summarized in Figure 5.2 below:

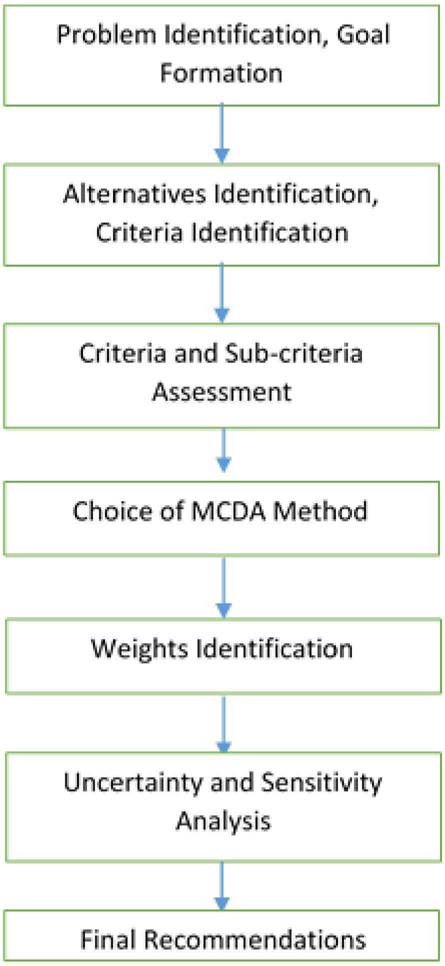

Figure 5.2: Overview of MCDA

Brief History

The early history of MCDM may be traced to the game theory, which is in turn defied as "a theory of rational decision in conflict situations". Later, several researchers worked on theories of sequential decision processes (Howard 1966), goal programming (Charnes and Cooper 1975), design of bargaining or negotiating models (Korhonen et al. 1980), the development of interactive methods (Karwan et al. 1985), decision support systems (Korhonen et al. 1992), and multi-attribute value theory (Keeney and Raiffa 1993). The acronym MCDM (Multi-criteria decision-making) was popularized in 1979, coined by Stephen Zionts (Zionts 1979). On this solid basis of robust research, the second set of researchers flourished by designing newer MCDA tools with their own sets of advantages and disadvantages. The ELECTRE method propounded by Bernard Roy in the 1960s Roy (1990) has been considered seminal in this field. Brief details of these methods have been provided in section 5.2.

Currently, MCDA/ MCDM tools are being applied extensively for real-life problem solving in a variety of settings – be it for the government, by business owners or medicine and healthcare. Lately, fields such as land and real estate, environmental management, and public utility have also begun utilizing multi-criteria decision-making tools.

Managerial advantages of MCDA

- Legitimizing previous decisions, which may have been a source of contention
- Enhancing transparency
- Integrating multiple viewpoints (individual versus collective approach)
- Justifying decisions taken even on the basis of incomplete information by accepting qualitative as well as quantitative inputs and by quantifying the uncertainty
- Enhancing ease of decision-making – situations that may appear to be insurmountable and have remained undecided for long may be tackled afresh using MCDA tools

Disadvantages of MCDA

However, challenges to MCDA do exist. For instance as per Kujaowski (2003),

- Conflicting results may be obtained using different MCDA methods, as one method may end up assigning a different score to a sub-criteria than the other, even if same problem and criteria are fed as inputs. In fact, this has been described as the Decision-making paradox by Triantaphyllou (2000)
- Improper selection of the MCDA software can yield confusing results
- Final interpretation of results may suffer from the inexperience of the analyst
- The conclusion at which an MCDA exercise arrives at need not be the 'best' solution – it is merely the most suitable solution depending on the alternatives and criteria selected. In other words, the output is dependent on the inputs, and if the inputs are incomplete or inaccurate, the output is bound to suffer

Hence, a detailed ex-post analysis of MCDA applications is necessary to ensure that the challenges outlined above are addressed.

5.2 MCDA Tools

The field of MCDA is a highly dynamic one, with several researchers involved in designing newer methods and software tools to improve accuracy of decision-making. However, this sub-section is restricted to the conventional MCDA methods, their overview and fundamentals included. Once the basic concepts are in place, the newer tools may be explored.

Criteria selection

Selection of the relevant criteria must be on the basis of the following considerations:

- The criteria selected must possess the following characteristics:
- The criteria should be independent of each other
- They should be quantifiable
- They should be related with the alternatives and with the final outcome
- Criteria should fit in the same scale

Alternative selection

Similarly, selection of alternatives should also follow certain basic considerations:

- The alternatives should be real, not ideal
- They should be comparable
- They should be available

Compensatory and Outranking Methods of MCDA

As per the Compensatory Method, the various alternatives are evaluated on the basis of various criteria; it is quite possible that each alternative will have some attractive criteria and some unattractive ones (a car may give good mileage but may not have adequate safety features). Hence, a positive score on one criteria compensates for the negative score on the other. In short, there is a trade-off between the positive and negative attributes. Analytical Hierarchy Process and Fuzzy MCDA are examples of Compensatory methods of MCDA.

In the Outranking approach, pair-wise comparisons are made among alternatives under each criterion separately. Post this, the alternatives are placed in an order (ranked) according to criteria and decision-maker preference (strict preference, weak preference, indifference). Hence, there is no elimination.

Few selected MCDA methods, which have been used most popularly across literature, have been described briefly below. These include the WSM, WPM, AHP, TOPSIS, ELECTRE and PROMETHEE methods.

- Analytical Hierarchy Process (AHP) was propounded by Thomas L. Saaty in the 1970s. The first step of AHP is the building of the hierarchy, as illustrated in Figure 5.3 below:

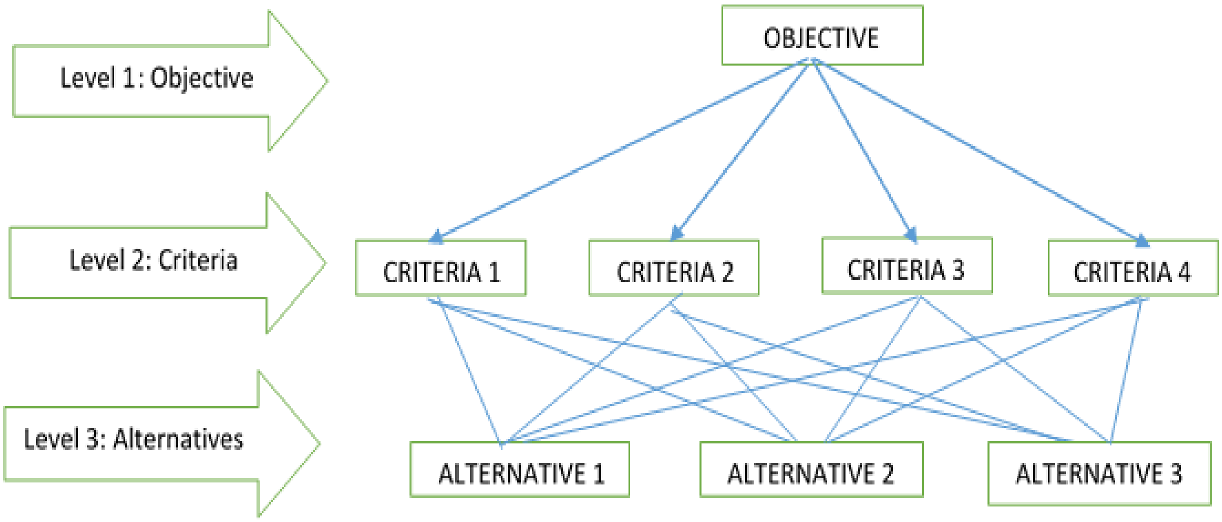

Figure 5.3: Overview of the Hierarchy Building Process in AHP

Once the hierarchy is in place, pairwise comparison of the criteria is initiated. The evaluation of the criteria is then converted into numbers, and a numerical weight is assigned to each element. In Table 5.1 below, the example scale for comparison as per Saaty and Vargas (1991) has been provided:

Table 5.1: Example scale for comparison of criteria in AHP

Scale	Degree of Preference
1	Equal importance
3	Moderate importance of one factor over another
5	Strong or essential importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Values for inverse comparison

In the step of pairwise comparison, the criteria weight in the row and that in the column are compared.

- Weighted Sum Model – WSM is a simple MCDM approach, used commonly for single dimension problems. This model works on the additive utility hypothesis, as per which, the overall value of every alternative is equivalent to the products' total sum. An assumption of the WSM method is that all the criteria are benefit criteria (higher the values, better it is). To represent the same mathematically,

$$A^*_{WSM} = \max \sum_{i}^{m} a_{ij} w_j$$

For a decision problem with

- ‘m’ alternatives
- ‘n’ criteria
- i can take values of 1, 2, 3…..m
- j can take values of 1, 2, 3…..n
- aij is the score of the i^{th} alternative with respect to the j^{th} criterion
- wj is the weight of the j^{th} criterion

- Weighted Product Model – WPM is a modified version of the WSM, designed to overcome disadvantages of WSM. It is suitable for multi-dimensional as well as single-dimensional problems. Each alternative is compared to the rest through a multiplication of ratios that are related to every criterion. Mathematically,

$$R\left(\frac{Ak}{Al}\right) = \prod_{j=1}^{n} \left(a_{ij}\right)$$

While comparing the solutions A_k and A_l, the best solu A_k when $R\left(\frac{Ak}{Al}\right)$ is > 1.

Here, too,

- m’ alternatives
- ‘n’ criteria
- i can take values of 1, 2, 3…..m
- j can take values of 1, 2, 3…..n
- aij is the score of the i^{th} alternative with respect to the j^{th} criterion
- wj is the weight of the j^{th} criterion

Both for WSM and WPM it is necessary that the criteria are in the same range.

- TOPSIS stands for the Technique for Order Preference by Similarly to Ideal Solution, which was developed by Hwang and Yoon in 1980. In the TOPSIS method, an ideal and a negative ideal solution are determined, and at the conclusion of the TOPSIS process, that alternative is selected which is closes to the ideal solution and farthest from the negative ideal solution. Overview of the TOPSIS methodology has been provided below:

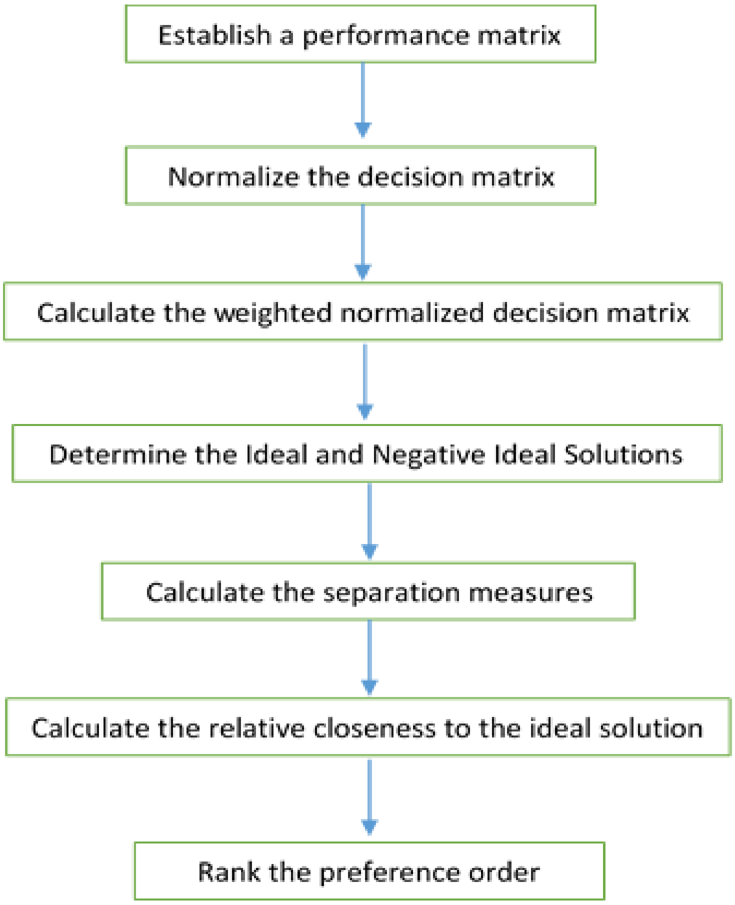

Figure 5.4: Overview of the TOPSIS Methodology

- ELECTRE (Elimination Et Choix Traduisant la Realité, translated as ELimination and Choice Expressing REality), as discussed above, was a radically different MCDA approach propounded by Roy (1990). Currently, several versions of ELECTRE are available (ELECTRE I, II, III, IV, IS and TRI) that together form the ELECTRE family of outranking MCDA tools. ELECTRE is better suited for problem cases involving at least three criteria (Figueira et al. 2005). ELECTRE offers the opportunity to model preferences using the binary outranking approach using S that stands for 'at least as good as.' Hence, if there are two actions 'a' and 'b', four situations can emerge:
    - aSb and not bSa
    - bSa and not aSb
    - aSb and bSa
    - Not aSb and not bSa

Thus, in these four cases, the four different outputs obtained are –

- a is strictly preferred to b (aPb)
- b is strictly preferred to a (bPa)

- a is indifferent to b (aIb)
- a is incomparable to b (aRb)

The uniqueness of ELECTRE lies in the fourth output, wherein the decision-maker is granted the opportunity to not compare when situations do not permit a rational comparison.

Concordance and Non-discordance are the two conceptual pillars on which outranking relations are poised:

- Concordance – for the validation of aSb, a sufficient majority of criteria must be in support
- Non-discordance – once concordance has been established, a strong opposition should not be observed from any of the criteria in minority

Interestingly, a second MCDA tool can be applied to the data that has been processed using ELECTRE, which has helped discard the unacceptable alternatives in step 1.

- PROMETHEE (Preference ranking organization method for enrichment evaluation) - The process initiates with a set of n actions and q criteria. Using these, an n × q table is generated with each row corresponding to an action and each column corresponding to a criterion. Following this, a pair-wise comparison is conducted and a preference degree is assigned. While PROMETHEE I uses partial ranking, complete ranking is used in PROMETHEE II. In PROMETHEE III, the ranks are based on intervals. In contrast, PROMETHEE IV is continuous. PROMETHEE V includes integer linear programming and net flows while the human brain is epitomized by PRMOETHEE VI.

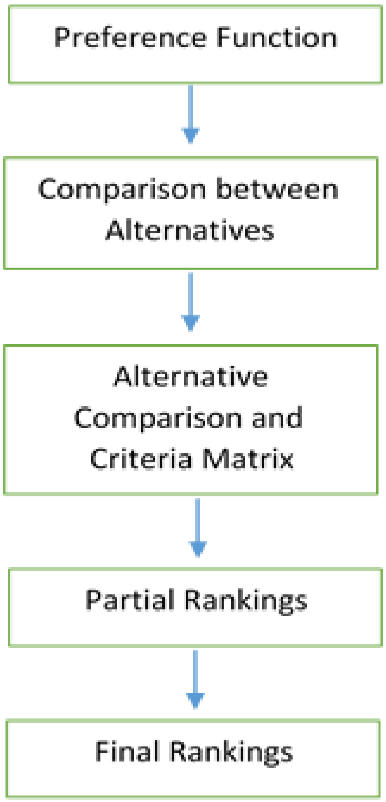

Figure 5.5: Overview of the PROMETHEE MCDA Method

- GAIA (Geometric analysis for interactive aid) is the descriptive complement of the PROMETHEE method.

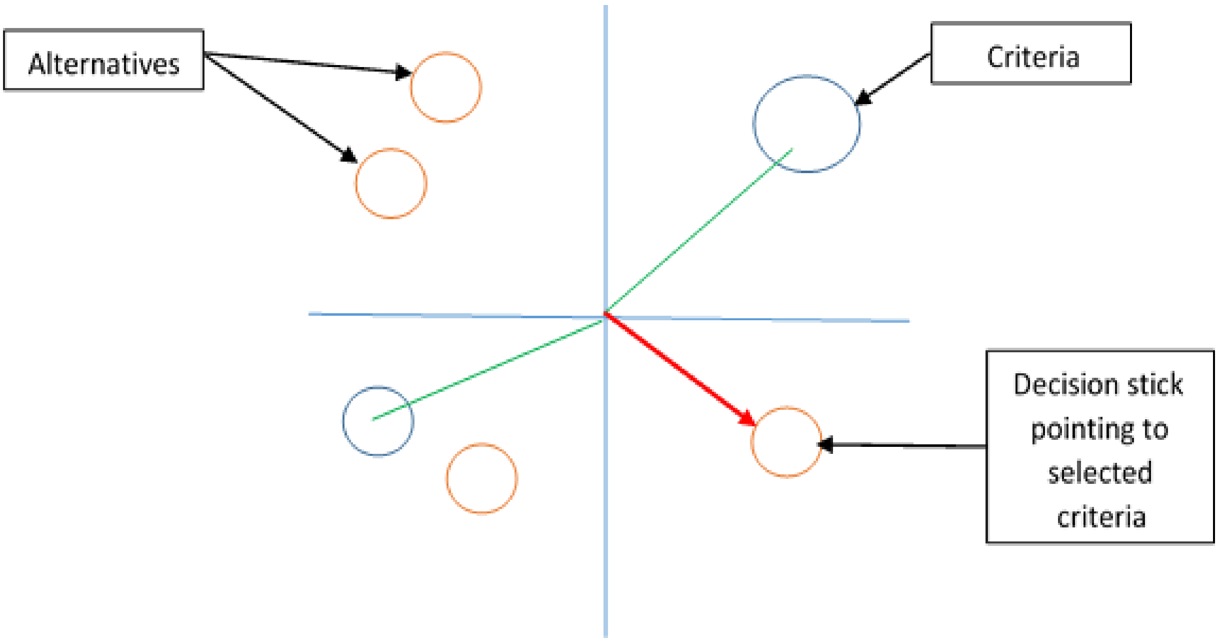

Figure 5.6: Representation of the GAIA Method

Cegan et al. (2017) reviewed as many as 3000 research publications, investigating trends in the use of MCDA tools in environmental decision-making. They concluded that AHP/ANP and MAUT/MAVT were the most popular tools.

A comparison of AHP and ELECTRE has been provided in Table 5.2 below:

Table 5.2: Comparative Analysis of AHP and ELECTRE MCDA Methods

Criteria	AHP	ELECTRE
Problem decomposition	Hierarchy	No
Evaluation criteria	Obtain the mechanism for evaluation	Requires and assessment of evaluation
Subjectivity	Large	Large
User-friendliness	Yes	Yes
Organization of research	Easy	Difficult
Time period required for the study	Short	Long
Ease of result processing	Easy	Difficult
Resources needed	Few	Several
Issue of incomparability of alternatives	No	Yes
Closely mimics natural, intuitive and typical human processes of prioritization	Yes	No

Source: Ivlev et al. (2014)

5.3 MCDA Software

It will be impractical to manually carry out the complicated MCDA calculations discussed above. Fortunately, a multitude of software packages are commercially available, containing a combination of MCDA tools, pre-programmed to accept user input, carry out the computations and yield the output. Some simple MCDA calculations can even be carried out in Microsoft Excel. A comprehensive list of MCDA software available commercially has been provided in this section, along with relevant details of each:

- DEFINITE 3.1. – DEFINITE stands for DEcisions on a FINITE set of alternatives. It includes 5 MCDA tools, in addition to Cost Benefit and Cost Effectiveness analysis tools. It has a simple, WINDOWS-based user interface and closely mimics Microsoft Office, which enhances its appeal for the non-technical user.
- modeFRONTIER - modeFRONTIER modular environment is key to reducing complexity, improving efficiency and cutting down on development time. The modeFRONTIER platform guarantees the management of all logical steps of an engineering design process. It includes

multi-strategy algorithms (Hybrid, FAST, pilOPT, SANGEA) that can combine different optimization methods.

- Super Decisions – Based on Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP), Super Decisions employ pairwise comparison and sensitivity analysis to help decision-makers reach consensus.
- Decision Lens – Similar to Super Decisions, Decision Lens is also AHP and ANP based. Pairwise comparison, group evaluation and sensitivity analysis are employed herein.
- IDS – IDS stands for Intelligent Decision System. It is used for Multiple Criteria Decision Analysis under Uncertainty (using the Evidential Reasoning Approach). The advantage of IDS is its ability to handle accuracy-afflicting conditions such as missing data, uncertainty, and subjectivity or a combination of the above. It is based on the MCDA approach of Evidential Reasoning Approach.
- D-Sight - It is a visual and interactive tool that is used for multi-criteria decision aid problems based on the PROMETHEE methods and Multi-Attribute Utility Theory.
- DecideIT – The DecideIT software is based on the Delta MCDA method and MAUT (Multi-attribute utility theory), employing pairwise comparison, sensitivity analysis as well as group evaluation.
- Expert Choice – this is another AHP-based software available in the market, involving the use of pairwise comparison, group evaluation and sensitivity analysis
- MEM – Multiplex ElectionisMethodus (Multiple Election Method) is based on the AHP.
- IDSS Software - IDSS stands for Intelligent Decision Support Systems. This system makes maximum use of artificial intelligence. It allows one or more people to take decisions in a concrete domain. Formal quantitative models such as logic, logic, simulation and optimization models are used to represent the decision model. Fuzzy logic and case-based reasoning are used.
- DiViz - It helps researchers to construct algorithmic MCDA workflows. It functions by allowing the user to compare, add and calculate. It relies on ACUTA and linear additive value functions.
- MCDA Package for R – this package uses a wide variety of MCDA algorithms along with the R statistical environment.
- MACBETH for MCDA/ M-MACBETH – MACBETH for MCDA stands for Measuring Attractiveness by a Categorical Based Evaluation Technique in Multi-criteria Decision Aid. Interestingly, this method relies only on qualitative judgments regarding the value difference between alternatives.

- Ahoona – This free-of-charge web-based network uses the MCDA tools of Weighted Sum Model (WSM) and Utility theory and relies on Group evaluation. The Ahoona project traces its roots to the I-Corps initiative of the National Science Foundation.
- AltovaMetaTeam – It is also WSM and Group Evaluation based.
- PriEsT – PriEst stands for Priority Estimation Tool. It is a tool used for analysis of the decision. It can be used for ranking available options or in budgeting problems. It is based on the popular MCDA tool Analytical Hierarchy Process (AHP).
- IND-NIMBUS – It is used for solving non-linear multi-objective optimization problems. It contains the implementation of different interactive multi-objective optimization methods. It is available for different operating systems.
- Criterium DecisionPlus – Based on AHP and Simple Multi-Attribute Rating Technique (SMART), Criterium DecisionPlus employs sensitivity analysis and pairwise comparison.
- 1000Minds – It is a web application used for decision making and conjoint analysis. It helps governments, NGOs and business corporates to make decisions that are based on considering multiple objectives/ criteria. The method used in this software is one of their own design, patented in three countries, and named as PAPRIKA (Potentially All Pairwise Rankings of all Possible Alternatives).
- IRIS and VIP - IRIS stands for Interactive Robustness analysis and parameters' Inference software for multi-criteria Sorting problems and VIP - Variable Interdependent Parameters Analysis software. This software has been built to support the assignment of actions (alternatives, projects, candidates) described by their evaluation (performance) at multiple dimensions (criteria)
- Interalg - InterAlg stands for Interval Logarithm. It is a free solver for multi-objective optimization by providing specifically accuracy, possibly with categorical variables and general logical constraints. It can handle problems with hundreds of variables.
- MakeItRational - One can use it to make complex decisions when one knows how to measure strength, weaknesses and overall utility of each option. One can evaluate projects, technologies, candidates, products, employees, Suppliers, software packages, buildings, processes, investments, locations, subcontractors, cars, outsourcing companies, players, strategies, markets, customers, requirements, and ERP systems. It is based on the AHP MCDA tool.
- Hiview3 – This software employs direct rating and swing weighting methods and employs group evaluation and sensitivity analysis.

- BENSOLVE - This tool is based on Benson's algorithm and its extensions. It is used as a solver for vector linear programs (VLP), in particular, for the subclass of multiple objective linear programs (MOLP).
- Bubble Chart Pro Optimal - It is a desktop software application that integrates a variety of bubble chart types with a SMART (Simple Multi-Attribute Ranking Technique) prioritizer and an easy-to-use LP optimizer.
- ChemDecide – this software package includes 3 MCDA tools – Analytical Hierarchy Process (AHP), MARE and ELECTRE III.
- Comprehensive Package for Multi-objective Integer Programming
- Decisionarium – this is a site that houses several web-based and Windows-based software to be used for decision-making.
- DEXi – DEXi is the upgraded version of DEX. While DEX is still superior in its ability to deal with incomplete option descriptions, DEXi scores with a better user interface and improved graphical outputs. The DEXi MCDA software employs the Delphi process, and is available free-of-cost in a Microsoft Windows-compatible version.
- Logical Decisions – Logical Decisions is yet another AHP-based MCDA software also utilizing the benefits of MAUT, involving pairwise comparison, group evaluation and sensitivity analysis.

As is apparent from the above list, several MCDA software tools are available in the market. Most of these software rely on the Analytical Hierarchy Process (AHP).
However, selection of the most suitable MCDA software is critical, as it will have an impact on the final output. The selection of a given software will largely depend on its:

- Purpose for which the software will be utilized (Environment impact assessment? Landfill site selection? Healthcare product selection? Vendor finalization?)
- Cost
- Ease of operation
- Simplicity of user interface
- Visual representation of the output
- Most critically, the types and numbers of MCDA tools included in the package, as this would directly affect the accuracy of the final result; hence, selection of the most suitable MCDA software pre-supposes a deep understanding of the fundamentals of MCDA methods on the part of the user.

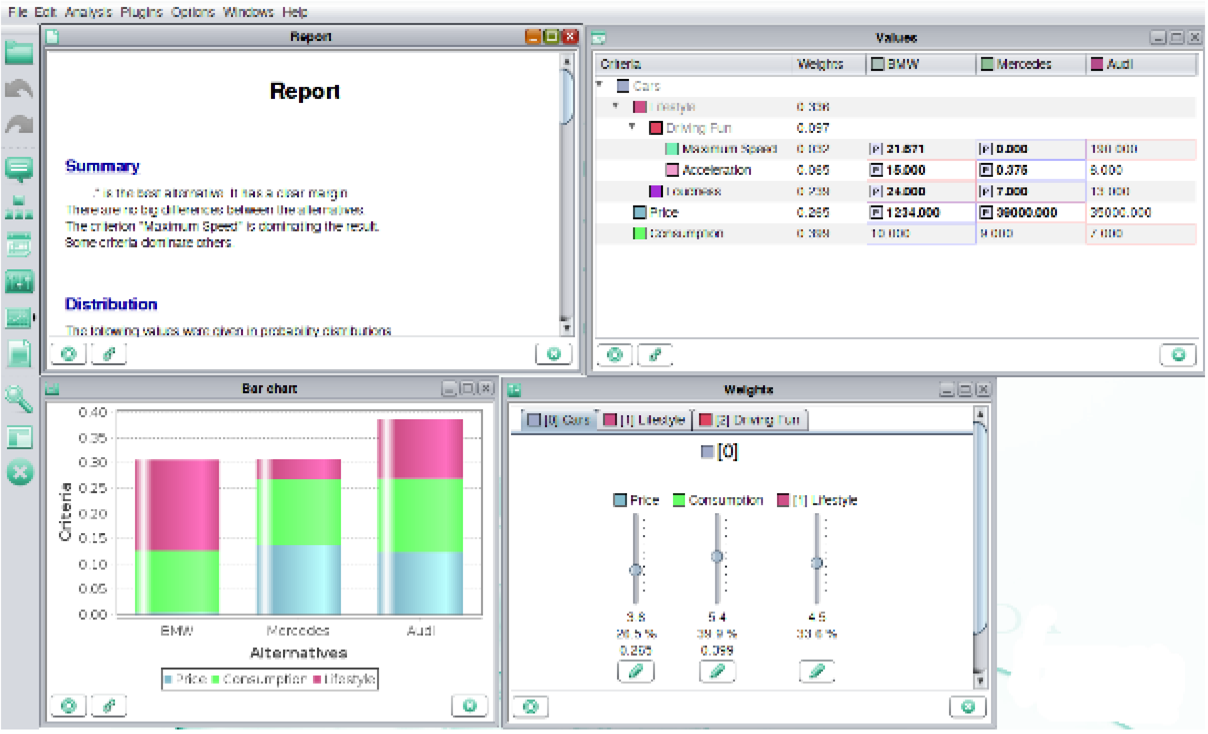

Figure 5.7: Screenshot of a typical MCDA Software Visual Display

To-Do activity: Follow the tutorial of any one MCDA software (freely available on their website) and ascertain which among the above software are most suitable for environmental studies

5.4 MCDA in Waste Management

Waste management is one sector providing ample scope for the application of MCDA statistical tools – given the conflicting aspects of environment and socio-economics that help shape decision-making. Indeed, waste management today may be one of the most complex subjects challenging local administrative bodies, given the enhanced stringency of government legislation and rising public awareness.

The different viewpoints

- Environmental viewpoint – from the environmental viewpoint, the significant criteria affecting the decision-making process are –
    - Choice of technology – how green the technology is or how small its environmental footprint is; in other words, the technology's requirement of energy, chemicals and other resources is computed.
    - Location of technology set-up – whether it is clashing with an existing ecological feature. For example, the Kanjur Marg dumping ground of Mumbai is in close vicinity

of mangroves; the Guwahati dumping ground is on the banks of an internationally acclaimed water body – the DeeporBeel.

- Technological viewpoint – from the technical perspective, the essential criteria that emerge are –
  - Efficiency of the technology and its applicability to the type of waste being treated - for instance, incineration of MSW in India, where most of the MSW is largely wet waste, may not be a suitable option.
  - Ease of operation – easier the operation, better the chances of acceptance of a given technology.
  - Energy, chemical and manpower input required – for instance, Phytorid and Soil Biotechnology are low on such input requirements
  - AMC requirements – the lower the better
- Administrative viewpoint
  - Cost – the lower the better. However, this comes with a rider – several times, in technology-neutral tenders, cost becomes the deciding criterion, overriding the importance of selecting the correct technology.
  - Policies – for instance, in a few local municipalities, application of patented technologies becomes difficult with enhanced requirement of documentation and paperwork
- Topographical viewpoint
  - Land availability
  - Site topography
- Social viewpoint
  - Consent to operate yielded by the local population – it is critical if the technology in question is likely to generate noise, malodor, heat or harmful chemicals
  - Safety of the equipment on site - threat of theft and vandalism is very real, especially if there is general disapproval from the locals regarding the upcoming project.
  - Social benefits, if any,which emerge from the decision – for instance, more employment opportunities, infrastructural growth etc. can be a boost to the proposal.

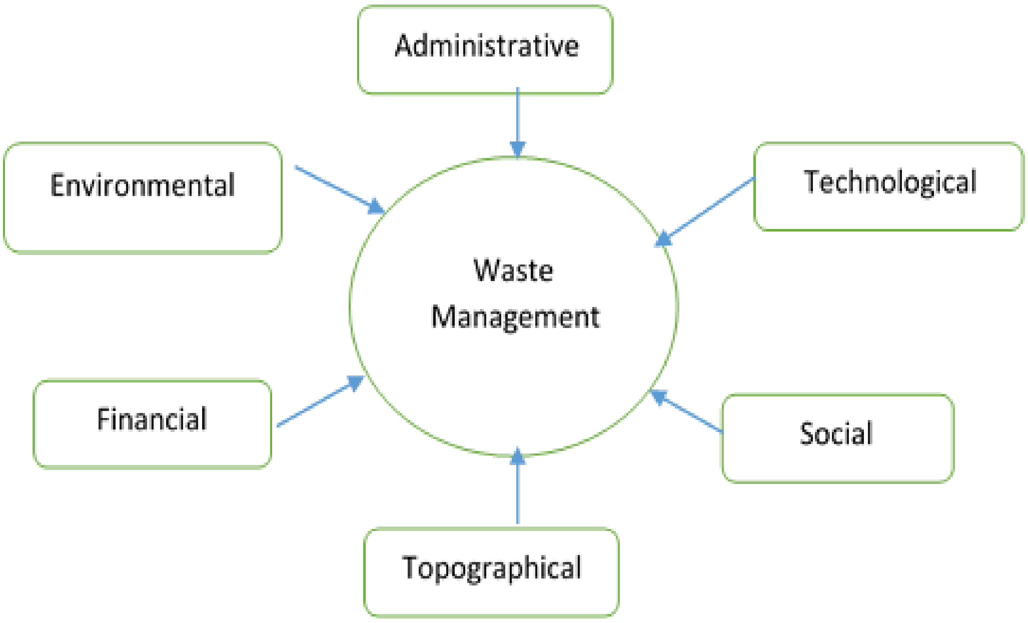

Figure 5.8: Multiple Aspects of Waste Management MCDA

While this provides an overview, MCDA exercise may be required even at lower and finer levels of decision-making. For instance, at the finer level, it may be required to employ MCDA to select the most optimum route to be followed by the solid waste collection vehicle, while at the higher levels, MCDA may help decide the most cost-efficient way of waste management at the municipality level.

Although gradually gaining importance in the Indian scenario in the last few years, waste management in Europe and USA has often relied on MCDA tools where it is a part of the protocol in several administrative units. Importantly, even third-world countries are investing in cutting-edge research in waste management-related MCDA.

5.5 Drivers for and Challenges against Enhancing the Use of MCDA by Decision-makers in India, Case Studies & Recommendations

Drivers

- Plenty of opportunity for application – in a culturally, ecologically and economically diverse and populated country like India where resources are limited and their usage almost always conflicted, there are humungous opportunities for the application of MCDA tools. Waste management is merely one among several other fields where MCDA tools can aid decision-makers in India.

- Requirement of transparency – one managerial advantage of MCDA pointed out in section 5.1 is the degree of transparency that the tools bring about. This can be a significant driver for public-spirited and aware citizens.
- Possibility of cost-reduction – quicker decision-making, and selection of most suitable options can improve the economic aspects of an issue.

Challenges

- Cost – MCDA software tools and the skilled manpower required to operate them have a cost that many municipalities may find beyond their budget. This is especially true for small municipalities and town and village panchayats.
- Social acceptability – on several occasions, it is possible that MCDA statistical tools help arrive at a decision that had already been propounded and accepted by the local administrative decision-makers as it happened to be a common sense decision. In other words, on occasions, the MCDA predictions can only end up providing a buttress to the committee decision. Under such circumstances, the outcry may be that public money was spent in purchasing a tool that could add but little to the manual decision-making process. This may be especially true for small municipalities and town and village panchayats.
- Lack of awareness among decision-makers – as described above, decision-making at the level of local government in small Indian towns and villages is often a contentious topic, involving several local nagarsevaks who have the political will and wherewithal to influence decision-making but who may not be technically aware of the credibility of statistical tools or the wholesomeness of statistically-aided decisions.
- Vested interests and corruption – this may further impact the application of MCDA statistical tools
- Manpower shortage – in many small local municipalities, manpower shortage is a challenge. There often exist occasions where there is a struggle even to provide the basic amenities to the local public. Under such circumstances, it may be difficult to divert manpower to form an MCDA team.

Recommendations

- Using MCDA statistical tools is a technical process that requires statistical software, skilled manpower, and a certain minimum time-frame for basic data collection and analysis. It is, therefore, strongly recommended that each local administrative body responsible for centralized solid and liquid waste management ties up with a local academic institute wherefrom the technical knowhow can be sourced.

- Among academic institutions as well, adequate attention must be directed towards MCDA-related research. Such research in India is not being addressed with the requisite vigor. While larger municipalities can turn to local academic experts, such may not be true for smaller municipalities and town and village panchayats.
- Regular training sessions must be organized with the help of the academic institutes so that the resident staff of the local administrative body gets familiar with the statistical procedures.
- One-time investment can be planned to purchase the necessary software. Else, options of software rental can be explored and budgeted.
- In small municipalities or village and town panchayats, company CSR funds may be requested to facilitate the usage of MCDA tools.
- It must be understood that MCDA statistical tools need not be limited to solid and liquid waste management related decisions – these tools have applicability in almost every field.
- It may be appreciated that MCDA tools do involve complicated mathematical calculations and technical jargons; for a managerial and administrative team to grasp the nuances of a lengthy statistical procedure may be difficult. Hence, it is important that academicians attempt to ease the user interface for the managerial and administrative team likely to be the long-term end-user.

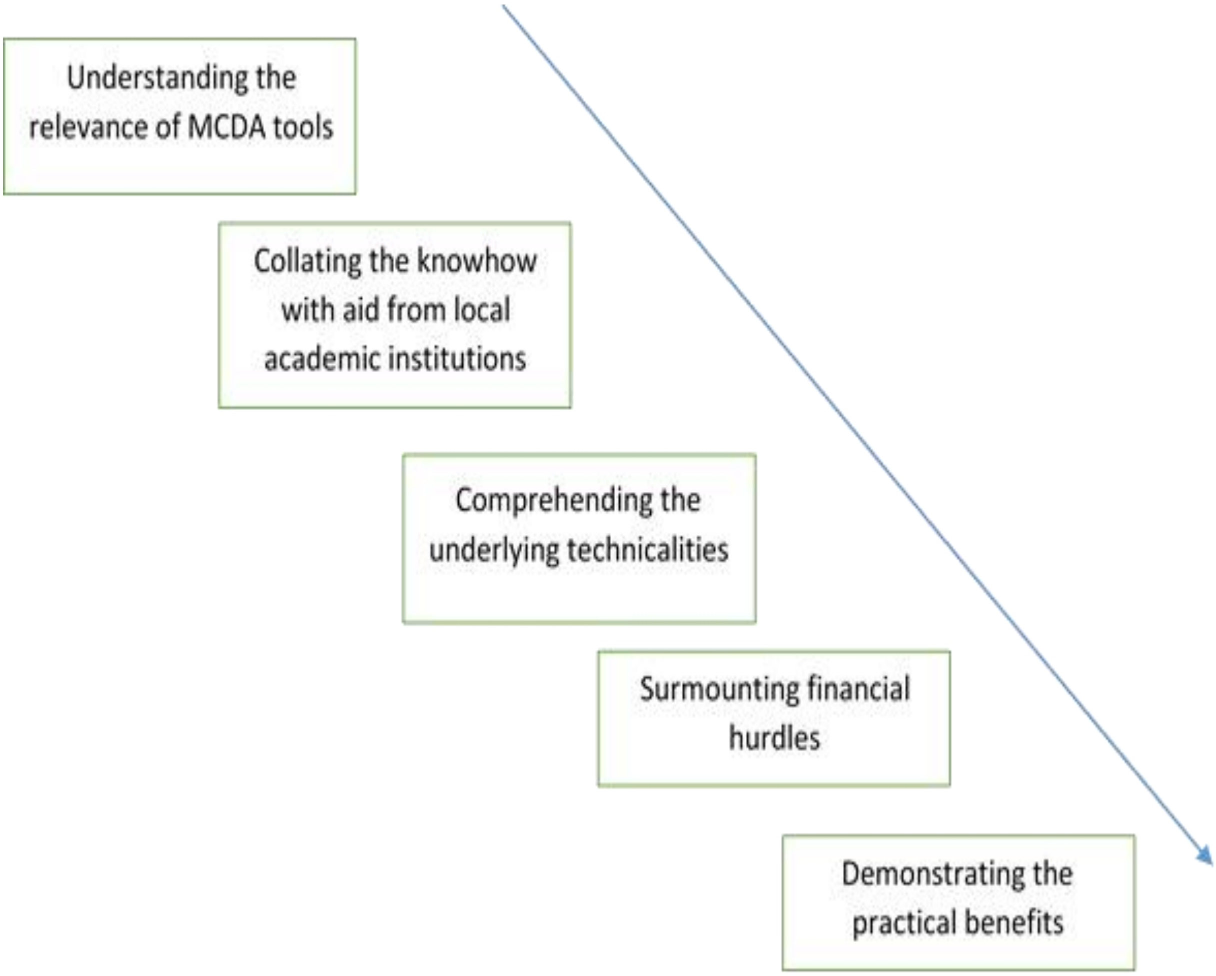

Figure 5.9: Integrating MCDA into Government Decision-making

Case studies

Landfill/Waste management site selection

- Cheng et al. (2002) employed a set of MCDA tools (Simple Weighted Addition method, Weighted Product method, TOPSIS, cooperative game theory, and ELECTRE) to help select the most suitable landfill site inRegina of Saskatchewan Canada.
- Vego et al. (2008) employed the MCDA tools PROMETHEE and GAIA to finalize the number and location of waste management centers at the country-level.
- Onut and Soner (2008) used TOPSIS and AHP (under fuzzy environment) for solid waste trans-shipment site selection

Technology or process selection

- Qazi et al. (2018) used AHP MCDA tool for the most suitable Waste to energy technology selection in the Sultanate of Oman

- Gomez-Lopez et al. (2009) showed that chlorination and UV disinfection were two wastewater disinfection options that emerged as most suitable under different scenarios, using TOPSIS.
- DEMATEL and fuzzy MULTIMOORA MCDA techniques were used to select the most suitable healthcare waste management technology by Liu et al. (2015) in the context of the Chinese city of Shanghai.
- Ilangkumaran et al. (2013) made use of Fuzzy AHP, PROMETHEE and GRA MCDA tools to select the most suitable wastewater treatment technology
- Based on TOPSIS, Kalbar et al. (2012) evaluated 7 criteria with 12 indicators to select the most suitable wastewater treatment technology in the Indian context. The technologies compared were Constructed Wetland, Sequencing Batch Reactors, Activated Sludge Process and Upflow Anaerobic Sludge Blanket. All the technologies were selected under different scenarios. The CW technology ranked 1 under four of the six technologies.
- Centralized incineration emerged as the most suitable waste management technology in the Uusimaa region of Finland, using ELECTRE II as the MCDA tool (Hokkanen et al. 1995).
- Karagiannidis and Moussiopoulos (1997) employed ELECTRE III to accentuate the importance of at-source separate waste collection to be critical to MSWM in the context of Greece.
- Garfi et al (2009) employed the Analytical hierarchy Process (AHP) MCDA tool for selecting the most feasible waste management solution in the Saharawi refugee camps (Algeria). They compared the following four scenarios:

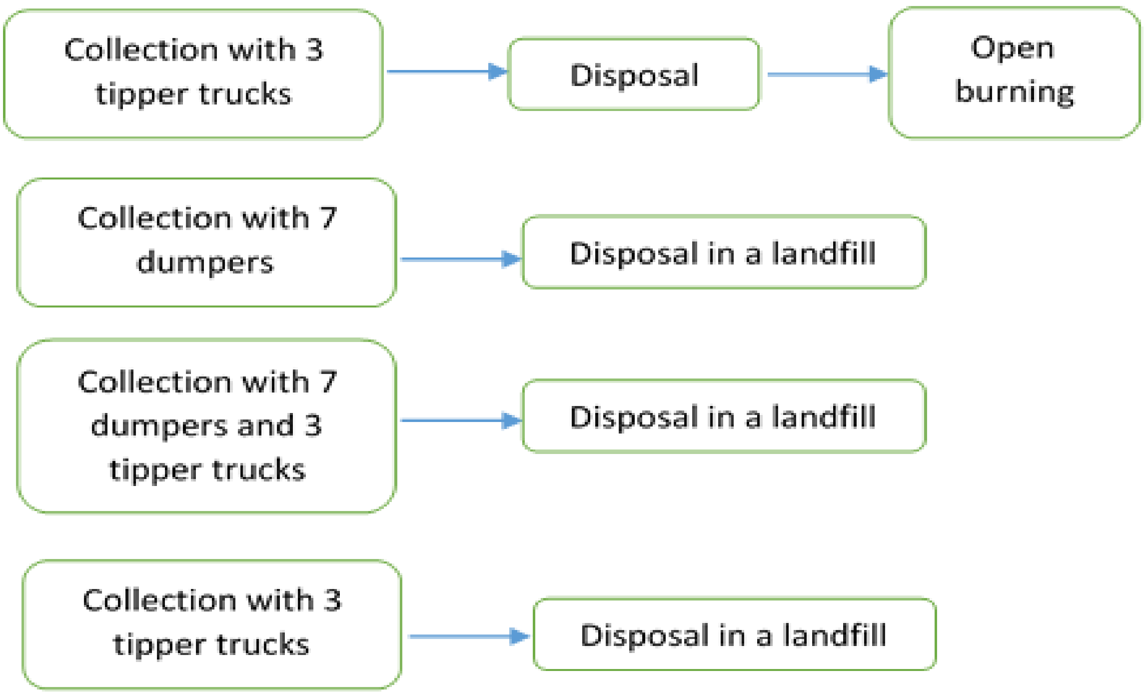

Figure 5.10: Description of waste management scenarios adapted from Garfi et al. (2009)

As per the authors, options two and three were found to be the most suitable based on environmental, social and technological concerns. The scenarios described by Garfi et al. (2009) are similar to those experienced in Indian rural and small town settings and the approach taken is relatively simple and can be adopted.

Vendor Selection

- Gumus (2009) made use of fuzzy AHP and TOPSIS methodologies to select the most suitable firm for hazardous waste transport.
- Hsu et al. (2012) employed two MCDA tools (VIKOR and DANP) to select the most suitable vendor for resource recovery from waste.
- Büyüközkan and Çifçi (2012) selected most suitable green suppliers using three MCDA tools – fuzzy TOPSIS, fuzzy ANP and fuzzy DEMATEL.
- On the basis of AHP and TOPSIS, Yazdani (2014) selected the most suitable green suppliers.
- Integrating grey based method with ELECTRE and VIKOR approaches, Chithambaranathan et al. (2015) aimed at a green supply chain.

Waste Transport Route Selection

- Chen et al. (2008) employed a multi-objective Geographic Information System (GIS) for selecting the most optimum transport route for nuclear waste.

Hence, to conclude, MCDA tools have the potential to make waste management decision-making more precise, quicker, and more clear-cut. MCDA tools are ideally equipped to address a situation where uncertainty, data deficiency, qualitative attributes and subjective judgments impact decision-making. It may seem a far cry today, for large to small municipalities and villages in India still struggling with basic municipal solid waste segregation and decentralized liquid waste management; however, instead of making this a hen-and-egg problem, it is necessary to employ well-proven techniques even at the grass-root levels and even at the first step of waste management.

Model Questions

Q. How would you select the most suitable MCDA tool for the multi-criteria decision-making problem of landfill site selection for a small town municipality?

Q. Try out the demo/trial version of any one MCDA software with a dummy problem, and analyze your experience.

Q. Can you sense a business opportunity in providing technical support to municipalities in conducting statistical analyses? Give an overview of your sales pitch.

Suggested Reading

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Dr. W. G. Prasanna Kumar, PhD in Education with basic degree in Social Work and Master's Degrees in Sociology, Public Administration and Political Science has professional education in Environmental Economics, Public Relations, Communication and Training and Development. Presently Chairman, Mahatma Gandhi National Council of Rural Education (MGNCRE) under the Ministry of Human Resource Development, in Government of India strives to promote resilient rural India through Higher Education interventions. The national initiative of reviving Mahatma Gandhi's ideas of Nai Talim, spearheaded by Dr. W G Prasanna Kumar, has met unprecedented success at both national and state levels. The primary objective of this initiative is to promote Gandhiji's ideas on Experiential Learning, NaiTalim, Work Education and Community Engagement, and mainstreaming them in School Education and Teacher Education Curriculum & Pedagogy. As Professor and Head Centre for Climate Education and Disaster Management in Dr MCR HRD Institute, conducted several capacity building and action research programmes in climate education, disaster management and crowd management. He has handled many regional, national and international environmental education programmes and events including UN CoP11 to Convention on Biological Diversity and Media Information Management on Environmental Issues.

He was Director in National Green Corps in the State Government for over 11 years and Senior Social Scientist in State Pollution Control Board for 6 years. Conducted various curriculum and non-curriculum related training programmes in environmental education. He was a Resource Person for AP Judicial Academy, AP Police Academy, AP Forest Academy, EPTRI, Commissonerate of Higher Education and Intermediate Education, State Council for Educational Research and Training and National Council for Educational Research and Training New Delhi, CCRT, Bharathiya Vidyapeet University Pune, CPR Environmental Education Centre Chennai and Centre for Environment Education Ahmedabad. Dr W G Prasanna Kumar was trained in Community Consultation for Developmental Projects in EPA Victoria Australia in 1997 trained as State Chief Information Officer by IIM Ahmedabad and MCRHRDI Government of Andhra Pradesh in 2004 and trained in Environmental Education and Waste Management Technique by JICA, Japan in 2011.

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