GENERAL INTRODUCTION

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Chapter 1

SOLID WASTE MANAGEMENT

1.1.1 Introduction

Growth of population, increasing urbanisation, rising standards of living due to technological advancements have contributed to an increase in the quantity and variety of solid wastes. These wastes are generally dumped on land or discharged into water bodies, without adequate treatment, and thus become a large source of environmental pollution and health hazard. Globally the estimated quantity of wastes generation was 12 billion tonnes in the year 2002 of which 11 billion tonnes were industrial wastes and 1.6 billion tonnes were municipal solid wastes (MSW). About 19 billion tonnes of solid wastes are expected to be generated annually by the year 2025 (Yoshizawa et al., 2004). Annually, Asia alone generates ~4.4 billion tonnes of solid wastes and MSW comprise 790 million tonnes (MT) of which about 48 (~6%) MT is generated in India. By the year 2047, MSW generation in India, is expected to reach 300 MT and land requirement for disposal of this waste would be 169.6km² as against which only 20.2km² were occupied in 1997 for management of 48MT (CPCB 2003; Yoshizama et al., 2004). Apart from municipal wastes, the organic wastes from agricultural sources alone contribute more than 350 MT per year. However, it is reported that about 600 MT of wastes have been generated in India from agricultural sources alone. The major quantity of wastes generated from agricultural sources are
sugarcane bagasse, paddy and wheat straw and husk, wastes of vegetables, food products, tea, oil production, jute fibre, groundnut shell, wooden mill waste, coconut husk, cotton stalk etc.,

India, with a population of over 1.21 billion account for 17.5% of the world population (Census of India, 2011). According to the provisional figures of Census of India 2011, 377 million people live in the urban areas of the country. This is 31.16 % of the Country’s total population. It also suggests that average municipal solid waste production from 0.21 to 0.50 kg per capita per day in India. The urban population of India is approximately 341 million in 2010. It is also projected that MSW quantities are expected to increase from 34 million tonnes in 2000 to 83.8 million tonnes in 2015 and to 221 million tonnes in 2030. It is also reported that per capita per day production will increase to 1.032 kg, and urban population as 586 million in 2030.

As far as India is concerned excepting the metropolitan cities and few major cities MSW management includes only the following steps: Collection, transportation and disposal of MSW in a huge open dump yard. The Govt.ofIndia spends about Rs.230 million annually for waste disposal alone which comprises the cost of collection, transportation and disposal (Abbasi and Ramasamy, 2001). Besides this, open burning of the garbage is a frequent phenomena which can be noticed at many places. Open dumping of MSW leads severe pollution of land, water and air affecting the public health. When it rains the water percolates through the MSW dump solubilising many toxic components of the dump the water moves down further to contaminate the soil and ground water. While aerobic and anaerobic decomposition of the organic fraction of MSW (OFMSW) may release green house gases (GHGs) and pollute the air. The leachate is a dark coloured liquid-resultant of percolation of rain water through MSW dump - contain harmful pathogenic microbes besides the toxic substances which ultimately contaminate the water bodies or ground water.

Open burning is the burning of unwanted materials in a manner that causes smoke and other emissions released directly into the air without passing through a chimney or stack. This includes the burning of outdoor piles, burning in a burn barrel
and the use of incinerators which have no pollution control devices and as such release the gaseous by products directly into the atmosphere. Open burning has been practiced by a number of urban centres because it reduces the volume of refuse received at the dump and therefore extends the life of their dumpsite. Garbage may be burnt because of the ease and convenience of the method or because of the cheapness of the method. In countries where households need to pay for garbage disposal, burning of waste in the backyard allows the household to avoid paying the costs associated with collecting, hauling and dumping the waste. Open burning has many negative effects on human health and the environment. This uncontrolled burning of garbage releases many pollutants into the atmosphere. These include dioxins, particulate matter, polycyclic aromatic compounds, volatile organic compounds, carbon monoxide, hexachlorobenzene and ash. All these chemicals pose serious risks to human health. Dioxins are capable of producing a multitude of health problems; they can have adverse effects on reproduction, development, disrupt the hormonal systems or even cause cancer. The polycyclic aromatic compounds and the hexachlorobenzene are considered to be carcinogenic. The particulate matter can be harmful to persons with respiratory problems such as asthma or bronchitis and carbon monoxide can cause neurological symptoms.

Therefore, municipal solid waste management (MSWM) is one of the major environmental problems of Indian megacities. However, Govt. of India has come out with the Municipal Solid Waste (Management and Handling) Rules 2000 (MoEF) under the Environment Protection Act of India, which make it mandatory for all the municipalities to introduce integrated solid waste management system. It envisages segregated storage at source, prompt collection from the sources and secured transportation based on the principles of ‘no waste on ground’, setting up processing plants using appropriate technology, encouraging and promoting Reduction, Reuse Recycling (3 Rs) of wastes, developing engineered landfill site for disposal of refuse and inert; also to establish secured landfill for municipal hazardous waste. The Municipal and Panchayat Raj Act of Kerala also include provision for the local self Govt. Institutions (LSGI’s) to take appropriate steps for the management of domestic garbage (Varma, 2006). In summary, MSW management essentially include three steps (i) collection and transportation (ii) processing/treatment (iii) safe disposal of MSW residues. Once MSW is treated/processed then the residues which remain need to be safely disposed in sanitary landfills.
Sanitary landfills

Sanitary landfills are designed to greatly reduce or eliminate the risks that waste disposal may pose to the public health and environmental quality. They are usually placed in areas where land features act as natural buffers between the landfill and the environment. For example, the area may be comprised of clay soil which is fairly impermeable due to its tightly packed particles, or the area may be characterised by a low water table and an absence of surface water bodies thus preventing the threat of water contamination. In addition to the strategic placement of the landfill other protective measures are incorporated into its design. The bottom and sides of landfills are lined with layers of clay or plastic to keep the liquid waste, known as leachate, from escaping into the soil. A landfill is divided into a series of individual cells and only a few cells of the site are filled with trash at any one time. This minimizes exposure to wind and rain. The daily waste is spread and compacted to reduce the volume, a cover is then applied to reduce odours and keep out pests. When the landfill has reached its capacity it is capped with an impermeable seal which is typically composed of clay soil. Some sanitary landfills are used to recover energy.

1.1.2 Reduce, Reuse, Recycle (Three ‘R’ concept)

Methods of waste reduction, waste reuse and recycling are the preferred options when managing waste. There are many environmental benefits that can be derived from the use of these methods. They reduce or prevent green house gas emissions, reduce the release of pollutants, conserve resources, save energy and reduce the demand for waste treatment technology and landfill space. Therefore it is advisable that these methods be adopted and incorporated as part of the waste management plan.

Waste reduction and reuse

Waste reduction and reuse of products are both methods of waste prevention. They eliminate the production of waste at the source of usual generation and reduce the
demands for large scale treatment and disposal facilities. Methods of waste reduction include manufacturing products with less packaging, encouraging customers to bring their own reusable bags for packaging, encouraging the public to choose reusable products such as cloth napkins and reusable plastic and glass containers, backyard composting and sharing and donating any unwanted items rather than discarding them.

Recycling

Recycling refers to the removal of items from the waste stream to be used as raw materials in the manufacture of new products. Thus from this definition recycling occurs in three phases: first the waste is sorted and recyclables are collected, the recyclables are used to create raw materials. These raw materials are then used in the production of new products.

1.1.3 Waste treatment/processing: an important step in waste management

Waste treatment techniques are aimed at reducing the volume of the waste, recovery of materials or energy while processing it and to reduce the toxicity of the waste thus making the waste easier to dispose of. Treatment methods are selected based on the composition, quantity, and form of the waste material. Some waste treatment methods being used today include subjecting the waste to extremely high temperatures (Incineration, Pyrolysis) or use of biological processes (anaerobic digestion, composting, and vermicomposting) to treat the waste. Thus, waste treatment options include thermal treatment and/or biological treatment.

1.1.3.1 Thermal treatment

This refers to processes that involve the use of heat to treat waste. Common heat treatment techniques include:

a) Incineration
Incineration is the most common thermal treatment process. This is the combustion of waste in the presence of oxygen. After incineration, the wastes are converted to carbon dioxide, water vapour and ash. This method may be used as a means of recovering energy to be used in heating or the supply of electricity. In addition to supplying energy, incineration technologies have the advantage of reducing the volume of the waste, rendering it harmless, reducing transportation costs and reducing the production of the greenhouse gas methane. The incinerators need to be operated carefully with necessary scrubbing facilities so that the harmful emissions can be prevented from reaching the air/atmosphere and causing air pollution.

b) Pyrolysis and Gasification

Pyrolysis and gasification are similar processes they both decompose organic waste by exposing it to high temperatures and low amounts of oxygen. Gasification uses a low oxygen environment while pyrolysis allows no oxygen. These techniques use heat and an oxygen starved environment to convert biomass into other forms. A mixture of combustible and non-combustible gases as well as pyroligenous liquid is produced by these processes. All of these products have a high heat value and can be utilized as fuels. Gasification is advantageous since it allows for the incineration of waste with energy recovery and without the air pollution that is characteristic of other incineration methods.

1.1.3.2 Biological waste treatment

The major objective in the biological waste treatment is the conversion of the organic matter in the waste to a stable end product. Biological waste treatment include anaerobic digestion, aerobic composting vermicomposting etc.

a) Anaerobic Digestion

Anaerobic digestion uses biological processes to decompose organic waste. However, anaerobic digestion uses bacteria and an oxygen free environment to decompose the waste. Aerobic respiration, typical of composting, results in the
formation of Carbon dioxide and water. While the anaerobic respiration results in the formation of Carbon Dioxide and methane (Abbasi and Ramasamy, 1998). In addition to generating the humus which is used as a soil conditioner. Anaerobic Digestion is also used as a method of producing biogas which can be used to generate electricity. Optimal conditions for the anaerobic process require nutrients such as nitrogen, phosphorous and potassium, it requires that the pH be maintained around 7 and the alkalinity be appropriate to buffer pH changes, temperature should also be controlled.

b) Composting

Composting is the controlled aerobic decomposition of organic matter by the action of micro organisms and small invertebrates. There are a number of composting techniques being used today. These include: in vessel composting, windrow composting and static pile composting. The process is controlled by making the environmental conditions optimum for the waste decomposers to thrive. The rate of compost formation is controlled by the composition and constituents of the materials i.e. their Carbon/Nitrogen (C/N) ratio, the temperature, the moisture content and the amount of air. The C/N ratio is very important for the process to be efficient. The microorganisms require carbon as an energy source and nitrogen for the synthesis of some proteins. If the correct C/N ratio is not achieved, then application of the compost with either a high or low C/N ratio can have adverse effects on both the soil and the plants. A high C/N ratio can be corrected by dehydrated mud and a low ratio corrected by adding cellulose (Tchobanoglous et al., 1997).

Appropriate moisture content greatly influences the composting process. The microbes need the moisture to perform their metabolic functions. If the waste becomes too dry the composting is not favoured. If however there is too much moisture then it is possible that it may displace the air in the compost heap depriving the organisms of oxygen leading to anaerobic conditions (Abbasi and Ramasamy, 2001).

A high temperature is desirable for the elimination of pathogenic organisms. However, if temperatures are too high, above 75°C then the organisms necessary to complete the composting process are destroyed. Optimum temperatures for the process are in the range of 50-60°C with the ideal being 60°C. Aeration is a very
important and the quantity of air needs to be properly controlled when composting. If there is insufficient oxygen the aerobes will begin to die and will be replaced by anaerobes. The anaerobes are undesirable since they will slow the process, produce odours and also produce the highly flammable methane gas. Air can be incorporated by churning the compost.

c) Vermicomposting

Vermicomposting is composting aided by earthworms (Abbasi and Ramasamy, 2001). In this process, certain species of earthworms are used to enhance the process of waste conversion and produce a better end product. Vermicomposting differs from composting in several ways (Gandhi et al., 1997). It is a mesophilic process, utilizing microorganisms and earthworms that are active at 10–32°C (not ambient temperature but temperature within the pile of moist organic material). The process is faster than composting; because the material passes through the earthworm gut, a significant but not yet fully understood transformation takes place, whereby the resulting earthworm castings (worm manure) are rich in microbial activity and plant growth regulators, and fortified with pest repellence attributes as well! In short, earthworms, through a type of biological alchemy, are capable of transforming garbage into ‘biomanure’.

Vermicomposting is a non-thermophilic biological oxidation process in which organic material are converted into vermicompost which is a peat like material, exhibiting high porosity, aeration, drainage, water holding capacity and rich microbial activities (Edwards 1998; Atiyeh et al., 2000b; Arancon et al., 2004a), through the interactions between earthworms and associated microbes. Earthworms are the crucial drivers of the process, as they aerate, condition and fragment the substrate and thereby drastically alter the microbial activity and their biodegradation potential (Fracchia et al., 2006; Lazcano et al., 2008). Several enzymes, intestinal mucus and antibiotics in earthworm’s intestinal tract play an important role in the breakdown of organic macromolecules.

Vermicomposting is the best alternative to conventional composting and differs from it in several ways (Gandhi et al., 1997). Vermicomposting hastens the decomposition process by 2–5 times, thereby quickens the conversion of wastes into valuable biofertilizer and produces much more homogenous materials compared to thermophilic composting (Atiyeh et al., 2000a). Distinct differences exist between the
microbial communities found in vermicomposts and composts and hence the nature of the microbial processes is quite different in vermicomposting and composting (Subleret et al., 1998). Vermicompost has better market value than compost, apart from proving organic carbon, NPK to the soil which compost does, vermicompost is believed to have additional attributes of providing enzyme and hormones which stimulates plant growth (Gaajalakshmiet et al., 2005; Abbasi and Ramasamy, 1999).

1.1.4 Earthworms

Earthworms are capable of transforming garbage into ‘nutrient rich natural manure. Charles Darwin described earthworms as the ‘unheralded soldiers of mankind’, and Aristotle called them as the ‘intestine of earth’, as they could digest a wide variety of organic materials (Darwin and Seward, 1903; Martin, 1976). Soil volume, microflora and fauna influenced by earthworms have been termed as "drilosphere" and the soil volume includes the external structures produced by earthworms such as surface and below ground casts, burrows, middens, diapause chambers as well as the earthworm’s body surface.

Earthworms, grouped under phylum annelida are long, narrow, cylindrical, bilaterally symmetrical, segmented soil dwelling invertebrates with a glistening dark brown body covered with delicate cuticle. They are hermaphrodites and weigh over 1,400–1,500 mg after 8–10 weeks. Their body contains 65% protein (70–80% high quality ‘lysine rich protein’ on a dry weight basis), 14% fats, 14% carbohydrates, and 3% ash. Their life span varies between 3–7 years depending upon the species and ecological situation. The gut of earthworm is a straight tube starting from mouth followed by a muscular pharynx, oesophagus, thin walled crop, muscular gizzard, foregut, midgut, hindgut, associated digestive glands, and ending with anus. The gut consisted of mucus containing protein and polysaccharides, organic and mineral matter, amino acids and microbial symbionts viz., bacteria, protozoa and microfungi. The increased organic carbon, total organic carbon and nitrogen and moisture content in the earthworm gut provide an optimal environment for the activation of dormant microbes and germination of endospores etc. A wide array of digestive enzymes such as amylase, cellulase, protease, lipase, chitinase and urease were reported from earthworm’s alimentary canal. The gut microbes were found to be responsible for the cellulase and mannose activities.
Earthworms comminutes the substrate, thereby increases the surface area for microbial degradation constituting to the active phase of vermicomposting. As this crushed organic matter passes through the gut it get mixed up with the gut associated microbes and the digestive enzymes and finally leaves the gut in partially digested form as “casts” after which the microbes takes up the process of decomposition contributing to the maturation phase (Lazcano et al., 2008).

Earthworms play an essential role in carbon turnover, soil formation, participates profoundly affects the physical, chemical and biological properties of soil. Earthworms are voracious feeders of organic wastes and they utilize only a small portion of these wastes for their growth and excrete a large proportion of wastes consumed in a half digested form (Edwards and Lofty, 1977; Abbasi and Ramasamy, 2001; Kale and Bano, 1986). Earthworm’s intestine contains a wide range of microorganisms, enzymes and hormones which aid in rapid decomposition of half-digested material transforming them into vermicompost in a short time (nearly 4–8 weeks). Ghosh et al., (1999) compared to traditional composting process which takes the advantage of microbes alone and thereby requires a prolonged period (nearly 20 weeks) for compost production. As the organic matter passes through the gizzard of the earthworm it is grounded into a fine powder after which the digestive enzymes, microorganisms and other fermenting substances act on them further aiding their breakdown within the gut, and finally passes out in the form of “casts” which are later acted upon by earthworm gut associated microbes converting them into mature product, the “Vermicomposts” (Domínguez and Edwards, 2004).

Earthworm activity engineers the soil by forming extensive burrows which loosen the soil and makes it porous. These pores improve aeration, water absorption, drainage and easy root penetration. Soil aggregates formed by earthworms and associated microbes, in the casts and burrow walls play an indispensible role in soil air ecosystem. These aggregates are mineral granules bonded in a way to resist erosion and to avoid soil compaction both in wet and dry condition. Earthworms speed up soil reclamation and make them productive by restoring beneficial microflora. Thus degraded unproductive soils and land degraded by mining could be engineered physically, chemically and biologically and made productive by earthworms. Hence earthworms are termed as ecosystem engineers (Brown et al., 2000).