C H A P T E R - I

INTRODUCTION

This chapter describes the solid waste, the origin of solid waste, nature and composition, and methods of disposal.

Man's day to day needs comprise of many materials like food, clothing and shelter. In the process of consumption and use of material part of it is spoiled and the containers, nonusable parts or spoiled material accumulate as waste. The materials like packagings, paper, food discards, vegetable leaves form the solid waste whereas the liquid material like products of metabolism, all sorts of washings form the liquid waste, which have relatively little usage at the source of their generation and recovery of any useful and valuables at the sources is uneconomical. The solid wastes are useless, unwanted or discarded materials that arise from man's activities and are not free flowing.' (WHO Expert Committee Report, 1971)[1]

1.1 Classification of Solid Waste

Depending on its origin the solid waste can be classified broadly as (1) Domesdtic (Municipal) Solid Waste (2) Industrial Solid Waste and (3) Agricultural Solid Waste.

1.1.1 Domestic or Municipal Solid Waste

Man's activities result in the production of some sort or the other type of waste from preparation of food and sweeping although the quantity and type of waste varies. It comprises of paper pieces, rags, vegetable discards, leaves and where food is cooked by fuel - like wood and charcoal-ash also forms the waste. Although formerly paper was confined to cities and towns, rarely occured in villages, today the situation has considerably changed. Use of paper have been increased. Formerly paper was used for production of books and writing material and the circulation of news paper was also less, but today, paper is used as packaging material also and finds more use than in past even in small villages. Paper forms considerable portion of solid wastes in developed urban areas. Tins and bottles also form the solid waste in urban areas which are less seen in the solid waste produced in rural areas and shanty towns.

Waste from offices and shops is strictly commercial one but it is usually considered as household waste. The waste from vegetable markets mostly consists of waste vegetable components, spoiled leaves, roots, rinds and bark, rotten vegetables, small pieces of fruit, stems seeds and fibre, including leaves often used for wrapping purchases. Most of the waste from hotels, restaurants, boarding schools and hospitals is domestic in nature, mostly comprises of food waste, plate washings, fruit rinds and seeds. Clinics and dressing stations have waste consisting of dressing cotton, bandages, waste medicines, disposable syringes, veils, ampules, unused tablets, powders, deter-

-gents and disinfectant residues. Some of the constituents like blood and puss contain harmful microorganisms which when thrown carelessly into wastebaskets find a better biotic conditions for multiplication because decaying waste is slightly warm. It is expected that the waste from hospitals and dispensaries should be properly treated with suitable disinfectants or completely incinerated.

Construction of new buildings, demolition or renovation of old buildings contribute to the solid waste, which is mostly inert in nature and consists of pieces of bricks, tiles and morter, stone, rubal and sand, wood shavings and broken metal objects like fittings and fixtures. Street cleaning, especially in central market areas is important to make towns clean. With the litter swept from streets, large quantities of stones, dust, debris fallen from passing vehicles and animal excreta form major portion of solid waste produced from street cleaning.

The slaughtering of animals and dressing of carcases is usually done near the market for the meat in towns and cities. It is dirtiest and most dangerous decaying constituent of biological waste consisting of dried blood, hoofs, horns, waste tissue, pieces of skin, non-edible components, bones and hair. Decay rate of these materials is very high and worms and insects are immediately formed in such waste. Together it becomes a foul smelling, totally unhygienic and dangerous component of solid waste.

1.1.2 Industrial Solid Waste

Industrial solid waste varies as much as their raw materials and products. There will be packagings, offcuts and spoiled materials and unwanted byproducts. Oil refineries produce a great deal of bituminous waste. In many factories, there are rasidues from fuel used for power generation or incineration of chemicals. Domestic type of waste is produced from canteen and recreation units of factory. In industrially developed areas the industrial wastes may well exceed the domestic waste.

Tanneries produce lot of residues from chemical treatment of raw hide, dippings and shavings of hide and leather, lime residues and other chemical wastes which constitute tannary waste.

Food processing mainly gives rise to unedible parts of vegetable, the barks, rinds and seeds, food grains, husk and shells, sediments from fruit juices, waste scums from syrups, spoiled and chared residue and scrapping from cans, bottles, their labels, cartoons, corks, sealing caps, plastic bag shavings and tins.

Textile waste contains cotton and polymer fibres, the waste yarn, rags, spoiled residues of chemicals and wood, rubber and broken metal parts of machines.

The waste produced from auto service stations contains metal and plastic pieces of broken parts, used lubricants, pieces of tubing, nuts and bolts, rusted sheets of metals, rubber flaps of tubes and tyres, brake linings, upholstery, rags, wire and cotton waste.

The waste produced by industries may be flammable waste, if mixed with other waste can set fire to the whole and some process wastes can become explosive if mixed with other materials. The poisonous or toxic wastes need very special attention while disposing.

1.1.3 Agricultural Solid Waste

Crop residues, bagasse, waste straws, and animal manure mainly constitue the agricultural waste. Most of it is used or returned to the land in rural areas after composting. This form of agricultural waste forms very little portion of urban solid waste. The slaughtering of animals and dressing of carcases also contribute to the agricultural waste in rural areas. Unless there is a local processing plant, the unusable parts must be removed and covered quickly to avoid nuisance. Production of compost from vegetable wastes, crop residues, animal manure alongwith night soil is a common practice in rural areas as a disposal method.

1.2 City Solid Waste : Nature and Composition

The city solid waste is one of the most heterogeneous mixtures comprising of all types of materials in varied composition. The data available to date regarding composition and physical characteristics of solid waste produced is insufficient and unreliable,[2] because the solid waste is removed as early as possible from its source without bothering too much about what it measures, weighs and looks like. This trend is changing because of increased transportation costs and evolution of various alternative methods of disposal dictated by unhygienic conditions that are created by improper solid waste management.

A survey of Calcutta city solid waste by CPHERI[3] (1970) shows fruits and vegetables 14-16%, leaves, grass etc. 18%, paper and cardboard 3.2%, rags 3.2%, glass, porcelain pieces and bones 7.4%, metal tins 0.7%, plastic 0.6%, dust ash and cinder 41.6%. But another survey conducted by Ghosh et al.,[4] of solid waste produced in the same city shows, fruit and vegetables 14%, rags 2%, glass, pieces of China clay dishes and bones 4%, metal tins 4%, dust, ash and cinder 69%, miscellaneous 7%.

A survey of Delhi City solid waste conducted by Bijlani et al.[5] shows the solid waste comprising of fruit and vegetable 20.3%, paper and cardboard 5.9%, rags 3.6%, glass, procelain pieces and bones 0.6%, plastics 0.5%, dust, ash and cinder 6.0%.

The composition of solid waste on world range[1] is fruit and vegetable 5 - 90%, paper and cardboard 0.25 - 55%, plastics 0.1 - 7%.

The story of the other cities fits within a comparable pattern of compositions covered in the above survey. There are regional and seasonal variations and also the variations depending on the pattern of life which varies with income, community customs, social awareness, food habits, hygienic and health care habits, population pattern, association with animals like dogs and cattle.

As it is evident from the above data, the composition of solid waste varies from city to city, area to area as well as for different years. Also the method adopted to assign the composition and nature varies. Thus, whenever an attempt is made in developing the technology

for collection, transportation and disposal of city solid waste, it is inevitable that it should be based on proper sampling and analysis of waste produced in that particular city over a long period, depending on pattern of life, degree of industrialization, efficiency of municipal waste collection mechanism, civic sense and education.

Different categories of analysis of solid waste based on final disposal method is put forward,[6] which is gaining much importance as a common analysis technique and reporting procedure in countries of European Economic Community. It is important that any base classification have to be used with flexibility to meet the needs of various policy management and design decision.

Utmost importance must be given to the data analysis. Extensive sampling and analysis in small selected areas and their careful analysis and interpretation of data by using computer technique and standard methods may help us to have a fairly reliable set of observations and results.

1.3 Collection and Transportation

The accumulation of solid waste nearby dwelling areas creates lot of health hazards, and becomes an obstacle for free movement of citizens and their vehicles. The scattered glass pieces and tins may cause dangerous cuts. The rudents and worms thriving on decaying edible things may be a source of epidemic and human and animal wastes may stink and make the living impossible. Thus the refuse should be removed regularly and frequently. In humid tropics, waste food gets

putrified very quickly and consequently there should be daily collection and removal of waste. Paper or packs may be used for collection of waste, which is an efficient way in handling waste, but due to increased cost and volume it is not in use. Most of the collection of waste from domestic source is usually dumped into dust bins made up of sheet metal or concrete, and of different shapes. These dust bins are usually provided by municipal authorities. When the refuse production is more and the dust bins are insufficient, these dust bins overflow and create unhygienic conditions. The frequency of removal of waste from these dust bins must be proper otherwise these dust bins are overflooded, and animal burrow these heaps in search for edible components, also the beggers in their search for something useful scatter the waste. These days almost everything has some value and therefore, in developing countries search for salable material in dust bin continues repeatedly by groups of low income community, jobless raw persons and their family members. Such a search for waste plastics, rubber flaps, metal and broken glass, wood shavings, results in spreading the waste causing a lot of inconvenience to labour who collects and loads the waste. Incidently the tendency develops to lift the main heap and ignore the scatter.

Vehicles play major role in transportation of solid waste from collection points to disposal sites. If the vehicles are not properly maintained, the waste continuously falls off the trailer and sizable percentage of waste is scattered over the entire track. Thus the transportation method should avoid spillage and trucks should be of

adequate capacity with suitable covers and facilities for tipping or unloading with case. Manoeurability for narrow and winding roads is important.[7]

The cost of maintaining old vehicles may well exceed the annual cost of replacement, and a programme for regular replacement of vechicles may well prove economical. Daily washing of vehicles and regular repainting with bituminous paint reduce corrosion. There is advantage in keeping vehicles and collection under single control (CHPERI 1970).[3]

1.4 Methods of Disposal

The disposal operation consists of the activities directed at the ultimate removal of the wastes in a satisfactory manner. Methods of refuse disposal may be divided into two broad classifications, (1) those involving disposal of refuse as it is taken from the generator and (2) those involving some type of treatment or processing of entire amount, or some portion of the amount collected. Open dumping, disposal at sea, and various methods of sanitary landfill are of the first type, biogasification and incinaretion, composting and pulverizing are examples of the latter. The former methods can be called ultimate disposal techniques, while the latter are intermediary techniques that utilize a sanitary landfill for ultimate disposal.

In treatment of disposal of solid wastes, the following points should be considered while selecting the suitable method.

(1) The quantity and character of refuse and likely changes.

(2) Land available for final disposal.

(3) Constraints on temporary and ultimate use of possible tipping sites.

(4) The health of the public and refuse workers.

(5) The choice between the manpower and mechanical equipments based on availability and cost.

(6) The need for compost due to soil structure and type of agricultural activities.

(7) Potential use of power or heat obtained by incineration.

(8) The cost of possible methods.

(9) Nature of biproducts and residues of treatment.

1.4.1 Composting

In rural areas vegetable waste has been composted since ancient times. The composted waste was used as manure and land conditioner. Micro organisms, already present in the waste stabilize organic matter to produce a land conditioner. It is a recycling process returning organic matter to the earth and there are no specific requirements except for rejects, the materials which cannot be converted. The government has launched campaigns of propagating rigorous implementation of the composting activity. Government subsidy is available for proper implementation of this technique. Generally cost of digging and cost of lining is given as subsidy and farmers are encouraged to put every plant and animal residue in such pits. In this process most of the organic matter and biologically significant metal salts are continuously passing through a cycle of utilization. But compost is

having little value as soil conditioner as it requires about 75 tons per hectare. It is bulky and the cost of transportation and spreading is high. In tropical areas where high intensity rainfall and rapid run off result in the errosion of humus from land, the composting proves to be advantageous and make up the erroded humus, which has got good moisture retaining capacity and is not so easily washed away as chemical fertilizer (CPHERI 1971). It helps to improve the soil structure and to control soil erosion.

The manurial value of the compost can be increased by adding night soil or sewage sludge. This solves the disposal problem of night soil and sewage sludge. In developing countries, where labour is abundant, non mechanised methods of composting can be used. Refuse in developing countries is more suitable for manual composting and the resulting material is of higher quality than that obtained in a fully machinized plant.

In India two methods of composting night soil refuse mixtures are in practice. In BANGALORE METHOD alternate 150 mm deep layers of vegetable wastes and thiner layers of night soil are spread in a trench about a meter deep. At first aerobic organisms use the air trapped around waste but the mass soon becomes unaerobic. Decomposition is then slower and it takes six months or more to produce a good compost. In INDORE METHOD, layers of night soil and vegetable wastes are alternated in the same way either in a trench or to form a mound above ground called a windrow. This is kept aerobic by turning

regularly for two or three months. Then the compost is left for another month or so without turning, the whole process thus taking about four months to produce compost.

1.4.2 Sanitary Landfill or Controlled Tipping

Sanitary landfill is a method of disposal of solid waste without any pretreatment, in which each days wastes are compacted and covered by a layer of inert material. This method of disposal of solid waste is most commonly used, because it has been the least expensive. To allow the compaction, the layers of waste should be of not more than 2.4 m depth and to provide an adequate seal, the cover should be of 2 m thickness. This type of disposal is helpful in many ways, in limiting the emission of odour, in preventing light refuse being blown away by wind, in preventing the breading of flies, in reducing the risk of fire and in providing good condition for the biological degradation of organic matter.

Biological degradation of organic matter is carried out by micro organisms which are already present in refuse. The temperature in the sanitary landfill may rise to 65° C and higher. This high temperature destroys the pathogens in the refuse. The waste products of the microorganisms include gases such as carbon dioxide and methane. The methane component of landfill gas is having a good heating value and can serve as fuel. Now a days methods to tap these landfill gases are in developing stages.

Small bulldozers or tractor loader showel are used in tipping the waste and cover. This helps in compacting the refuse. Usually it is better to cover the sides of freshly tipped refuse as soon as possible by the end of working day. Fish waste, animal waste, animal carcase, waste from hospitals and other noxious material should be covered with other refuse. Generally a large tip can be controlled better than smaller one. Controlled tipping is possible without any mechanical plant at all. The use of tip should be planned to reduce exposed sides and ends. One method is to divide the area into strips each 20 m wide. Tipping is first carried out on alternate strips providing cover on both sides, when the intermediate strips are used no cover is required at the sides.

No surface water should pass through a tip. Thus ditches should be dug along the upper side of the tip area to divert any water flowing across the surface following rainfall. This is especially very essential when the solid waste consists considerable amount of organic waste, night soil, cesspit contents, sewage sledge. In normal permeable soil bacteria do not penetrate more than 12 meters (WHO Expert Committee 1971). Fissured and loose rock may give a comparatively free passage for leachate to reach groundwater. A hydrogeological survey is essential before landfill sites are selected.

Leachate is caused by rain water percolating through the tipped material. The leachate from the organic and inorganic chemicals of domestic refuse, night soil may have a high biochemical oxygen demand (BOD) and high concentrations of ammonical nitrogen, chlorides and

sulfates, which render the groundwater unpalatable. To avoid the conta minated leachate to reach the groundwater, an impermeable barrier may be put at the bottom of the tip or where the underlying strata are fissured a layer of sand or gravel may be put at the bottom of the tip. Clay can be used as impervious cover to prevent rain reaching the tipped waste.

The sanitary landfill provides a meansto recovery of otherwise unusable land for recreational use as parks or golf courses after enough time is allowed for landfill to stabilize. However, as urban populations and intensity of land use have increased, close in sites and sites that do not create considerable community reaction have become scarce. Thus the sanitary landfill areas have to be selected far away from the cities, thereby increasing the haul costs and overall costs of managing waste. There are external costs associated with landfills as a result of production of leachate and methane gas in the completed landfill. Improperly managed landfills present problems of odour, fires and blowing light refuse and ill health.

1.4.3 Biogas

It is a process of methane production by fermentation of farm and human wastes. This fermentation process takes place in a unit which is simple in design and operation, and accepts the waste materials which ferment or digest without access to oxygen. Thus all the components of the city solid waste are not useful in the production of biogas. Only the animal excreta, night soil and vegetable discards are useful.

The components of waste can be generally classified as (1) Biodegradable components and (2) Non-biodegradable components.

Biodegradable components are generally organic matters sucn as animal and plant products and wastes, cotton, yarn and linter, nide and leatner, and wood. These constituents are attacked by micro organisms giving rise to simple organic molecules.

The non biodegradable materials are generally inert materials like stone, rubble, sand, clay, metal parts, metal rust resudues, many polymers and rubber, and sucn materials remain uncnanged over a long period, slowly affected by weatnering and can only succumb to combustion.

The biogas, largely a mixture of metnane and carbon dioxide, bubbles out of liquid slurry wnicn can be conveniently tapped for nousenold lignting or cooking. The digested mixture or slurry can be used on tne land as a soil conditioner and fertilizer. The tneoretical detension time of tne slurry (mostly cow dung diluted with water in 1:1 proportion) in the digester is normally 30 to 50 days whicn allows for gas production and destruction of most of the pathogenic microorganisms, Methane being the energy source determine the fuel value of the biogas, which ranges from 18.4 to 39.7 kJ m^{-3} depending on the feed.

Tne financial and economical viability of production of biogas being difficult to quantify and in many instances its financial viability is in doubt. Despite this drawback tne biogas plants are in use in several countries of Asia.

1.4.4 Production of Refuse Derived Fuel

The production of Refuse Derived Fuel from the domesdtic waste is a technique which gives a fuel of considerable calorific value which can be used as an alternative to the conventional fuels such as fuel oil and coal. It is a resource recovery technique and intermediary. Only the combustible fraction of the waste is useful in the production of Refuse Derived Fuel. The non-combustible fraction of the waste is to be separated by mechanical means and disposed off by landfilling. The combustible fraction of the waste is powdered or used as it is in making the briquettes or pellets which can be conveniently handled. The problem associated with the burning of the Refuse Derived Fuel is similar to the problems associated with the incineration technique because the burning of Refuse Derived Fuel is essentially incineration. The production of Refuse Derived Fuel is economical if the combustible fraction of the solid waste is considerable.

Ramon[8] has explained the method of manufacturing of RDF in which the solid waste is milled, soil, ash, sand, metals and glass particles are removed. The organic material with particle size < 50 mm is mixed with $CaCO_3$ to neutralize Cl from PVC and compressed to cylinders and heated to 60°C and cooled to form solid fuel having moisture content 8-12% with density of 600 $kg-m^3$ and calorific value of 12500-13300 $kJ-kg^{-1}$.

Braker et al[9] have explained a pilot plant to manufacturing of fuel from municipal solid waste with 5 $tons-hr^{-1}$ capacity. The produced fuel is dust like and can be made into briquettes and stored. 300 kg of fuel with calorific value 18 $GJ-ton^{-1}$ is available from 1 ton of municipal solid waste.

A detailed discussion regarding this method is dealt with in subsequent chapters. To avoid the repeatation here it is dealt with in brief.

1.4.5 Incineration (Open Air Burning)

It is an intermediary technique in disposal of solid waste. The solid waste is burnt at temperatures as high as 950°C - 1100°C. The combustible organic fraction of solid waste burns producing incineration residue and flue gases. The flue gases may contribute to the air pollution unless incineration plants are designed, equipped and operated to meet air pollution requirements (WHO Expert Committee 1971). Dust arresting equipment must be installed and a high chimney is needed to disperse gases. The flue gases produced during incineration mainly are constituted of NO and NO_x alongwith polychloro dibenzo-dioxins (PCDD) and polychlorobenzofurans (PCDF).[10] The PCDD and PCDF and chlorobenzene were formed mostly in the electrostatic precipitator. The concentration of NO showed an exponential increase as the temperature at incinerator outlet ranged from 600°C to 1000°C. Two zones in the incinerator 1100°C - 1200°C and 800°C - 1000°C are the major sites where thermal NO_x is formed and fuel NO_x is converted.[11]

The residual slag after incineration of waste has a volume of about one tenth of the original refuse or 23-25% by weight of refuse. The residue can be used as enbackment fill material and pavement base courses,[12] and in producing building materials. When disposed off as

landfill, it affected the land pollution least because of extremely low solubility of metals and metal oxides present in the incineration residue.[13] Solids from dry or semidry waste gas has no use and must be disposed off by landfilling. In disposal of slags as landfill controlling the pH of leachate at 7-9, prevention of waste scattering by wetting and preventing the contact with solvent is essential.[14]

Another product of incineration of solid waste is the heat energy. This heat can be utilized in generation of electricity and for running boilers. The calorific value of solid waste is in the range of 7000 - 8400 $^{K}J\ kg^{-1}$. The recovery of heat energy hardly makes up the annual operating cost.

Although incineration is wasteful it must be remembered that a critical mass of waste is necessary for treatment by economic methods and the problem of disposing much larger quantity of waste is easier and economical, than handling smaller quantity and irregular components. Hence it is necessary to adopt suitable techniques depending on amount of waste produced per unit time.

1.4.6 Pyrolysis

Pyrolysis is burning in the absence of oxygen or more technically, chemical change brought about by the action of heat. When applied to combustible fraction of solid waste in an oxygen free atmosphere, this process yields water, combustible gases, tarry liquids and a stable residue as products of the thermochemical conversion of complex organic solids. It is thus a resource recovery

technique. High temperature pyrolysis units will produce residues that appear to be much higher in quality and for the slagging units, much lower in volume than residue from more conventional incinerators. The slags can be discharged as landfill. The slag appears to be excellent for fill and road base construction and show potential when crushed and sized as concerete aggregate.

Excess combustible gases from pyrolysis processes would seem to offer potential for firing boilers, gas engines and other combustion processes. Such use of these gases would seem to offer a simple means of utilising waste heat. Pyrolytic processes does not introduce new problems in air pollution control.

The tarry liquids are a means of chemical source for many phenolic compounds.[15] The recovery of these tarry liquids may prove economical as raw material source to many organic compounds.

To avoid the repeatation, more detailed discussion and data collection are dealt with the subsequent chapters.

1.5 Epilogue

From the above study, it may be inferred that a proper study of sampling, careful analysis, collection of representative data for areas, seasons, application of statistical treatments, appropriate methods to quantify the waste, careful management of waste collection and transport, and further processing of waste so as to get optimum value of the products and suitable distribution of gas or heat and

development of methods of using some constituents of products as a source of chemicals should be developed. This can be done if critical mass of the waste has been determined. The nature of problem is dynamic since natural resources are dwindling, other raw materials are becoming costlier, and with the advent of technology, improved methods and continuous search for processing will make it possible to the entire process economical.

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