Chapter II

CONCEPT AND REVIEW OF LITERATURE

Chapter II is divided into two parts. Part I deals with Theories and solid waste management concept. Part II deals with Empirical studies and Review of literature

Part I

Part I deals with Theories and Solid Waste Management Concept

Definition

According to the National Academy of Sciences, “Pollution” is any unfavourable change in the physical, chemical or biological characteristics of air, land and water that may or will harmfully affect the living conditions and cultural aspects or that may or will deteriorate raw material resources. The World Health Organization (WHO) has defined pollution as the substance which got into the environment by the activity of man in concentration, sufficient to cause harmful effects to his health, vegetation, property or to interfere with employment of his property.

Pollution means introduction by man, directly or indirectly any hazardous waste into the environment as a result of which there arises many hazards to human health, plant or animal life, harm to living resources or ecosystems damage to amenities or interference with other legitimate uses of the environment.

The environmental pollution results from returning of residual materials of economic activities to the environment as wastes. But it is important to realize that not all emissions or residuals cause pollution. This is because the environment has a certain assimilative capacity to degrade the materials that it receives and thereby to convert them into harmless or even useful forms; the best
example of this is human waste. Sewage at least up to a certain concentration is rapidly degraded by bacteria and made harmless and is utilized as food by other organisms. Even crude oil in the sea is eventually incorporated into the ecological chain as food for bacteria. However the assimilative capacity of the environment within a given time period has a limit. Heavy metals are not degraded by natural forces and they accumulate in the environment when they are ejected by producers. Once the assimilative capacity is exceeded detrimental effects may result from further emission and that is the beginning of pollution therefore pollution means discharge of wastes into the environment beyond its assimilative capacity.

To tie together some of the points made in the previous paragraph, it is useful to review environmental pollution and its control as a material flow (balance) problem for the entire economy. Energy residuals could be treated in the entirely parallel fashion. The inputs to the productive system are fuels, tools, and raw materials which are partly converted into final products, and partly become residuals. Except for increase in inventory, final goods also ultimately enter the residual system. The goods which are consumed really render service temporarily. Their material substance remains in existence and must either be reused or discharged to the environment. This is explained with the help of a chart on material flow by Bohn and Kneese. According to material flow approach most of the resources and raw materials are discharged into the environment as solid, liquid and gaseous wastes through production process. Consumption activities also cause large amount of waste. Durable consumer goods are also discarded after certain period of time. Ultimately large amounts of waste are disposed into the environment and that has resulted in environmental pollution.
Economics and Ecology

Economics may be considered as a branch of human ecology, since it studies the interactions of energy and materials among individuals in the economic system. Ecology may be considered as economics of environment. Since it is considered with the introduction and exchange of energy and materials among individuals in sociological system.

Uncontrolled consumption patterns depleted precious non-renewable natural resources, upon which future development depends. Rapid population and economic growth also stimulates the demand for scarce resources. Economic activity produces waste which is discarded to the environment, as if it is the receptacle. This is the economic aspect of it.

Growth Vs Environment

Many environmentalists regard noise, effluent, and smoke pollution ad the destruction of wildlife and natural beauty that followed in the process of expanding industry and communication as harmful. To them the continued pursuit of growth by the Western Society is more likely on balance to reduce rather than increase the social welfare. Economic growth in terms of Gross National Product is conflicting with the quality of life. Yet, a raise in GNP may also enable a nation more easily to bear the cost of eliminating pollution.

The Concept of externality

Externalities are non-exchangeable and inter-dependencies between individuals and firms. Perhaps the most relevant feature of environmental goods and environmental degradation is the “spill-over” effects, notably in public goods. Another way of talking abut these effects is to say that public goods exhibit external benefits and public bads exhibit external costs. The externality
is observed to be wider phenomenon than publicness, because interference of this kind tends to be a basic feature of any economy.

Externality may arise because of the inputs used, or because the act of consumption itself is a nuisance. In the former case pollution may be an offensive behavior. Essence of an externality is that it involves.

1. Interdependence between two or more economic agents, and
2. A failure to price it’s by economic agents that are independent.

The production of commodities by firms generates an externality that affects adversely its consumers. Externality is a pure public good or bad. What one person consumes does not affect the amount available for consumption by others. Although environmental pollution is clearly a public good, externality in the sense, varies geographically. Some areas are more polluted than others. It may be said that the same aggregate emission enters all utility functions, but disutility suffered by any consumer depends also in part on his consumption of land or in other words, on where he lives.

An externality is defined to occur whenever a decision variable of one economic agent enters into the production or utility function of some other agent. Hiller and Starrett define an externality to occur whenever the private economy does not offer sufficient measures to create a potential market. They argue that their definition is not only general enough to include pecuniary externality, but also provides a key to determining what types of economic situations are likely to lead to externalities occur in situation, when it is either costly or impossible to define private property, whereas pecuniary externalities occur when set up costs rule out of competitive market. They also say that externality occurs as absence of markets. It is also insisted that externality can always be associated with the failure of some potential markets to operate properly. Therefore all externality
problems can be treated to some more fundamental problem having to do with market failure. Market failure might be due to (a) non-exclusiveness of commodities (b) non-competitive behavior and imperfect or incomplete information.

The basic economic principle of environmental policy is to be found in the theory of externality. Externality characterizes pollution as a “public bad”. That can be expressed in the form of an equation.

\[ X = F(L, E, Q) \quad - (1) \]
\[ Q = Q(E) \quad - (2) \]

- \( Q \) - Level of Pollution
- \( X \) - Amount of goods
- \( L \) - Labour input
- \( E \) - Waste emission.

In this formulation waste emission is treated simply as another factor of production. This seems reasonable because attempts to cut back waste discharge will involve the diversion of other inputs to abatement activities, thereby reducing the availability of these other inputs for the production of goods.

The economic explanation for the existence of pollution is the desire of the firm and people to keep to a minimum their use of resources that they have to pay for. The theory that is based on the premise is known as the theory of external cost. “An external cost exists when a production or consumption activity induces a direct loss of utility; or the production cost which does not enter the decision calculus of the controller of the activity”. In this definition cost includes all adverse effects. The effects are ‘adverse’ in any pollution induced change in any component of the environment adversely. Adverse effects on human beings, plants, animals and material goods are considered. For
example, the impact of effluent disposal is direct, not via price changes and truly external cost may well be a reduction of the productive potential of the economic resources. Effluent discharge reduces the value of environmental goods and makes them scarce.

**Theory of pervasive external cost**

Mishon and Kapp observes that, with so many materials circulating in the atmosphere, in rivers, lakes and oceans, in underground water tables, in the soil and in the bodies of wildlife, all of them may be turned over as private property to people for use in market transaction. However, there is no basis for assuming that by making more resources into property would yield better results than leaving only fewer resources as property. This is an application of “the theory of second best”. According to this theory if markets for several factors in an economy are imperfect, hen making one more market perfect would not necessarily move the economy to a better position.

Polanyi argues with the same view, but he goes further by including the benefits of stable social communities along with the use of air and water and basic bio-geochemical cycles, among the things that can be made into property. He argues that there are disastrous consequences in making part of a society into a commodity (labour) that is moved about by the result of price changes and by making part of nature into a commodity (land) whose uses can be altered by similar price changes. Polanyi’s belief is that any attempt to run the economy by a self-regulating market was utopian experiment that fails. Society he argues has to take charge of the economy to prevent disaster. The replacement of market forces by planning is necessary, only question being whether the planning should be democratic or dictatorial.
The Roskill’s and Walter’s Model

Roskill’s and Walter improve the property price approach. It is based on the concept that individuals would buy peace like properties for a price, choosing to locate their homes in peaceful areas by choosing to work for employers who have located their activities in such areas. Both explain their concepts on the valuation of noise. The essentials of these approaches are that (i) they might be useful for the estimation of property price depreciation and (ii) the estimation of consumer’s surplus.

Theory of Unmarketed goods

The main feature of my environmental goods and bads is that they have no market at least in the normal sense. It is often suggested that commodities outside the sphere of markets can not be measured by money units. But environmental goods too have a price, though the price is not observed in the market. Though prices of such goods appear to be zero, their “true” prices are positive. Some times environmental goods may fetch higher prices than what cost-benefit studies suggest as price.

Input-Output Environment Models

Victor has attempted to estimate the demand for water (an economic commodity in his terminology) and discharge of waste by industries in Canada. First, pollutants are regarded widely regulated as very important from the ecological point of view and the list of input-output co-efficient, that show how much pollutant is produced per unit value of output is worked out industry wise. For the purpose, the input-output table is sufficiently disaggregated. Second, developing the first idea, one would assess the total waste from each industry. Finally an attempt to place a monetary valuation on the environmental commodities and discharges is made. To do this, the standard prices effecting society’s evaluation of these items on a conceptual basis is required. Thus going
from cost benefit theory to practice is at the very base, but it is difficult and often virtually impossible. Although some figures can be obtained, they have no meaning. Victor’s study uses only relative weights, that is, he does not attempt to use absolute money values for items, and the weights are derived by asking an expert to assign them.

**Leontief’s extended input-output model**

Leontief extended the input and output tables which he originated to include a pollution abatement sector. This is an important departure. Since pollution is itself an industry requiring inputs from other industries. Pollution co-efficient are estimated relating tons of pollutants to the units that pollute.

No flow from the environment to industry is incorporated, so that like most of the other models, the principle of material balance is not included in the model.

**The general structure of Leontief’s extended model is tabulated as follows**

<table>
<thead>
<tr>
<th></th>
<th>Industry Output</th>
<th>Anti-pollution activities</th>
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<tbody>
<tr>
<td>Industry inputs</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Industry outputs</td>
<td>C</td>
<td>D</td>
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Matrix A is the traditional input-output matrix relating inputs to outputs to outputs. Matrix B relates industrial inputs to pollution estimation activities, which are noted as a cardinal feature or Leontief’s system. Matrix C relates pollution emission to industrial outputs Matrix D shows the pollution reduction as a result of anti-pollution activity. By manipulating the table, Leotief is able to assess the effect of the level of emission in individual sector for the particular level of final demand. At the aggregate level, the model permits the estimation of the total level of pollution that world result if a given projected level of final demand occurred. This model could also estimate the price effect of particular
anti-pollution measures, a feature of input-output model that is desirable from the point of government.

The Controversy over limit to growth Theories

A study on limits to growth conducted by M.I.T. Team of system of analysis, argues that the limit of earth’s capacity to absorb the waste products from agriculture, industry and large cities would be reached long before resources are exhausted. If every country in the world is to become as industrialized and as urbanized as the United States and Japan, there is little doubt that the earth would be subject to ecological disruption. According to Meadows if the present growth trends in world population, industrialization pollution, food production and resource depletion continued unchanged, the limit to growth on this planet would be reached somewhere within the next 100 years.

The Social Psychology Model

The social psychology model is based on the altitude behavior Theory. This includes three different interrelated response components, a cognitive component, an affective component and a conative component. Cognitive component refers to knowledge and belief about pollution, the affective component refers to feelings and emotions regarding pollution, the conative component refer to both overt behavioral responses to pollution and verbal report of intuitive act in some manner regarding environmental pollution. It is demand for empirical data is enormous.

The Concept of “Spaceship Earth”

The phrase discussed by Boulding suggests that pollution is the material residuals from production and consumption activity, and will always and increasingly be with the people. Because the earth is like a spaceship, it is a closed system with respect to materials. A related concept developed by Ayres
and Kneese in 1969 is that of “materials balance”. According to physical law of conservation of mass, the residuals would be roughly equal in mass, to the total amount of fuels, foods and raw materials entering the economy. If the economy is growing, so is pollution. It follows that pollution would be pervasively associated with economic activities, not just the few that the theorists of the 1950s and before have suggested.

One example of the phenomenon of “environmental reservoirs” is the increasing concentration of CO, CO$_2$ from fossil fuel in the global atmosphere. The fear is that this may lead to a warming and melting of the polar caps; with the attendant adverse effects, including the flooding of coastal areas.

**Social Cost and Externality**

Externality reduces the resources of the economy and it is responsible for resource depletion and pollution. Underlying analysis of externality is a concept of social cost. Edel defines social cost “as a loss to society as a whole, as a result of some activity”. This cost may be measured in terms of opportunity cost (The value of the resources used up in the process could have produced to society in other possible use) or in term of disability (psychological cost of doing the work and foregoing other resource uses). Economists considers an activity justifiable if the social cost is less than social benefit that the activity brings about and recommends carrying out only that amount of the activity that will equate marginal benefits and costs. If private industry produces larger amount at lower cost social cost is greater than private cost. The external cost imposed by private industry is responsible for pollution in the economy. The difference between social cost and private cost is external cost.

**Pollution Externality**

The private market allocates resources efficiently only when all individuals affected by the market decision are involved in making those decisions, which is difficult to be seen.
Dowing explains pollution externalities by giving the example of cola production. The production of cola creates wastes, which are released into river. These wastes reduce the number of fish living in the river and therefore the number that can be caught by the commercial fishing industry. If the firm decides to produce more cola, it will release more waste into the river. Its decision to increase production does not take into account the cost to society of the release of waste into the river. In an unregulated private market, such environmental costs are not reflected in the firm’s marginal cost.

The production and sale of cola involves market agreements between the owners of factors of production and producers of cola. At no time does it include agreement with the fishing industry. Fishing is external to the agreement, but fishers are directly affected by the firm’s decisions. Such effects on parties not directly involved in market agreements are called pollution externality.

**Pollution Cost**

The effects of pollution have a cost to the society. It is called pollution cost. Pollution cost can be divided into two (i) pollution damage cost and (ii) pollution damage reduction cost.

**Pollution Abatement**

Large amount of production of output involves larger amount of emission or effluent. A reduction in the amount of emission or effluent wills involves a sacrifice of output. The cost to the firm in this case is the loss of profit on the unit of output eliminated. So that the abatement cost is derived from the firms profit curve.

Initially one unit of output cut leads to larger reduction in pollution. But as production declines a unit cut becomes less successful, at abating pollution...
because the lower output levels are not the heavy polluters. This is one reason why savings in pollution of a given size require increasingly larger sacrifice of output and profit as the firm moves towards total abatement i.e., zero pollution. The other reason is that the loss of profit for an extra unit of output sacrificed increases as output falls because with rising marginal cost, the initial unit of output yields more profit than the extra ones.

The cost of abating to the firm through output cut is dependent on the demand for the product. An increase in the demand raises marginal revenue and shifts up the marginal abatement cost curve. The benefits to individual polluters obtained from polluting therefore depend on demand for their products. This is the logic of saying that economic growth is characterized by rising demand and consequently by an increasing incentive to pollute.

**Pollution Damage Cost**

Once pollution has occurred owing to the failure of the polluter to abate pollution, cost is incurred by the society and this is called pollution damage cost. Other members of the society are not responding to mitigate pollution effect. Therefore pollution reduces the value of consumption and production activities in the economy. By failing to reduce pollution the damage cost is incurred by the society. Pollution damage cost can be divided into further two types namely i) Money cost and ii) Real cost. Pollution causes damage to material goods or tangible goods. Air and water are polluted by the emissions or effluent discharged by a firm. The society incurs cost to purify polluted air and water by installing treatment plant. Society makes arrangement to supply protected drinking water in the water polluted area. The cost incurred for such efforts can be easily measured in monetary terms. It is called money cost.

Air quality or water quality deterioration causes detrimental consequences on the mental and physical well being of the people. Clearly such health effects
reduce their efficiency as factors of production. Because of disease number of man-days of work is lost. This is real cost. If this can be valued in terms of money, then it is the money cost.

One who is affected by pollution incurs cost to reduce the damage covered by environmental quality deterioration and this is called damage reduction cost. This arises from defensive operations undertaken by the pollute.

**Explicit and Implicit Cost**

Damage reduction cost may be i) explicit or ii) implicit. The owner of the property incurs cost for rectifying the damage caused by pollution activity, it is explicit in nature that can be seen and measured.

Health hazards caused by pollution reduce the efficiency of human being and working capacity in course of time. In order to cure the disease the affected person the pollutes incurs cost and this is implicit because reduction in the number of working days and efficiency due to this cause is difficult to be separated from the effect of other causes of ill-health. The cost incurred to overcome such hazards is called implicit cost.

Thus pollution is an externality that results in pollution abatement cost, pollution damage cost and pollution damage reduction cost.

External costs affect the general economic welfare or well being in two ways. In the absence of any private or government compensation arrangements, pollution leads to uncompensated losses being incurred by some one who is not responsible for it and hence it is socially unjust.

Efficiency of the economy represented by Pareto’s optimality criteria is a situation in which it is impossible to make any change in the economy’s
consumption or production arrangements that would improve the welfare of one any other individual with out reducing the welfare of in the society. The gainer’s gain should off set the loosers losses. In the case of pollution polluter gains at the cost of others affected by pollution. It is an unjust situation that needs a specific policy to correct it. Judgment about the desirability of consequences of a change may therefore be based not only on the size of the net gains generated, but also on the degree of just protection offered to loosers. Just protection is not the same thing as distributive equality, but is refers to the compensation by polluter to those who suffer from pollution.

Just protection requires the full compensation of polluter for the cost imposed on them by pollution. Even though there is a disagreement about the characteristics of just solution to pollution problems, as justice requires compensation, that it forces the analyst to confront the possibility of a trade off between justice and efficiency.

Pollutees find compensation for the losses suffered by them acceptable for some level or types of pollutant but not for higher level or insidious type, and may refuse an offer of extremely high compensation to accept risk.

Efficiency refers to proper allocation of resources among various uses of economic activities. But the costs of externality are likely to cause misallocation of resources. However, such misallocation of resources could be corrected if the cost of it is internalized either through a bargain between the parties or by a tax imposed on polluter to compensate the affected persons, then social efficiency can be achieved through the responses of polluter and the pollutee.

Secondly, the conditions that guarantee social efficiency in the classical sense namely $P = MSC$ (Price is equal to Marginal Social Cost) can be brought out.
Thirdly, with a fixed technology and strong preference of the polluter for the pollutee’s locality, pollution control necessarily involves a lowering of output. Fourthly, if assimilative capacity of the environment may be maintained, but cutting back output, then there will be efficiency.

**Policy**

Pollution Control Policy aims at controlling environment degradation and resource depletion in the economy. Improviding the environment quality is essential to sustain the growth process. Pollution control policy may consist of some or all the following components.

- Government direct action to pollution control.
- Pollution control laws imposing restriction on output and resource use.
- Regulatory approach
- An economic incentive system for reducing pollution control.
- Allocation of property right.
- Voluntary agency services to motivate and assist people in controlling pollution.

Private market will not allocate resources towards pollution control efficiently primarily because there are externalities involved in the cost of pollution and pollution control is by nature a public good. The private market in the absence of government intervention allows emitters to reduce their paid out cost by releasing waste that damages the environment and harm the people.
The balancing of interest group pressures can generate a policy that does not necessarily lead to efficiency in pollution control.

The goal of a firm’s owner is to make as much profit as possible. One of the ways a firm can maximize profit is to produce its output at the lowest possible cost by discharging waste into the environment. Pollution is found due to their production activity. This needs enforcement of stringent pollution control laws. But certain emitters lobby reduces, the stringency of pollution control laws, for their personal gain at the social loss by exerting influence on the policy makers.

Recipient Lobby

Persons affected by pollution will seek to reduce damages in many ways. One way is to act politically to encourage government action. Individuals will assess the benefit and cost and extend their political action to the point where their private marginal benefit equals their marginal cost. Any political action taken by the recipient other recipients better off, hence it allows for free riders.

Interactions of Principal Actors in Pollution Control Implementation

Environmental policy is formed as a result of a complex set of interactions among affected parties. A simple representation of these interactions is shown in
this figure. An arrow represents the direction of influence. A word that labels a line of influence that is influenced or that does the influencing. Thus, for example, an emitters lobby influences the control agency budget by using political pressure.


**Chart 2.** Showing pollution control arrangement
Public policy on pollution control is the result of a complex set of intercessions among the emitter lobby, the recipients lobby, the government policy through direct negotiation, political pressure on the control agency and the budget. They can also affect control agency policy through court action. The following figure illustrates some of the possible interaction flow of information and reactions of the group. When the emitters do not implement the pollution control laws, the case is taken to the court. If they disobey the court orders, the industry to be closed.

The complex interactive bargaining that generates pollution control policy contributes for the implementation of the policy. By implementing various laws environment is protected. The water (Prevention and control of pollution Act) 1974 was passed in India to control pollution of water. The Air (Prevention and Control of Pollution Act) 1981 was passed to protect air quality. The Environment Protection Act 1986 was passed by the government to control environment degradation.

Regulation is the basic approach to pollution control adopted by government in the United States and in most other countries. The government defines a desired goal and formulates specific rules or regulations that mandates the action needed to meet that goal and develops an enforcement programme to ensure compliance.

**Coase Theorem and Transaction Cost**

We have to discuss the impact of transaction costs on environmental allocation that is Coase Solution with Transaction Cost. This is illustrated in the figure.
Pollution

In the figure OD denotes marginal prevented damage and SOC indicated marginal abatement cost as in previous figure. Assume that transaction costs arise and they are carried by the party who tries to induce the owner of the environment to agree to a different use. Further, it is also assumed that transaction costs can be defined per unit of emission so that in this interpretation, we can talk of marginal transaction costs. It is also assumed that marginal transaction costs are constant.

Now, again, we shall discuss distinguishing the two different cases of property titles as done previously.

**Case I:** If the environment is owned by the pollute (consumer), the polluter will be willing to compensate the pollute according to the polluter’s marginal cost curve CSO. In this case, however, the polluter has also to carry the marginal transaction costs; the net transfer according to the pollute who is endowed with exclusive property right, therefore is given by the marginal abatement costs minus transaction costs. Relative to the situation without
transaction cost, the compensation offered to the pollute is reduced; the polluter’s bargaining curve shifts downwards from SOC to YT2 (as indicated in figure).

**COASE SOLUTION WITH TRANSACTION COST**

The vertical distance between the curves represents the transaction costs per unit; not that the curve shifts in a parallel fashion, as the transaction costs are assumed to be constant.

Due to transaction cost, the new solution is at point ‘V’ instead of point S1 so that more pollutants are abated (i.e., So V instead of SOS1) and thereby higher environmental quality is obtained. The result is specifically clear. Transaction costs raise the price of the right to pollute for the firm, so that the firm has an incentive to abate more. Note that the curve YT2 in the figure shows the net benefit for the pollutee.

**Case II:** If the environment is owned by the polluter, the pollutee’s upper limit to compensate the polluter is the prevented damage (OD). But the pollutee will also have to carry the marginal costs of transactions so that he can only offer compensation to the polluter consisting of the marginal prevented damages minus the transaction costs. The bargaining curve of the pollute shifts downwards from OD to ZT1. This implies, there is reduced incentive to abate pollutants because the polluter receives a smaller transfer payment. Instead of SOS1, only SOR pollutants will be abated. The environmental quality will be lower.

When transaction costs exist, the environmental quality reached in a bargaining process varies with the institutional arrangement of property rights. The Coase theorem no longer holds.

The Coase Theorem has been criticized by economists on several grounds, including the existence of differences in bargaining positions, relevance of
transaction costs, insufficient analysis of the bargaining process and equity considerations. The crucial factor, in reality is that we have more than one person in each bargaining party. Consequently, environmental quality is a public good for the consumer with non-rivalry in use and the problem of free-rider arises. By assuming only one pollutee, the Coase Theorem has assumed away the existence of public goods.

**Pollution Fee or Tax**

Charge for the amount of waste or pollution Examples include the BTU tax that was an early casualty in the president’s budget bill. Several European nations have air and water pollution chargers; unit pricing for trash pick up, charging by the amount of trash collected (or the size of the container). The charge makes it worthwhile for a producer to cut back, right up to the point where it begins to cost more to reduce pollution than to pay the tax. A system like this also raises money for government, if it chooses, to reduce, taxes in other areas while collecting the same amount of total revenue.

**Pollution Charges**

Pollution charges are based on ‘polluter pays’ principle and it levels the economic playing field by confronting all managers with the same price of each unit of pollution generated. “The country experiences from Philippines and Colombia have shown that faced with a continuous financial outflow in the form of charges, plant managers have moved quickly to reduce pollution charges, thus giving maximum flexibility to the managers. Flexibility is an important key to effective reform, pollution charges work well because they provide economic incentives for a cleanup while affording maximum flexibility to factory managers”.
Environment Quality Standards (EQS)

An environmental quality standard states the minimum level of environmental quality that the air or water must meet. It is usually stated in specific technical terms that include both the time and the location of application. Environmental quality standard can be set according to various criteria which can be classified into three types, viz., effects on use, technical feasibility, and, economic efficiency. Effluent standard states that an individual source must take a required action to control emissions. These are of two types: a) prescriptive regulations and b) emission standards.

Prescriptive Regulation

Prescriptive regulation states that an emitting source must take a specific technical control action. The action may be the installation of control device or the use of a particular input. The regulation does not require that this action generates an emission reduction. It presumes that the required action will produce the desired level of control. One of the most common prescriptive regulations is the requirement to turn low sulfur fuels.

Emission Standards

Emission standard requires that emission of pollutants should be controlled to a specified level. In other wards emission standards states that a source can not emit more than the specified amount of waste over a certain period. The form of the specification varies. In the 1960’s it was common to specify emission standards as concentration such as parts per million. But a source could meet the standard by simply diluting the effluent, rather than actually reducing emission quality and the measure becomes ineffective.
Economic Incentive System (EIS)

Another important approach for controlling pollution is ‘An economic incentive system’. There are two types of incentives. a) Effluent fee and b) Subsidy.

Effluent Fee

Pollution is an externality for which the emitting source does not pay. Market rarely corrects this omission of cost. Producers do not however waste resources for which they have to pay. Costs cause them to weigh their use of resource carefully. Then it follows that one solution to the pollution problem is to make the emission of pollutants costly to the source. In other words there would be a charge for emissions into the environment. Such a charge is referred to as effluent fee. Effluent fee will cut the excess output because it increases the price of the commodity produced.

Subsidy

Under a subsidy system each source is paid for each unit of pollution, it does not release. A subsidy will have an effect on a firm’s output decisions that is somewhat different from what an effluent fee has. Rather than increasing production costs as does an effluent fee the subsidy reduces production cost. The initial impact is to generate profit. The existence of profit includes other firm’s to enter the industry. The new entrants increase supply causing price for final goods to decline. This is also another fiscal tool adopted to abate pollution.

Property Right

Coase’s theorem suggests the assigning of property right as a solution for pollution problem. If property right is to be given, adjustment will be brought out between polluter and pollute. Since environment is a public good, allocation
of property right is impossible. Adoption of fiscal instruments can to some extent solve this problem of pollution.

**Motivation**

Voluntary agencies are playing a significant role in creating environmental awareness among the people. In a peaceful manner they solve the problem of pollution by educating the people about the evil effects of pollution. They clean up the environment and also make the people keep the environment unpolluted. This motivation encourages actions that help conservation and preservation of environmental resources that are possible and feasible. By improving the quality of the environment, this way, the world will be a better place to live for living organisms, especially human being.

**Accounting for the Environment**

The conventional system of national accounts based upon the System of National Accounts (SNA) designed by the United Nation’s complete indicator of a country’s economic performance. Defined as the total monetary value of all finished goods and service in an economy, in one year. GNP is the basis upon which countries are ranked from rich to poor. It is regarded as an indicator of the health of an economy—a rising GNP indicating that the country’s health GNP’s popularity as an economic indicator continued unchallenged so long as the environmental side effects of production and consumption activities were negligible and insignificant. But today economic activities result in significant damages to environment, which impose considerable costs on existing as well as on future generation. The particular way we measure GNP and GDP and other measure based on GNP or GDP fails to consider many issues that are very important for accurate economic assessments and valid policy making. In its annual report on world development indicators, the World Bank observes;
A country’s economic book keeping consists of income accounts and capital accounts. While income accounts produce the GNP figure, capital accounts track changes in wealth. As lumber factories, textile mills, office buildings and other artifacts become old and fall into disrepair, a subtraction is made from the capital accounts to reflect their depreciation in value. However no similar subtraction is made for the deterioration of forests, soils, air quality and other natural endowments. When trees are cut and sold for timbers, the revenue form it is counted as income and reflected in GNP. But no deduction is made for the deterioration of the forest destruction of a natural asset. This will give an inflated figure of income and wealth. The country with such inflated levels of GNP will be considered better off than it really is and will be ranked higher on performance scale. In the words of Robert Repelto of the World Resource Institute, this failure to account for natural resource destruction that occurs in the process of income generation makes GNP,

“a false beacon and can draw those who steer by it onto the rocks”.

Such omissions will make the country an ecological bankrupt, even though its GNP is increasing.

Environmentalists argue for three kinds of adjustments to nation income to reflect the impact of income generation activities on environment. These are, as noted already, adjustments for depletion of natural capital, adjustment for environmental degradation and adjustment for defensive expenditure.

Adjustment for depletion of natural capital requires that stocks of natural resources such as oil and gas reserves, stock of fish, forests etc. should be treated in the same way as stock of manmade capital. Therefore a reduction should be made for the depletion of natural capital. Under the conventional system, NNP would be defined as:

\[ \text{NNP} = \text{GNP} - D_M \]

where ‘\( D_M \)’ is depreciation of manmade capital. If accounting is attempted for depletion for natural capital,

\[ \text{NNP} = \text{GNP} - D_M - D_N \]
where $D_N$ is depletion of natural capital. There are two ways of calculating $D_N$:

1. Depreciation Method.
2. User cost method.

In the depreciation method, depletion is valued as that part of receipts from the sales of resource which can be uniquely attributed to that resource. Assuming zero extraction costs, whole receipts $R$, would be attributed to depletion of the resource. Hence environmentally adjusted GNP, referred to as ENP, and would be:

$$ENP = GNP - D_M - R$$

<table>
<thead>
<tr>
<th>Items</th>
<th>Change During (1980-90)</th>
<th>Annual GDP Growth Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damage to health and ecology due to air pollution</td>
<td>- 45,299</td>
<td></td>
</tr>
<tr>
<td>Water environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground water mining</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; Quantitative decline</td>
<td>- 96,900</td>
<td></td>
</tr>
<tr>
<td>&gt; Qualitative degradation</td>
<td>-24,985</td>
<td></td>
</tr>
<tr>
<td>Surface water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; pollution avoidance cost</td>
<td>-1,014</td>
<td></td>
</tr>
<tr>
<td>Land degradation</td>
<td>-138,750</td>
<td></td>
</tr>
<tr>
<td>Productivity loss due to land degradation</td>
<td>-24,000</td>
<td></td>
</tr>
<tr>
<td>Land rejuvenation cost</td>
<td>-2,704</td>
<td></td>
</tr>
<tr>
<td>Forest cover decline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of serves/value</td>
<td>-131,298</td>
<td></td>
</tr>
<tr>
<td>Total environment and ecological damage</td>
<td>-333,652</td>
<td></td>
</tr>
<tr>
<td>Adjusted GDP growth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source: National Environmental Engineering Research Institute, Nagpur.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Recycling

Recycling is the most popular method practiced today for conserving resources. Recycling simply means extending the life of a resource. It is the re-use of a given input or output. For example, from the effluents of distilleries manufacturing alcohol, methane is separated by a chemical process which is then recycled in the production process as fuel for boiler. The residual liquid of the effluent after separation of methane contains nitrogen, phosphate and potassium and is canalized in cane fields and has resulted in considerable increases in cane yield. Empirical evidence suggests that recovering and re-using industrial wastes is both technically feasible and economically attractive. A profit seeking company, however, will recycle a product only when its cost is lower than the use of the virgin material and this cost differential should be neither transitory nor cyclical. There are social costs and benefits associated with recycling, which private firms may not consider. The benefits of recycling essentially arise from the extension in the life of the recycled resource, the reduced pollution impact and the reduced demand for land for dumping. However, recycling is not a costless exercise. Hence, optimal level of recycling is said to be at the point at which extra costs of recycling outweighs extra benefits.

Optimum Recycling

From the point of view of the private firm, the total cost has to be minimized, i.e., minimize,

\[ C = TC_V + TC_R \]

Where TCv and TCR are total costs of virgin and recycled resources respectively, used in the production of X.

Total cost is minimized when,

\[ MC_V = MC_R \]

From the social point of view, the objective into minimize,

\[ S = TC_V + TC_R + TEC_R \]

Where TECV and TECR are total external costs of pollution from using virgin materials and recycling process respectively.
This simplified model is illustrated in the horizontal axis shows recycling ratio. When \( r = 1 \), there is complete recycling. When \( r = 0 \), production is by original material only. \( \text{TC}_R \) will rise as \( r \) approaches 1. \( \text{TC}_V = 0 \), when \( r = 1 \) and \( \text{TC}_V \) will be positive \( r = 0 \). \( \text{TC}_V \) will decrease with increase in recycling activities while \( \text{TEC}_R \) will rise with increase in recycling activities. Minimizing total social cost implies maximizing net social benefits. Gross social benefits are shown in the figure as the straight line \( bb_1 \), because they are assumed to be invariant with recycling ratio. Net social benefits are obviously the distance between total social cost curve and \( bb_1 \) line.

Total social cost is the sum of \( \text{TC}_V \), \( \text{TC}_R \), \( \text{TEC}_V \) and \( \text{TEC}_R \). Thus at \( E \) where, total social costs are minimum, net social benefits are maximum. This is the socially optimum recycling level \( R_{SOS} \). It is to the right of private optimum recycling level \( R_{PRIV} \). This implies that more recycling is socially desirable than what the private firms are willing to do. Such a difference between socially optimum recycling and private optimum recycling (\( R_{SOS} > R_{PRIV} \)) calls for fiscal intervention like a tax or subsidy to achieve the socially optimum level. However, it should be mentioned that the \( Y_{SOS} \) can be to the left to \( R_{PRIV} \) also. (i.e., \( R_{SOS} < R_{PRIV} \)). This implies that the level of recycling should be reduced. This may be because the pollution from recycling is a greater problem than the problem of disposal of waste from virgin resources.
Marketability of industrial wastes is also suggested as an alternative for recycling. The recycled wastes of an industry may find a market as an input in another industry. A number of companies are today re-using their wastes in their own production process after treating them or they are marketing them. The Union Carbide in the USA, for example has been marketing some of its wastes since 1970s. The sugar industry today has found a permanent market for its by-product bagasse in the paper manufacturing industry. This strategy of marketing the wastes can be compared to the market solution to externality problem, in which firms exploit the possibilities of earnings revenue while accounting for its external costs.

There are a number of other measures which supplement those already mentioned. Developing and using products requiring less material per unit of product (like smaller automobiles), substituting re-usable products for single use disposable products, increasing the number of units of products times the items are re-used and reducing the number of units of products consumed per household are some of the measures in practice.

Conservation of renewable resources like forests, fisheries etc. require a careful and well designed Government policy. Appropriate land use policy measure, a good forest policy and efficient use of alternative energy sources can to a great extent ameliorate misuse of renewable resources. What is required is a holistic approach to resource management. Renewable resources are mixed together. Land that grows trees for timber also provides habitat for wild life besides storing and filtering water. It may also contain deposits of precious metals. Hence resources cannot be managed with blinders; the damage inflicted on a resource has devastating effect on one or few more resources. Hence we need an integrated and holistic approach. When it comes to resources, we must consider them all together. Only an integrated and holistic approach will lead to optimal use of resources.
CONCEPT OF SOLID WASTE MANAGEMENT

According to the Department of the Environment (DoE, 1990; DETR, 2000), “waste is any substance which constitute scrap material or an effluent or other unwanted surplus substance arising from the application of a process, or any substance or article which requires to be disposed of as being broken, worn out, contaminated or otherwise spoiled”. On the other hand, Igoni et al., (2007) viewed waste as, “any material which has no value to the producer and must therefore be disposed of”. The basic point of agreement between the two definitions is therefore on the issue of value; they both agree this must be defined by the owner or producer of the waste. For the purposes of this investigation however, the definition by the EU Framework Directive on Waste (91/156/EEC) has been adopted.

Waste UNEP defined wastes as substances or objects, which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law. Waste also refers to (Mugambwa, 2009:1), “an item, material or substance you as an individual consider useless at a given time and place”. Waste is a dynamic concept which can be defined in different ways (Pongrácz, 2009:93). (Pongrácz, 2009:93) introduces an innovative description of waste in what she refers to as “object-oriented modeling language, PSSP. PSSP stands for purpose, structure, state and performance, which are object attributes”. In most cases, the definition of waste depends on the type or category of waste under consideration. Some of the dominant types of waste include; municipal waste, solid waste, hazardous waste and, electronic waste. I will define municipal and solid waste, which are relevant to this study.

Waste Management (Rao K. J 2004) is the collection, transport, processing, recycling or disposal and monitoring of waste materials. The term usually relates to materials produced by human activity, and is generally
undertaken to reduce their effect on health, the environment or aesthetics. Waste management is also carried out to recover resources from it. Waste management can involve solid, liquid, gaseous or radioactive substances, with different methods and fields of expertise for each.

(Solid) Waste Management (Mugambwa, 2009) refers to the “collection, transportation, processing, recycling or disposal of waste materials”.

Waste Management Practices (Ahsan 1998) differ for developed and developing nations, for urban and rural areas, and for residential and industrial producers. Management for nonhazardous waste residential and institutional waste in metropolitan areas is usually the responsibility of local government authorities, while management for non-hazardous commercial and industrial waste is usually the responsibility of the generator.

Solid wastes [Laurent Hodges, 1979] includes garbage [decomposable wastes], paper, wood, glass, ashes, demolition rubble, junked appliances and automobiles, items discarded by modern society.

Solid wastes [S.K. Shukla, P.R. Srivastava, 1992] are sometimes referred to as “the third pollution”. In some ways the problems of dealing with solid wastes are easier than are those for air and water pollution.

Solid Waste Debate on what constitutes waste is still ongoing within the research community (Read, 2001). Contemporary definitions of solid waste are converging on the essential ingredients of the definition i.e. origin or sources of the material, characteristics and potential to cause harm to the environment.

Solid waste [SC. Bhatia, 2003] is the term now used the world over to describe all non-liquid waste materials arising from domestic, trade, commercial,
industrial, agricultural, and mining activities, as also from public services. The term ‘refuse’ is often used interchangeably with ‘solid waste’.

**Solid waste** *(Zerboc 2003)* is broadly comprised of non-hazardous domestic, commercial and industrial refuse including household organic waste, hospital and institutional garbage, street sweepings, and construction wastes. Domestic solid waste includes all solid wastes generated in the community and generally includes food scraps, containers and packaging, discarded durable and non-durable goods, yard trimmings, miscellaneous inorganic debris, including household hazardous wastes (for instance insecticides, pesticides, batteries, left over paints etc., and often, construction and demolition debris.

**Solid wastes** *(Gilbert M. Masters, 2004)* are wastes that are not liquid or gaseous, such as durable goods, nondurable goods, containers and packaging, food scraps, yard trimmings, and miscellaneous inorganic wastes. Solid waste is more or less synonymous with the term refuse, but solid waste is the preferred term.

**Solid Waste**, also known as garbage is not very different from municipal waste. This study takes on the definition by the **State of the Environment Report for Uganda** *(NEMA, 2007)* that defines solid waste as “organic and inorganic waste materials produced by households, commercial, institutional and industrial activities that have lost value in the sight of the initial user”. I found it prudent to adopt a definition and meaning of solid waste that is in the context of the area of study.

**Solid wastes** *(Gerard kiely, 2006)* are defined as those wastes from human and animal activities. In the domestic environment the solid wastes include paper, plastics, food wastes, ash, etc.
Municipal waste Cointreau-Levine and Coad (2000) take municipal waste to refer “to wastes from domestic, commercial, institutional, municipal and industrial sources, but excluding excreta, except when it is mixed with solid waste”.

Municipal solid waste consists of household waste, contraction and demolition debris, sanitation residue, and waste from streets. This garbage is generated mainly from residential and commercial complexes.

Article 2(b) of the European Union Landfill Directive (EU Landfill Directive, 1999) broadened the definition further by defining MSW as waste arising from households as well as other wastes, which because of their nature and composition are similar to waste from households (EEA, 2003).

This implies MSW (Ezeah, 2006), that may often include biodegradable components such as paper, wood, textiles, food and garden waste, as well as non-degradable fractions such as glass, plastics, tyres and bottles. The various sources of these wastes in any community may include: residential houses, institutions, commercial organizations, municipal services, allotments and treatment sites (Ezeah, 2006).

In essence, MSW (Tchobanoglous et al., 1993) would normally include all wastes from the neighbourhood except industrial, agricultural and hazardous wastes.

Municipal Solid Waste (Read, 1999), has been defined as household waste and any other waste collected by a Waste Collection Authority (WCA) or its agents, including waste from parks, beaches, commercial establishments, offices, industries and fly tipping.
Municipal Solid Waste (MSW) [Gilbert M. Masters, 2004] is solid waste from residential, commercial, institutional, and industrial sources, but it does not include such things as construction waste, automobile bodies, municipal sludge’s, combustion ash, and industrial process wastes even though those wastes might also be disposed of the municipal waste landfills or incinerators.

Municipal Solid Waste [Gerard kiely, 2006] is all waste collected by private or public authorities from domestic, commercial and some industrial (non-hazardous) sources.

Other experts insist that MSW include (Cointreau, 1982; Igoni et al., 2007) all non-air and sewage emissions created within and collected by private as well as public authorities in any municipality from domestic, commercial and industrial (non-hazardous) sources.

1. Residential: (Chakrabarti and Sarkhel 2003). Includes waste generated in household units, such as food and fruit peels, rubbish, ashes etc.

2. Industrial: Has two components hazardous, which is toxic; corrosive; flammable; a strong sensitizer or irritant and may pose a substantial present or potential danger to human health or the environment when improperly processed, stored, transported, or disposed of or otherwise managed. Non-hazardous which includes inert and essentially insoluble industrial solid waste, usually including, but not limited to, materials such as rock, brick, glass, dirt, and certain plastics and rubber, etc., that are not readily decomposable

3. Commercial: Waste produced by wholesale, retail or service establishments, such as restaurants, stores, markets, theaters, hotels and warehouses.
4. **Institutional:** Waste that originates in schools, hospitals, research institutions and public buildings.

5. **Construction and demolition:** Waste building material and rubble resulting from construction, remodeling, repair, and demolition operations on houses, commercial buildings, pavements and other structures.

6. **Municipal services:** Sludge from a sewage treatment plant which has been digested and dewatered and does not require liquid handling equipment etc.

7. **Process:** Treatment plant wastes principally composed of residual sludge and

8. **Agricultural:** Spoiled food wastes, agricultural wastes, rubbish, hazardous wastes.

   **Garbage,** or **Food Waste,** [Gilbert M. Masters, 2004] is the animal and vegetable residue resulting from the preparation, cooking, and serving of food. This waste is largely putrescible organic matter and moisture. Home kitchens, restaurants, and markets are sources of garbage, but the term usually does not include wastes from large food processing facilities such as canneries, packing plants, and slaughterhouses.

   “**Garbage** (Baljeet 2001) that is not produced does not have to be collected” is a simple enough concept.

   **Rubbish** [Gilbert M. Masters, 2004] consists of old tin cans, newspaper, tires, packaging materials, bottles, yard trimmings, plastics, and so forth. Both combustible and noncombustible solid wastes are included, but rubbish does not include garbage.
Generation [Gilbert M. Masters, 2004] refers to the amounts of materials and products that enter the waste stream. Activities that reduce the amount or toxicity of wastes before they enter the municipal waste system, such as reusing refillable glass bottles or reusing plastic bags, are not included.

Waste Generation [Gilbert M. Masters, 2004] Waste generation encompasses those activities in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal. From the standpoint of economics, the best place to sort waste materials for recovery is at the source of generation.

Materials recovery [Gilbert M. Masters, 2004] is the term used to cover the removal of materials from the waste stream for purposes of recycling or composting.

Discards [Gilbert M. Masters, 2004] are the solid waste remaining after materials are removed for recycling or composting. These are the materials that are burned or buried. In other words,

\[
\text{Waste generation} = \text{Materials recovered} + \text{Discards}.
\]

Biodegradable wastes [SC. Bhatia, 2003] Biodegradable wastes are generated in fruit processing industries, slaughter houses, cotton grinning [separation of cotton from seeds], textile mills, etc. Most of the wastes from these industries are reused; those which cannot be reused; those need to be processed as they are putrescible. Some of the wastes are amenable to composting, while others can also be paralyzed to produce char.

Non-Biodegradable waste [SC. Bhatia, 2003] Coal, stone, timber, metal scraps, sludge, etc., are the inert waste generated from colliery operations.
Refineries produce inert dry solids, combustible dry solids and varieties of sludge containing oil. Fly ash is the major solid waste from thermal power plants. Depending upon the activities, steel plants produce blast furnace slag, blast furnace flue dust, mill scale, etc. the problem of each plan should be considered separately; most of the wastes normally can be recycled or reused. The wastes not suitable for reuse or recycled are often found to be suitable for land filling.

Sanitary landfill (Mato, 1999) is a waste disposal method in which waste is disposed off on land which involves planning and application of sound engineering principles and construction techniques. The waste is spread in thin layers, with its volume compacted and there is provision of daily cover to protect the environment. With the cover and engineering principles, waste is deposited without creating nuisances or hazards to public health and contamination of ground or surface water (Cointreau, 1982).

Composting (S.K. Shukla 1992) Due to shortage of space for landfill in bigger cities, the biodegradable yard waste (kept separate from the municipal waste) is allowed to degrade or decompose in an oxygen rich medium. A good quality nutrient rich and environmental friendly manure is formed which improves the soil conditions and fertility.

Composting [Gilbert M. Masters, 2004] is the term used to describe the aerobic degradation of organic materials under controlled conditions, yielding a marketable soil amendment or mulch.

Recycling [Gilbert M. Masters, 2004] the term recycling is often misconstrued to include activities such as refilling bottles for reuse and remanufacturing products for resale to consumers, but it is better to use the term
recycling only when materials are collected and used as raw material for new products. The process of recycling includes collecting recyclables, separating them by type, processing them into new forms that are sold to manufacturers, and finally, purchasing and using goods made with reprocessed materials.

**Recycling plastics** [Gilbert M. Masters, 2004] the term plastics encompass a wide variety of resins or polymers with different characteristics and uses. Plastics are produced by converting basic hydro carbon building blocks such as methane and ethane into long chains of repeating molecules called polymers such as cellulose, starch, and natural rubbers, it is only the synthetic materials that are referred to as plastics.

**Integrated Solid Waste Management** [Gerard Kiely, 2006] is defined as the selection and application of suitable techniques, technologies and management programmes to achieve specific waste management objectives and goals.

**Sustainable development** has been defined by the **World Tourism Organization** (1994) as: “[meeting] the needs of present tourists and host regions while protecting and enhancing opportunity for the future. It is envisaged as leading to management of all resources in such a way that economic, social, and aesthetic needs can be fulfilled while maintaining cultural integrity, essential ecological processes, biological diversity, and life support systems”.

**Sustainable development** has been described by World Commission on Environment and Development (WCED) 1997 as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.
Part II
RELATED STUDIES AND RELATED LITERATURE
STUDIES

Tchobanoglous, G., H. Theisen and S. Vigil (1993) has defined topics covered include: the evolution of solid waste management; legislative trends and impacts; sources, types, composition and properties of municipal solid wastes; sources, types and properties of hazardous wastes found in municipal solid waste; engineering principles of solid waste generation, collection, separation, storage, transport, processing and transformation both at the source and off-site; disposal of solid wastes and residual matter (landfills, landfill leachates and landfill gases); separation, transformation and recycling of waste materials, including biological conversion technologies; closure, restoration and rehabilitation of landfills; and solid waste management and planning issues.

Miller (1993) has defined the National Solid Wastes Management Association also sponsored a study on the cost of materials recovery facilities. The analysis is based on a study of 10 actual MRFs, with throughputs ranging from 90 to 275 tonnes/day (100 to 300 tons/day), that process papers and commingled, recyclable containers. The study looked only at processing costs-revenues from the sale of recycled materials, avoided costs of disposal, and collection costs were not included. According to the study, the cost of processing a tone of recyclable materials at an MRF ranges from $31 to $80 per tone ($28 to $72/tone), with an average cost of $55/tone ($50/ton). If the recyclables are not commingled, then the recovery facility merely consolidated incoming materials that have already been separated and costs are closer to $5 to $15 per tone.
Michael Yhdego (1994) he said urban solid waste in Tanzania in general and in Dar es Salaam city in particular, is a serious environmental problem. Concurrent with recent socioeconomic development, coupled with liberalization of the economy and rapid population growth, the quantum of solid waste generated has increased at a rapid rate. The manner in which urban solid waste is managed in Dar es Salaam directly affects the metropolitan environment, the appearance of the city and the citizens day-to-day life. Hence, a special priority is attached to Dar es Salaam's solid waste management. The existing critical dimensions in the management of solid waste are scavenging, privatization, arresting environmental effects of waste disposal and institutional capacity building. A conceptual framework based on application of sustainability to waste prevention, utilization and recycling for urban solid waste management is proposed. The most appropriate waste management principles seem to be organized scavenging, followed by biological waste utilization and sanitary landfilling. The paper suggests several urban solid waste management challenges based on issues and principles analyzed and discussed.

Beede, D. N. and D. E. Bloom (1995), has defined the generation and management of municipal solid waste through the lens of economics. The authors estimate that the global burden of municipal solid waste amounted to 1.3 billion metric tons in 1990, or two-thirds of a kilogram of waste per person per day. Industrial countries account for a is proportionately high share of the world's waste relative to their share of world population, while developing countries account for a disproportionately high share of the world's waste relative to their share of world income. Analyses across countries and over time reveal that the generation of municipal solid waste is positively related to variations in per capita income and that the generation of municipal solid waste per capita does not vary with population size among countries with comparable per capita income.
**Fullerton, D. and T. C. Kinnaman (1996),** have said Employs individual household data to estimate the effect of per bag pricing of garbage on the garbage's weight in Charlottesville, Virginia. Inelasticity of garbage weight to price; Garbage volume's response to the scheme; Demographic considerations; indirect measures of the increase in illegal dumping; Pros and cons of collecting revenue from unit pricing.

**Kinnaman, T. C., D. Fullerton (1997),** this study defined the impact of a user fee and a curbside recycling program on garbage and recycling amounts, allowing for the possibility of endogenous policy choices. Previous estimates of the effects of these policies could be biased if unobserved variables such as local preference for the environment jointly impact the probability of implementing these policies and the levels of garbage and recycling collected in the community. A simple sequential model of local policymaking is estimated using original data gathered from a large cross-section of communities with user fees, combined with an even larger cross-section of towns without user fees but with and without curbside recycling programs. The combined data set is larger and more comprehensive than any used in previous studies. Without correction for endogenous policy, the price per unit of garbage collection has a negative effect on garbage and a positive cross-price effect on recycling. When we correct for endogenous policy, then the effect of the user fee on garbage increases, and the significance of the cross-price effect on recycling disappears.

**Gupta, S., K. Mohan, R. Prasad and A. Kansal (1998),** has defined in India, the collection, transportation and disposal of MSW are unscientific and chaotic. Uncontrolled dumping of wastes on outskirts of towns and cities has created overflowing landfills, which are not only impossible to reclaim because of the haphazard manner of dumping, but also have serious environmental implications in terms of ground water pollution and contribution to global
warming. Burning of waste leads to air pollution in terms of increased TSP and PM10 emissions, which is equivalent to vehicular emissions at times. In the absence of waste segregation practices, recycling has remained to be an informal sector working on outdated technology, but nevertheless thriving owing to waste material availability and market demand of cheaper recycled products. Paper and plastic recycling have been especially growing due to continuously increasing consumption levels of both the commodities. Composting-aerobic and anaerobic, both the options are available to the country for scientific disposal of waste in future. However, country also needs something in terms of policy and guidelines to enable the municipal corporations to run the waste services efficiently.

Agunwamba, J.C. (1998), has defined the problems of solid waste management in Nigeria and the important issues that must be addressed to achieve success. At the core of the problems of solid waste management are the absence of adequate policies, enabling legislation, and an environmentally stimulated and enlightened public. Government policies on the environment are piecemeal where they exist and are poorly implemented. Public enlightenment programmes lacked the needed coverage, intensity, and continuity to correct the apathetic public attitude towards the environment. Up to now the activities of the state environmental agencies have been hampered by poor funding, inadequate facilities and human resources, inappropriate technology, and an inequitable taxation system. Successful solid waste management in Nigeria will require a holistic program that will integrate all the technical, economic, social, cultural, and psychological factors that are often ignored in solid waste programs.

Kansal, A., R. K. Prasad and S. Gupta (1998), this study defined poor solid waste management has serious implications on environment, society and economy. This paper assesses the impacts associated with the present system of solid waste management in Delhi on environment and community health.
Turner, R.K., R. Salmons, and A. Craighill (1998), has defined interest among policymakers has recently focused on the role, efficiency and effectiveness of so-called green taxes. This paper surveys recent developments in the context of waste management policy and the emergence of resources such as recycling credits and the landfill tax. It is concluded that there is an important role that economic instruments can play in this policy area. The inherent efficiency gains that economic instruments will provide should be highlighted and advocated. The application of such instruments in the current political economy settings will however serve to reduce such efficiency gains, as multiple and conflicting policy objectives are introduced by the political process.

Trucker, P., D. Speirs and D. Smith (2000) have said the research monitors the changes in recycling performance indicators arising from halving the collection frequency of a kerbside newspaper collection scheme. The changes in the performance parameters are explained in terms of the underlying behavioural changes that could have occurred within the community. This interpretation is aided by a computer simulation of the kerbside recycling activity of the community. Moving from a 2-week collection to a 4-week collection did not substantially affect the number of households recycling, nor the overall weights collected. A small weight loss, however, may have occurred, from a small minority of households, unable to accommodate the extra storage demand of the new regime. Model predictions were consistent with the observed performance data. It is postulated that the scheme could withstand considerable intervention before significant behavioural changes are induced. It demonstrates that cost-cutting interventions can be undertaken without significantly compromising individual participations. The case-study also highlights the caution needed in the interpretation of the recycling performance indicators themselves.
Folorunso and Awosika (2001) has defined, related flooding in Lagos to clogging of drainage channels by dumped solid wastes. There is abundant release of gaseous toxic substances into Nigerian environment as well as jeopardizing of health of scavengers as a result of burning of obsolete e-wastes. Due to contact with smokes from burning of solid wastes and gaseous emission from dumpsites, cases of several diseases have been recorded (Oyelola et al., 2009).

Keith A. Weitz (2002) has defined Solid waste management deals with the way resources are used as well as with end-of-life deposition of materials in the waste stream. Often complex decisions are made regarding ways to collect, recycle, transport, and dispose of municipal solid waste (MSW) that affect cost and environmental releases. Prior to 1970, sanitary landfills were very rare. Wastes were “dumped” and organic materials in the dumps were burned to reduce volume. Waste incinerators with no pollution controls were common. Today, solid waste management involves technologies that are more energy efficient and protective of human health and the environment. These technological changes and improvements are the result of decisions made by local communities and can impact residents directly. Selection of collection, transportation, recycling, treatment, and disposal systems can determine the number of recycling bins needed, the day people must place their garbage at the curb, the truck routes through residential streets, and the cost of waste services to households. Thus, MSW management can be a significant issue for municipalities.

Maria Zannes (2002) her study in 1974, ~24 million metric tons of MSW, representing ~21% of U.S. MSW, was managed in combustion units without energy recovery. This technology was a net generator of GHG emissions. By 1997, ~33 million metric tons of MSW, representing ~17% of U.S. MSW, was managed by MSW combustion. This resulted in avoiding the release
of ~5.5 MMTCE of GHG emissions annually, as compared to GHG emissions if 1974 combustion technology was still employed. The GHG emissions from combustion facilities were based on emission test results provided to EPA and state environmental agencies.

Jurczak G. M. (2003) has defined, in recent years a significant increase in municipal solid waste (MSW) amount has been noted in Poland, and yet there is no fully efficient system for its treatment. Undertaking projects for rational MSW management requires considering both technical facilities and social barriers (waste reduction, re-use and segregation in households). In Poland, attempts to educate and mobilize society to segregate recyclables have not yet produced satisfactory results. Society's awareness in this field needs to be raised. The purpose of this study was to determine the level of knowledge and understanding about MSW management and the relationship between knowledge possessed and actions undertaken for various residential age groups in two Polish provinces. In all groups, 30% of the respondents showed a satisfactory level of knowledge, whilst an equally small number of individuals had undertaken actions for MSW management at home; people with a higher level of knowledge undertook such actions slightly more often. No significant differences between the provinces were found, but residents of town, where waste segregation has been introduced simultaneously with an information campaign, showed a higher level of knowledge. The study points to the need to further educate people about MSW, and to encourage the teaching of pro-environmental attitudes.

Kumar, S., V. Gawaikar, S. A. Gaikwad and S. Mukherjee (2004), has defined the advantages and disadvantages of alternatives for urban solid waste management are discussed. Landfill is considered to be a suitable and simple technology for tropical countries such as India. The recovery and reuse of landfill gas generated in MSW landfills is economically viable in most situations. A case
study of cost-benefit analysis of landfill system with gas recovery option has been carried out for Port Blair City, Andaman Islands, and India. A saying of about Rs 0.09 billion per annum with reference to existing system of MSW disposal is evaluated.

Horen, B. V. (2004) has said, not with standing the increasingly fragmented organizational relationships within Colombo's urban governance system, the cooperative nature of stakeholder relationships lends a high level of coherence to the overall system. Since 1995, Colombo's solid waste management system has been characterized by the increased role of the private sector, community-based organizations and NGOs. Whilst the increasingly fragmented nature of this system exhibits some deeply ingrained problems, there are also a number of positives associated with the increased role of civil society actors and, in particular, the informal sector. Reforming regulatory frameworks so as to integrate some of the social norms that are integral to the lives of the majority of urban residents will contribute to regulatory frameworks being considerably more enforceable than is currently the case. Such reform requires that institutional and regulatory frameworks need to be flexible enough to adapt to the changing social, political and economic context. In the Colombo case, effective cooperation between public sector and civil society stakeholders illustrates that adaptive institutional arrangements grounded in pragmatism are feasible. The challenge that arises is to translate these institutional arrangements into adaptive regulatory frameworks—something that would require a significant mind shift on the part of planners and urban managers.

Kandil, S. H., H. A. Bakr and L. Mortensen (2004) has defined, this case study is a presentation of systematic development of an awareness and communication multimedia package in solid waste management that was produced for Egyptian technical secondary schools. Representative teachers were
very much involved in the design and pretesting of the technical content of the package. They even suggested and influenced the format of the produced materials. The awareness and education materials, to be included in the package, were classified into four main sections: Environmental concepts: basic definitions, environmental spheres, identification of the environmental systems, Environmental issues: international, national, and local, solid waste management: sources of waste, life cycle analysis, recycling, technological aspects, environmental auditing, legislation for solid waste management, and Case studies: including specific success stories on solid waste management in various parts of Egypt. The threading skeleton of this package was a set of 25 extra-curricula activities. These were specially designed to help clarify the environmental concepts, convey the messages for the environmental protection, and identify the required attitudes to help sustainable development. The multimedia package is composed of an activity book equipped by concept papers and fact sheets, a set of transparencies for overhead projector (or power point illustrations), a video film that stresses the economic and environmental benefits of recycling, and a compact disc that contains all the components of the package. It is interesting to note that while developing this package with the technical help of the Academy of Educational Development, the basic criteria for excellence in environmental education and communication were fully observed. The feedback from the pilot schools was collected to monitor the implementation and impact of this package. The package was adopted by the Ministry of Education and was distributed to technical secondary schools in Egypt.

**Tongleta, M., P. S. Phillips and M. P. Batesb (2004)** has defined, New mandatory household recycling targets present a serious challenge to UK Local Authorities. Public participation in Local Authority schemes is key to increasing household recycling levels; however, the most effective way to reduce waste is to deal with it at source, through waste minimization. Understanding waste
minimization behaviour is key to achieving sustainable waste management and householder based projects which are theoretically underpinned by cognitive psychology and are promoted by carefully designed marketing/communications, over the long-term, should result in reductions in Municipal Solid Waste (MSW). Cognitive psychological modeling can provide the means to identify the driving forces behind recycling and waste minimization behaviors and in a given area determine the main likely success factors. Once these factors have been established, cost-effective campaigns can be designed to maximize the outcome. The Theory of Planned Behaviour provides a cognitive framework to understand and explain behavior, and its use in this study has provided valuable insights into the factors which underpin recycling behaviour. The findings suggest that recycling attitudes are the major determinant of recycling behaviour, and that these attitudes are influenced firstly, by having the appropriate opportunities, facilities and knowledge to recycle, and secondly, by not being deterred by the issues of physically recycling (e.g. time, space and inconvenience). Previous recycling experience, and a concern for the community and the consequences of recycling, is also significant predictors of recycling behaviour. The findings also provide support for the proposition that recycling; waste minimization through point of purchase and waste minimization through repair or re-use represent different dimensions of waste management behaviour, and thus will require different strategies and messages. It is suggested that waste minimization behaviour is likely to be influenced by a concern for the environment and the community, and is likely to be inhibited by perceptions of inconvenience and lack of time and knowledge.

Eriksson, O. (2004) has said different waste treatment options for municipal solid waste have been studied in a systems analysis. Different combinations of incineration, materials recycling of separated plastic and cardboard containers, and biological treatment (anaerobic digestion and
composting) of biodegradable waste, were studied and compared to landfilling. The evaluation covered use of energy resources, environmental impact and financial and environmental costs. In the study, a calculation model (Orware) based on methodology from life cycle assessment (LCA) was used. Case studies were performed in three Swedish municipalities: Uppsala, Stockholm, and Älvdalen. The study shows that reduced landfilling in favour of increased recycling of energy and materials lead to lower environmental impact, lower consumption of energy resources, and lower economic costs. Landfilling of energy-rich waste should be avoided as far as possible, partly because of the negative environmental impacts from landfilling, but mainly because of the low recovery of resources when landfilling. Differences between materials recycling, nutrient recycling and incineration are small but in general recycling of plastic is somewhat better than incineration and biological treatment somewhat worse. When planning waste management, it is important to know that the choice of waste treatment method affects processes outside the waste management system, such as generation of district heating, electricity, vehicle fuel, plastic, cardboard, and fertilizer.

**Braunegg, G., R. Bona, F. Schellauf and E. Wallner (2004)** have said, during the last decade plastic waste has become a major problem within the industrialized countries. Many new waste management associations have been founded, and new technologies for sorting, reutilization, and/or energy recovery from sorted or mixed plastic recycling fractions have developed. The main developments will be demonstrated based on the examples of plastic waste treatment in Austria and Germany, and an outlook for the development in Europe will be given.

**Agrawal, A., K. K. Sahu and B. D. Pandey (2004)** has defined, this paper highlights the production capacity, type and quantity of solid wastes
generated their chemical composition and treatment/disposal options for the Indian aluminium, copper lead and zinc industries. Red mud, spent pot lining (SPL), fly ash from aluminium industries; scrap, slag, dross, reverts, slime, flue dust, mill scales, sludge etc. from copper industries; zinc tailing, slag, leach residue, jarosite residue, cake, etc. from zinc industries and BF slag, flue dust, ISF slag etc. from lead industries are the major solid waste generated from the process. Common practices of waste management in these industries are through recycling and recovering the metal values and dumping. Owing to the presence of the toxic elements in some of the solid wastes cause environmental degradation. Stringent pollution control rules are being enacted and implemented as a result of which all the metal producing industries in organized sector are now taking care of the environment and waste management related problems, but pollution from unorganized lead units are the major cause of concern. Permissible limits of toxic constituents in zinc based secondaries and threshold zinc concentration for both indigenous and imported raw material were worked out at National Metallurgical Laboratory (NML) and based on these results a recommendation to MOEF, Government of India was made to specify the permissible limits for the import of zinc secondaries. An overview of the attempts made to recycle/recover metal values and production of value added products, at NML are also mentioned in the text.

Veasna, K., A. Sharp and N. Harnpornchai (2004) have said, Though the solid waste management (SWM) system in Phnom Penh city in general has been upgraded since the waste collection service was franchised out to the private sector, the performance of the existing SWM system is still low. Unreliable and irregular collection service still exists. This means that there are shortcomings in the existing SWM system that needs correction. This paper is an attempt to identify those shortcomings in order to find ways to improve the existing system. First, the present SWM system is reviewed. Then the system is
evaluated to find constraints and shortfalls and finally some appropriate strategies are proposed that may help make SWM in the city more effective and efficient to meet environmentally sound objectives.

Woodard, R., M. K. Harder and N. Stantzos (2004) have said Sixteen percent of household waste in the UK is handled at household waste recycling centres (HWRC). These facilities will play an important role if the UK is to achieve the national target of recycling 25% of household waste by 2005, as most sites now provide containers for recyclables as well as a mixed waste pile. However, few published studies have been conducted regarding the activities of HWRC site users and the composition of waste that is delivered, especially to the mixed waste pile. This paper presents the results of a site survey in Sussex, UK and discusses the role of HWRC in handling household waste. During the week of sampling 969 site users were monitored. The target group was only those depositing material on the mixed waste pile. Two main categories of waste dominated. The first, identified as garden waste, was deposited by 37% of the target group and represents approximately 20% of arisings by observed volume. The second was miscellaneous bagged waste, present in 34% of loads and equating to approximately 21% of arisings by observed volume. Despite the availability of containers for segregating recyclable and compostable materials, 29% of users deposited these onto the mixed waste pile. The site was clearly not able to operate at its optimum. The reasons for this and potential solutions are presented.

Kaseva, M. E and S. E. Mbuligwe (2005) has defined, This paper presents findings of a study, which was carried out in Dar es Salaam city to assess post-privatisation of solid waste collection and disposal. Prior to the assessment, fieldwork studies indicated that current solid waste generation rate in the city is 0.4 kg/cap/day and total waste generation is within the range of 2425
tons/day. This study also indicated that out of the total waste generated, a total of 957 tons/day is collected by the three city municipalities (231 tons/day or equivalent to 10% of the total generation), private solid waste collection contractors (592 tons/day or equivalent of 24.4%) and through recycling (134 tons/day or equivalent of 5.5%). These findings suggest that as a result of privatisation of solid waste collection activities in Dar es Salaam city, solid waste collection has improved from 10% in 1994 to 40% of the total waste generated in the city daily in 2001. The paper recommends that waste recycling and composting activities be encouraged since this approach is considered to be the right measure in attaining sustainability in waste management.

Misra, V. and S.D. Pandey (2005) has defined, Industry has become an essential part of modern society, and waste production is an inevitable outcome of the developmental activities. A material becomes waste when it is discarded without expecting to be compensated for its inherent value. These wastes may pose a potential hazard to the human health or the environment (soil, air, water) when improperly treated, stored, transported or disposed off or managed. Currently in India even though hazardous wastes, emanations and effluents are regulated, solid wastes often are disposed off indiscriminately posing health and environmental risk. In view of this, management of hazardous wastes including their disposal in environment friendly and economically viable way is very important and therefore suggestions are made for developing better strategies. Out of the various categories of the wastes, solid waste contributes a major share towards environmental degradation. The present paper outlines the nature of the wastes, waste generating industries, waste characterization, health and environmental implications of wastes management practices, steps towards planning, design and development of models for effective hazardous waste management, treatment, approaches and regulations for disposal of hazardous waste. Appraisal of the whole situation with reference to Indian scenario is
attempted so that better cost effective strategies for waste management are evolved in future.

Mongkolnchaiarunya, J. (2005) he said, Yala is a city of some 80,000 people in southern Thailand, and is well known for tidiness and clean conditions. However, it has experienced problems in waste disposal and has sought ways of addressing these through alternative techniques, including recycling. A package of new practices was introduced, one of which ("Garbage for Eggs") is described here. Residents were encouraged to bring recyclable material to exchange for eggs, at monthly exchanges in local communities, with emphasis on poorer communities. The project aimed not only at garbage reduction, but also at community empowerment through self-reliance, establishing new relationships of more equality and less dependence, between poor communities and the municipal administration. The project succeeded initially in promoting clearance of a backlog of discarded items, especially glass, thus improving the environment of the communities; but the quantities brought for exchange then reduced steadily over a year of monitoring, to much lower levels. Various factors accounting for this are discussed, and the impacts of the exchange practice on other poor groups, such as waste-buyers, are analyzed.

McBeana, E.A., E. del Rossob and F.A. Roversb (2005) has defined, Contributing elements toward the development of a sustainable solid waste management system in Tucumán, Argentina, are described. Changes in the working environment for the waste pickers have been instrumental in providing a livable wage and diminished health and environmental risks to the waste pickers and to neighboring residents. Income levels to the waste pickers are now approximately 1.75 times minimum wages in Tucumán and are being driven almost entirely by the recycling of plastics. Educational improvements in Tucumán, which are assisting sustainability of the solid waste system, are being
significantly improved by the operation of a pilot scale project, by demonstrating opportunities to government officials and school children. Improved financial sustainability to the solid waste management system is also potentially available from carbon credit trading opportunities, presenting the opportunity for 1.2 times the income available from recycling efforts.

Agarwal, A., A. Singhmar, M. Kulshrestha and A. K. Mittal (2005) has defined, Recycling of the municipal solid waste (MSW) was investigated and analyzed in the Indian capital city of Delhi. It was found that an informal sector comprising waste recyclists and a hierarchy of recyclable dealers plays an important role in the management of solid waste. The associated activity transports nearly 17% of the waste to the recycling units (RU). In this process an entire market is created for the recycle trade. The present work covered an extensive study of this waste trade with emphasis on the most important unit of the waste chain, the recyclists. Extensive interviews and surveys with recyclists from various slums helped in evaluating the market mechanisms of the recycle trade in Delhi and in revealing details of this informal sector. Through a number of field interviews undertaken on recyclists, recyclables dealers and municipal authorities, a complete hierarchy from recyclists to the final sellers of the recycled product was identified and delineated and the profits at each level determined. The value addition to each product at every level of the waste trade was also determined. Two models were subsequently proposed to evaluate the possibility of formalizing the unorganized waste trade. It was concluded that it is possible to organize the sector, but this would leave more than 66,000 recyclists without employment, a consequence of organizing an activity that presently provides employment and daily living to nearly 89,600 recyclists who belong to the poorest strata of the society. The work also probes into the various aspects of the lives of the recyclists and provides details of the economics of MS.
Srivastava, P. K., K. Kulshreshtha, C. S. Mohanty, P. Pushpangandan and A. Singh (2005) have said the present investigation is a case study of Lucknow, the main metropolis in Northern India, which succumbs to a major problem of municipal solid waste and its management. A qualitative investigation using strengths, weaknesses, opportunities and threats analysis (SWOT) has been successfully implemented through this community participation study. This qualitative investigation emphasizes the limited capabilities of the municipal corporation’s resources to provide proper facilitation of the municipal solid waste management (MSWM) services without community participation in Lucknow city. The SWOT analysis was performed to formulate strategic action plans for MSWM in order to mobilize and utilize the community resources on the one hand and municipal corporation’s resources on the other. It has allowed the introduction of a participatory approach for better collaboration between the community and Municipal Corporation in Lucknow (India). With this stakeholder-based SWOT analysis, efforts were made to explore the ways and means of converting the possible ‘threats’ into ‘opportunities’ and changing the ‘weaknesses’ into ‘strengths’ regarding a community based MSWM programme. By this investigation, concrete strategic action plans were developed for both the community and Municipal Corporation to improve MSWM in Lucknow.

Pokhrel, D. and T. Viraraghavan (2005) have said Solid waste management in Kathmandu valley of Nepal, especially concerning the siting of landfills, has been a challenge for over a decade. The current practice of the illegal dumping of solid waste on the river banks has created a serious environmental and public health problem. The focus of this study was to carry out an evaluation of solid waste management in Nepal based on published information. The data showed that 70% of the solid wastes generated in Nepal are of organic origin. As such, composting of the solid waste and using it on the
land is the best way of solid waste disposal. This will reduce the waste volume transported to the landfill and will increase its life.

**Nissim, I., T. Shohat and Y. Inbar (2005),** has defined to address the problem of solid waste in Israel, the Ministry of the Environment has formulated a policy based on integrated waste management. The policy calls for reduction of waste at source, reuse, recycling (including composting), waste-to-energy technologies, and landfilling. Due to the implementation of this policy, all the large dumps were closed, state-of the art landfills were built, and recovery rates have increased from 3% in the beginning of the 1990s to almost 20% in 2003. More than 95% of the municipal solid waste is disposed and treated in an environmentally sound manner – in comparison to a mere 10% just a decade ago. The policy was implemented utilizing both enforcement and financial support (“stick and carrot” approach).

**Chen, M. C., A. Ruijs and J. Wesseler (2005) has defined,** Municipalities of small islands have limited capacities for waste disposal. In the case of Green Island, Taiwan, continuing with business as usual would only allow the disposal of waste on the island for another 8 years. Three alternatives for solid waste management (SWM) are compared. The cost-effective solution is the one, which is the most expensive in the short run: continuing business as usual and introducing an incineration plant in the year 2010. The results indicate furthermore that deviations from optimal timing of investment only slightly change average annual costs. In the long run, the municipality can hardly avoid transporting waste to the mainland. By investing in an incineration plant, they can buy additional time to investigate alternative SWM strategies.

**Kitakyushu (2005) has defined** as a result, Nonthaburi demonstrated tangible success in improving solid waste management for these two
communities by increasing recycling rates by 22% and reducing the amount of waste sent to the landfill by 42%. Following this success, the municipality has further expanded its initiative and assisted 30 other communities to adopt similar activities on a self-sustainable basis, while also adopting comprehensive programmes to improve its solid waste policies compassing broader aspects of reduction, recycling, collection and final disposal.

G.D. Agrawal, A.P.S. Rathore and A.B. Gupta (2005) has said Indian socio-economic data and annual solid waste generation per capita data for the last 50 years are utilized for the development of a mathematical model. The model can predict yearly waste generation per capita (kg/person/yr), which plays an important role in the identification of type and estimation of suitable size for collection system, transportation system and processing equipments and also for the panning of an overall management of MSW (Municipal Solid Waste) and monitoring the performance of sub-systems of solid waste management. The proposed model is based on multiple regression analysis (MRA), where the effect of various socioeconomic parameters, like urban population, GDP, population density, literacy rate, per capita income and human development index on the rate of annual waste generation per capita have been analyzed. Based on extensive statistical analysis two linear multiple regression models, retaining urban population, GDP and human development index as independent variables have been recommended. Forecasted values of solid waste generation rate are in a good agreement with the actual values thus validating the model.

S.M. Pramanik, S.S. Ghatnekar and S.D. Ghatnekar (2005) has defined Pulp mill wastes today pose a great threat to our environment and hence it is imperative that this problem be addressed by finding economically and ecologically viable solutions. The authors have tried to explore the application of 4 types of solid wastes produced by pulp mill, as soil conditioners. The
present study was conducted to study the potential of pulp mill wastes both individually as well as in combination using state-of-the-art microbial technology. The objective was to compare the biodegradation potential of the wastes with that of standard bedding material which is used as a clean raw material to produce soil conditioners. The experimental scale was tone and the experimental time period was 45 day. The concentrations of the wastes selected or the study were 25%, 50%, 75% and 100%. Each concentration of the individual and combined wastes was mixed with standard bedding material and introduced into the experimental tanks. The mixture was then inoculated with genetically engineered BRC strains of selected microorganisms. Results indicated that 25% concentration of Bamboo dust had the highest degradation in relation to that of the ETP sludge, lime sludge and fly ash. In case of combined wastes too, the 25% concentration gave the highest total microbial count in relation to 50, 75 and 100% concentration. The experiments proved that organic wastes were easily degradable and even at 100% concentration.

**Nguyen Thi Dan (2005)** has defined the developmental level of a country is traditionally weighted by a well known economic indicator, such as GDP per capita. However, practice has shown that in aiming for high GDP growth, the issues related to human development have often been forgotten. Rapid economic growth usually results in environmental degradation due to overuse of the natural resources, heavy human migration due to job opportunity, and waste generation. Therefore, drastic changes have been made to the concept of development when it pertains to a healthy living environment, i.e. improved health, as well as educational and social status, is considered to be as important as economic growth. In addition to GDP per capita, a “Human Development Indicator” (HDI) representing morbidity, mortality, malnutrition in children, life expectancy, literacy etc., has been developed by UNDP for full consideration of the developmental level of a country.
J. Staniskis (2005) has defined no one single method of waste management can deal with all materials in waste in an environmental sustainable way. In reality any waste management is built up of many closely related processes, integrated together. Instead of focusing on and comparing individual options, for instance, incineration versus landfill, an attempt should be made to integrate waste management systems that can deal with the whole waste stream, and then compare their overall performances in environmental and economic terms. Integrated waste management approach looks at the overall environmental burdens and economic costs. Paper gives a holistic vision of waste management with the view to achieving environmental objectives using economically sustainable system principles.

Mohammad Tariq (2006) has defined Apart from Defence Colony project, Communities and Waste team of Toxics Link in partnership with Arpana Trust Delhi Services is also working in Gautampuri. Under this programme, TL is emphasising on door-to-door waste collection, segregation of waste and community based decentralised composting. After continuous efforts, the door-to-door waste collection system has been started with 1000 households out of total 2000 households in the colony. Before initiating the project, no system of waste management existed in the area and people were not aware about the segregation into dry and wet waste.

Dr V P Deshpande (2006) he said Solid waste management is a large, ongoing, vital public system spread over the entire city area and the system is responsible for maintaining the public surroundings. Hence, the system has to be planned rationally for a long and short term. Moreover, as the system handles huge quantities of solid waste, it is necessary to have detailed information on quantification and characterization of solid waste for proper handling of solid waste at different stages of the system. Presently, majority of Municipal
Corporations/ Councils do not weigh their waste but the quantities are estimated on the basis of number of trips of trucks which carry the waste to disposal site. Moreover, the solid waste management system is not planned or executed rationally due to non-availability of authentic or relevant information on waste generation. As the solid waste quantities are increasing in all cities and towns due to urbanization and industrialization, these have raised concerns about the economic viability and environmental compatibility of the current waste management methodologies.

*M. Ibrahim Bathusha and M.K. Saseetharam (2006)* has defined Urban society generates and rejects solid material regularly. The burgeoning population makes the rapid increase in production and consumption; volumes of wastes generated have increased considerably. Improper management of the solid wastes lead and led to public health hazards, environmental pollution, unaesthetic appearance, etc. Most parts of India are not efficient in handling wastes when compared to developed countries. In India, management of municipal solid waste is the last priority in municipal environment services. Hence declining quality of urban environment is a matter of concern and the importance of efficient solid waste management is to be recognized. In Coimbatore the solid waste collection is only 60% and does not follow any scientific approach in the collection, transportation, treatment and disposal. Among the various civic problems, the solid waste management has been identified as important one. It is the today’s need to develop and adopt efficient solid waste management system to overcome solid waste crisis. This paper summarizes the quantity of solid waste generated per day, present system of waste collection, vehicles used for collection and transportation, staff positions, processing and disposal methods. In order to improve the present practice an effort is made to analyze solid waste collection and transportation systems by incarnating the solid waste generation rate, sources and location, disposal sites, in order to fix optimal solid waste management strategy.
Dr. ABHILASHA SAINI & DR, AJAY SAINI (2006) has defined Environment, once the focus of geographical study has recently gained its position in earth sciences through out the entire globe. Now environmental studies are no longer confined to geography and allied disciplines, but have attracted the attention of common citizen. The theme of this year’s World Environment Day “GIVE EARTH A CHANGE” is meant to convey a message of urgency about the state of the earth and the broader quest for sustainable development. Sustainable development rests on three pillars, economic growth, social progress and protections of our environment and nature resources.

V Gawaikar (2006) he said the most important aspect of solid waste management is the quantity of waste to be managed. The quantity determines the size and number of functional units and equipments required for managing the waste. The quantities are measured in terms of weight and volume. The weight is fairly constant for a given set of discarded objects whereas volume is highly variable.

G. M. Jainal Abedin Bhuiya, Deputy Secretary Ministry of Industries (2007) has defined in the purview of management and legal aspects, the specific definition of solid waste has not been developed in Bangladesh’s solid-waste management, but broadly, all waste other than liquid and gaseous waste is considered solid waste. Four broad sources have been identified during the study of solid-waste management in Dhaka City. They are: domestic waste, commercial waste, industrial waste, and hospital waste. More than 4,000 metric tons of solid waste is produced each day in Dhaka City. This waste, when dumped with other municipal waste on the open land, poses a serious threat to the health of the city’s people. The generation details for various types of solid waste are given in the following sections.
Hsiao-Hsin Huang (2007) has defined there are more than 3 million people passing in and out of Taipei City every day. Thus a huge amount of municipal and industrial waste is generated daily. The household garbage collection program of Taipei City’s Department of Environmental Protection (TDEP) is based on fixed-time, fixed-route, and no-touch ground principles.

Augustine Koh (2007) has defined the current practice in most municipalities is to dispose of their waste into open garbage dumps. More economically advanced countries have opted for sanitary landfills and/or incinerators. These options are still, however, generating controversies within the population. The search for environmentally safe and socially acceptable sites for waste disposal has become a perennial concern that seems impossible to solve. Many municipalities have investigated many options, but finding a site for a new landfill is becoming extremely difficult because of the “not in my backyard” (NIMBY) syndrome. It is expected that with further urbanization and industrialization, this problem will worsen.

G. M. Jainal Abedin Bhuiya (2007) has defined Bangladesh faces a huge solid-waste management problem. Much of the country, and especially the capital city of Dhaka, is facing the impact of urbanization, as a growing population houses itself in congestion, leading to a severe pressure on infrastructure facilities at all levels. This has resulted in a decline in sanitation, which in turn causes adverse health impacts. The legal framework is not supported by timely enforcement actions and there is a general lack of funding to develop common facilities for efficient waste management. This report is a commentary on all these aspects.

Dass Ravi (2007) has defined Solid-waste management in Asian countries has given alarming signals because of their improper waste management. The
urbanization, industrialization, and an increase in economic status and activities have increased the quantity of municipal solid waste and altered its contents. A lack of motivation on the part of the municipalities has created a grave situation. Although the developing countries generate less solid waste per capita in comparison to developed countries, the collection, storage, transportation, processing, and disposal of solid waste is highly ineffective, and consequently damaging to the environment. A poor understanding of solid-waste management leads to different kinds of environmental problems within urban metropolises. The emission of greenhouse gases and air pollutants, the pollution of groundwater, occupational hazards, etc. are other areas of concern.

**Dr. Mohammad Ali Abduli (2007)** has said solid waste (SW) appears in different forms and has a broad spectrum. It consists of all kinds of waste arising from social, economic, and industrial activities. During the past 30 years, the solid waste generated in the Khazar region of northern Iran has changed in quality and quantity, but in principle the methods of collection, transport, and disposal have remained the same. As a result this region is facing serious environmental problems. For instance, some of the rivers are polluted and have been converted into dumping sites for waste from industrial, agricultural, and municipal activities. The main aim of this report is to assess the present state of SWM in this region and to evaluate alternative systems and the establishment of an efficient organization for SWM in the region. There are no universally applicable solid-waste management systems; every country must evolve an indigenous technology based on the quantity and characteristics of the waste, the level of national wealth, wage rates, its equipment-manufacturing capacity, energy costs, and the availability of foreign exchange for the purchase of imported plants. Although the utilization of data obtained in one region or country and the application of it to other regions or countries is technically inappropriate, some important similarities are evident in activities pertaining to the storage, collection, and transport of solid waste.
S. Esakku, A. Swaminathan (2007) has defined municipal solid waste management (MSWM) is a challenging problem for developing countries. Municipal solid waste (MSW) generation in Chennai, the fourth largest metropolitan city in India, has increased from 600 to 3500 tons per day (tpd) within 20 years. The highest per capita solid waste generation rate in India is in Chennai (0.6 kg/d). Chennai is divided into 10 zones of 155 wards and collection of garbage is carried out using door-to-door collection and street bin systems. The collected wastes are disposed at open dump sites located at a distance of 15 km from the city. Recent investigations on reclamation and hazard potential of the sites indicate the need for the rehabilitation of the sites. Chennai is the first city in India to contract out MSWM services to a foreign private agency-ONYX, a Singapore based company. The scope of privatization includes activities such as sweeping, collection, storing, transporting of MSW and creating public awareness in three municipal zones. ONYX collects about 1100 Metric tons of waste from three zones per day and transports it to open dumps. Various Community Based Organizations (CBO) are also involved in the MSWM of the city. A high rate biomethanation plant for power generation is in operation at the Koyembedu market. Total cost for street sweeping, collection and transportation per Metric ton of waste by Corporation of Chennai (CoC) and Onyx is approximately USD 33 and 25, respectively.

Tay Joo Hwa (2007) has said Solid-waste management may be defined as the discipline associated with controlling the generation, storage, collection, transfer and transport, processing, and disposal of solid waste in a manner that is in accordance with the best principles of health, economics, engineering, conservation, aesthetics, and other environmental considerations, and that is also responsive to public attitudes. In its scope, solid-waste management includes all administrative, financial, legal, planning, and engineering functions involved in the solutions to all problems of solid waste. The solutions may involve complex
interdisciplinary fields such as political science, city and regional planning, geography, economics, public health, sociology, demography, communications, and conservation, as well engineering and materials science. The growing volume of waste spawned by changes in consumption patterns is presenting a formidable challenge to all. The problem is how to deal with a large increase in waste without changing the lifestyles of the people. The current practice in most municipalities is to dispose of their waste into open garbage dumps. More economically advanced countries have opted for sanitary landfills and/or incinerators. These options are still, however, generating controversies within the population. The search for environmentally safe and socially acceptable sites for waste disposal has become a perennial concern that seems impossible to solve. Many municipalities have investigated many options, but finding a site for a new landfill is becoming extremely difficult because of the “not in my backyard” (NIMBY) syndrome. It is expected that with further urbanization and industrialization, this problem will worsen.

Pressure to protect the environment is now coming from the public through media reports and Non-Governmental Organizations (NGOs). Many governments have responded by finalizing solid-waste management bills or plans. These planned actions are putting pressure on industry to change the way solid waste is managed in order to be compliant in the future. As a result of these actions, there is a significant change in the attitudes of public and local authorities toward waste disposal, particularly with the management of open dumps, in view of the low initial capital investment and operating costs incurred by the local authorities. Most island states, however, have the problem of limited site options for the development of land dumps. As such, waste disposal and pollution control are national dilemmas that require a firm new initiative. New and innovative practical measures have to be implemented to avoid using landfill or incinerator options as the final and only solution, taking into account that land
is limited within many urban areas. Therefore issues have to be dealt with in an integrated perspective, one that is in line with the vision of sustainable development as agreed at the 2002 WSSD in Johannesburg and in the Barbados Programme of Action for small island states.

Chief Editor’s of IL&SF Interface Desk (2008) has defined the problem of MSW management is much more acute in metropolitan cities like Delhi where land available for landfill sites is scarce. Presently, Delhi generates approx. 7,000 MT of MSW every day, which is likely to increase to 18,000 MT per day by 2021. The integrated approach for MSW management developed by IL&FS IDC aims at tying up various aspects of MSW management and usage of a mix of technologies for processing, towards better management of MSW. With a view to support ULBs for waste management, IL&FS IDC created a team of experts and a dedicated Fund with support of Technology Development Board (TDB) Government of India and Andhra Pradesh Technology Development & Promotion Centre (APTDC). The Fund supports segregated waste collection activities from waste generators and provides the necessary resources during the project development phase.

Dinesh Kumar Mittal, IAS (2008) has defined India, one of the fastest growing economies in the world, faces a challenge of MSW Management. To address the issue, the Indian Government enacted MSW (Handling & Management) Rules in the year 2000 with a view to improve the present scenario. All Urban Local Bodies (ULBs) were supposed to have MSW management systems by end of year 2003. Being engrossed in their day-to-day activities and due to typical nature of Indian MSW, no single ULBs could achieve the targets. The Courts of Law in India are now issuing summons to ULBs for non compliance with the law of the land. Considering limitations of ULBs and alarming potential impacts, IL&FS IDC, in the year 2004, took the
initiative of bringing together experts in the field and working out an optimum solution to the problem. IL&FS IDC could develop an integrated concept to waste management and also presented the concept to one of the Experts Committees constituted by the Supreme Court of India. IL&FS IDC recognised the limitation of the ULBs and thus designed the concept involving their limited resource contribution. This edition of the Newsletter focuses on the opportunities available in the Management of Municipal Solid Waste and the successful projectization of one such opportunity in the form of the Timarpur-Okhla integrated municipal waste processing facility, in the state of Delhi. I hope you will enjoy reading IL&FS IDC Interface and look forward to receiving your feedback and suggestions.

**DAUDA, K. T. (2009)** this study has solid wastes could be defined as non-liquid and nongaseous products of human activities, regarded as being useless. It could take the forms of refuse, garbage and sludge (Leton and Omotosho, 2004). Cities in Nigeria, being among the fast growing cities in the world (Onibokun and Kumuyi, 1996) are faced with the problem of solid waste generation. The implication is serious when a country is growing rapidly and the wastes are not efficiently managed. Waste generation scenario in Nigeria has been of great concern both globally and locally. Of the different categories of wastes being generated, solid wastes had posed a hydra-headed problem beyond the cope of various solid waste management systems in Nigeria (Geoffrey, 2005), as the streets experience continual presence of solid waste from commercial activities. Various researchers have undertaken to study solid waste generation pattern in Nigeria, but most of the studies are usually a case study of a particular state or locality in Nigeria; and it seems the awareness about solid waste generation in several other cities are obscured.

**BABAYEMI, J. O: DAUDA, K. T.(2009)** has defined the quantity and rate of solid waste generation in the various states of Nigeria depends on the
population, level of industrialization, socio-economic status of the citizens and the kinds of commercial activities being predominant. Nigeria, having a population of 120 millions (Sridhar and Adeoye, 2003), generated 0.58Kg solid waste per person per day, and in some Nigerian cities as follows: Abeokuta in Ogun state (0.60Kg/person/day), Ado-Ekiti in Ekiti state (0.71Kg/person/day), Akure in Ondo state (0.54Kg/person/day), Ile-Ife in Osun state (0.46Kg/person/day) and Ibadan in Oyo state (0.71Kg/person/day) (Adewumi et al., 2005). About 55 200Kg per day of solid wastes were estimated to be generated in the traditional city of Oyo in Oyo state (Abel and Afolabi, 2007). Another source (GEO-2000), considering the population of Lagos to be 10.3 millions, reports the solid waste generation of 3.7 million tones per year for Lagos in 1990, and 401Kg/capita/year for Ibadan in 1997. Considering the population of Kano to be 1.4 million, Lewcock (1994) gave an estimate of total solid waste generated in the city as 450t per day. The per capita solid waste generation in Ilorin, the capital city of Kwara state, was projected to be 0.43Kg/person/day by the year 2020 (Yusuf and Oyewumi, 2008). As reported by Oluwemimo (2007), tones per year of solid waste generation in Kaduna, Onitsha, Aba, New Bussa and Uyo were estimated to be 4313, 124, 386, 593, 236703, 9518 and 20923 respectively. Report on solid waste generation in Maiduguri in Borno state, showed an estimate of 8.5 million tones for the year 2002 (Dauda and Osita, 2003). A study conducted on solid waste generation in Port Harcourt in River state, and Warri in Delta state, showed an estimate of 164029t/year and 66721t/year, respectively (Ajao and Anurigwo, 2002). Makurdi, an urban city in Benue state, generated a household solid waste of 0.54Kg/capita/day (Sha’Ato et al., 2006). Aziegbe (2007) recorded high generation of all sorts of polyethylene packaging materials in Benin. Between 0.55Kg and 0.58Kg of solid waste per person per day was generated in Abuja (Imam et al., 2007).
G. Arunachalam (2010) has studied the explosion of population coupled with rapid urbanization, rising income and consumption and increasing economic activities have changed the life style of Indian society into “throw-away society”. This new age of convenience and consumerism has brought about a sea change in the composition of wastes and has also resulted in an enormous solid waste generation (Rashid, 2007) which is an acute environmental problem. The per capita waste generation in urban areas varies with the size of population (NEERI, 2005) and has been reported to be of the order of 350g to 400 g per day in average Indian towns (Kala and Khan, 1994).

Bundela P.S., Gautam S.P.(2010), has defined, Agricultural application of Municipal Solid Waste (MSW), as nutrient source for plants and as soil conditioner, is the most cost effective option of MSW management because of its advantages over traditional means such as landfilling or incineration. However, agricultural application of MSW can lead to a potential environmental threat due to the presence of pathogens and toxic pollutants. Composting is an attractive alternative of MSW recycling. Application of MSW compost (MSWC) in agricultural soils can directly alter soil physicochemical properties as well as promote plant growth. The soil microbial biomass, considered as the living part of soil organic matter, is very closely related to the soil organic matter content in many arable agricultural soils. Numerous studies, with different MSWC amendment doses on different soil types and under different water regimes revealed no detrimental effect on soil microbial biomass. In this review, we show the state of art about the effects of MSWC amendment on soil microbial biomass.
What is waste and why does it require management

Waste is any material that is not needed by the owner, producer, or processor. Humans, animals, other organisms, and all processes of production and consumption produce waste. It has always been a part of the Earth’s ecosystem, but its nature and scale were such that the ecosystem could use this waste in its many cycles. In fact, there is no real waste in nature. The apparent waste from one process becomes an input in another.

It is the exponential growth of human activities that has made waste a problem that needs to be managed. We are simply producing far more waste than nature can handle.

It is, however, better to prevent waste generation than to produce waste and then try to ‘manage’ it. We cannot simply throw away waste. As they say, ‘There is no away in throw away’. What we dispose of remains in the ecosystem also and cause some form of pollution. This pollution can have an impact that is far away from the point of generation and far removed in time.

Integrated waste management and the waste hierarchy

In recent years, the concept of integrated waste management (IWM) has become popular as a new approach to waste management. As defined by the World Resource Foundation (WRF, cited in Environment Council, 2000:23), IWM refers to “the use of a range of different waste management options rather than using a single option”. In other words, IWM is an approach which relies not only on technical solutions to the waste problem, but on a wide range of complementary techniques in a holistic approach. The approach involves the selection and application of appropriate technologies, techniques and
management practices to design a programme that achieves the objectives of waste management (Tchobanoglous et al., 1993). The concept of IWM seems to have emerged from the realization that technical solutions alone do not adequately address the complex issue of waste management and that there is the need to employ a more holistic approach to waste management. As argued by Rhyner (1995:17), “a single choice of methods for waste management is frequently unsatisfactory, inadequate, and not economical”. Use of an integrated approach to managing solid waste has therefore evolved in response to the need for a more holistic approach to the waste problem. In this approach, all stakeholders participating in and affected by the waste management regime are brought on board to participate in waste management. Furthermore, issues such as social, cultural, economic and environmental factors are considered in the design of an IWM project (Tchobanoglous et al., 1993; Rhyner et al., 1995; Schubeller et al., 1996). These elements most commonly associated with integrated solid waste management are waste prevention, waste reduction/minimization, re-use of materials and products, material recovery from waste streams, recycling of materials, composting to produce manures, incineration with energy recovery, incineration without energy recovery and disposal in landfills in that order of priority (Durham County Council, 2007: online).

These elements of IWM are frequently formulated into a waste hierarchy model which Girling (2005:178) has described as “a penny-plain piece of common sense that places the various strategies for waste management in order of environmental friendliness, from best to worst”. As shown in the model, waste prevention and reduction are placed at the top to show that the best way to deal with waste is to prevent its production and, where this is not possible, to produce less of it. At the other extreme, disposal is placed at the bottom to show that it should be the last resort among the strategies for waste management.
SOLID WASTE

A waste is viewed as a discarded material, which has no consumer value to the person abandoning it. According to World Health Organization, (WHO) the term ‘solid waste’ is applied to unwanted and discarded materials from houses, street sweepings, commercial and agricultural operations arising out of mass activities. Solid Waste is the term used to describe non liquid materials arising from domestic, trade, commercial, agricultural and industrial activities and from public services. It is commonly known as garbage, refuse, rubbish or trash. Its main sources are residential premises, business establishments, and street sweepings. It is a mixture of vegetable and organic matter; inert matter like glass, metal, stones, ashes, cinders, textiles wood, grass etc., According to the
percentage of the ingredient, it would be highly compostable, or combustible, biodegradable or inert.

SOLID WASTE MANAGEMENT

Solid Waste Management is a science associated with the management of generation, storage, collection, transportation, processing and disposal of solid waste using the best principle and practices of public health, economics, engineering, conservation, aesthetics and other environmental conditions.

Solid Waste Management is one of the important obligatory functions of urban local bodies in India. It is also one of the primary responsibilities of the municipal authorities. Over the years, the quantum of waste generated by different category of waste producers (Households, Commercial centres, Institutions, Industries etc) has been increasing with the increase in urbanization, population growth and associated activities. The characteristics of the waste generated have also been varying with the habits of human being. Solid Waste Management is a part of public health and sanitation, and according to the Indian Constitution, falls within the purview of the State list. Since this activity is non-exclusive, non-rivaled and essential, the responsibility for providing the service lies within the public domain. The activity being of a local nature is entrusted to the Urban Local Bodies. The Urban Local Body undertakes the task of solid waste service delivery, with its own staff, equipment and funds. In a few cases, part of the said work is contracted out to private enterprises.
Types of Solid Wastes

As a basis for subsequent discussions, it will be helpful to categorize the solid wastes, in the most general way, on the basis of their origin as:

1. Municipal wastes
2. Industrial wastes
3. Hazardous wastes

Classification of materials comprising municipal solid wastes

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Wastes</td>
<td>The animal, fruit or vegetable residues (also called garbage) resulting from the handling, preparation, cooking and eating of foods. Because food wastes are putrescible, they decompose rapidly in warm weather.</td>
</tr>
<tr>
<td>Rubbish</td>
<td>Combustible and non-combustible solid wastes, excluding food wastes. Typically combustible rubbish consists of materials, such as paper, cardboard, plastics, textiles, rubber, leather, wood, furniture and garden trimmings. Non-combustible rubbish consists of items, such as glass, crockery, tins, cans, construction wastes, etc.</td>
</tr>
<tr>
<td>Ashes and Residues</td>
<td>Materials remaining from the burning of wood, coal, coke and other combustible wastes. Residues from power plants are normally not included in this category. Ashes and residues are normally cinders, clinkers and small amounts of burnt and partially burnt materials.</td>
</tr>
<tr>
<td>Demolition and construction wastes</td>
<td>Wastes from razed buildings and other structures are classified as demolition wastes. Wastes from construction of residential, commercial, industrial and similar structures are classified as construction wastes. These wastes may include dirt, stones, concrete, bricks, plaster and plumbing, heating and electrical parts.</td>
</tr>
<tr>
<td>Special wastes</td>
<td>Wastes, such as street-sweepings, roadside litter, catch-basin debris, dead animals and abandoned vehicles are classified as special wastes.</td>
</tr>
<tr>
<td>Treatment plant wastes</td>
<td>The solid and semi-solid wastes from water, waste-water and industrial waste treatment facilities are included in this category.</td>
</tr>
</tbody>
</table>
Municipal wastes

Table gives the description of various types of solid wastes arising from residential and commercial places, open areas and treatment plant sites, etc.

The sources and composition of Municipal Solid Wastes are given in table

Description of various types of solid wastes

<table>
<thead>
<tr>
<th>Source</th>
<th>Typical facilities, activities or locations where wastes are generated</th>
<th>Types of solid wastes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Single family and multi-family dwellings, low, medium and high-class apartments, etc.</td>
<td>Food wastes, rubbish, ashes, special wastes.</td>
</tr>
<tr>
<td>Commercial</td>
<td>Stores, restaurants, markets, office buildings, hotels, motels, print shops, auto repair shops, medical facilities and institutions, etc.</td>
<td>Food wastes, rubbish, ashes, demolition and construction wastes, and occasionally hazardous wastes</td>
</tr>
<tr>
<td>Open Areas</td>
<td>Streets, parks, vacant lots, playgrounds, beaches, highways.</td>
<td>Special wastes, rubbish</td>
</tr>
<tr>
<td>Treatment plant sites</td>
<td>Water, waste water and industrial wastes; treatment process wastes.</td>
<td>Treatment plant wastes, principally composed of residual sludge’s.</td>
</tr>
</tbody>
</table>

Industrial wastes

These result from industrial activities and typically include rubbish, ashes, demolition and construction wastes, waste plastic, rubber, glass, packing materials, waste equipment, broken machinery and tools, etc.

Hazardous wastes

Wastes that pose a substantial danger, immediately or over a period of time to human, plant or animal life, are classified as hazardous wastes. A waste is classified as hazardous if it exhibits any of the following characteristics:

(i) Ignitability,
(ii) Corrosivity,
(iii) Reactivity, and
(iv) Toxicity.
In the past, hazardous wastes were often grouped as: (i) radioactive substances, (ii) chemicals, (iii) biological wastes, (iv) flammable wastes and (v) explosives. The chemical category included wastes that are corrosive, reactive or toxic. The principal sources of biological wastes are hospitals and biological research centre.

CHARACTERISTICS OF SOLID WASTES

The composition of solid wastes, in percentage by weight, for Major Indian and typical European cities.

PHYSICAL CHARACTERISTICS

Some of the physical characteristics of solid wastes are as follows:

i) **Size of components**: The size of the component materials in solid wastes is of importance in the recovery of materials, especially by mechanical means, such as screens and magnetic separators. The size of the components of solid wastes may have any range, depending upon the type of the waste.

ii) **Moisture – content**: The moisture-content of solid wastes is usually expressed as the mass of moisture per unit mass of the material (wet or dry) In the wet-mass method of measurement, the moisture in a sample is expressed as a percentage of the wet mass of the material.

\[
\text{Moisture Content (\%) } = \frac{a - b}{a} \times 100
\]

where,

\[a = \text{initial mass of the sample.}\]

and \[b = \text{mass of sample, after drying.}\]

The types of solid wastes on the basis of their moisture content and their related hazards are given in table
Physical form and hazard of wastes generated in India

<table>
<thead>
<tr>
<th>Physical form of the waste</th>
<th>Description</th>
<th>Example</th>
<th>Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid</td>
<td>Very hard mass, moisture upto 30%</td>
<td>Spent catalyst, filter coke, etc.</td>
<td>Varied</td>
</tr>
<tr>
<td>Semi-solid</td>
<td>Paste, sticky, viscous.</td>
<td>Spent solvent distillation residues.</td>
<td>Substantial</td>
</tr>
<tr>
<td>Sludge</td>
<td>Soft, high moisture (upto 80%)</td>
<td>Bio-mass, dye stuff residues, sludge from waste water treatment plant.</td>
<td>Acute</td>
</tr>
<tr>
<td>Slurry</td>
<td>Suspensions, with 90% moisture.</td>
<td>Arsenic wastes from petro-coke process.</td>
<td>Chronic</td>
</tr>
</tbody>
</table>

iii) Density: The densities of solid wastes vary markedly, with geographic location, season of the year, and length of time in storage. Density can be estimated by using the following relation:

\[
\text{Density} = \frac{\text{Weight of the waste sample}}{\text{Volume occupied by the sample}}
\]

Average densities of solid wastes in some Indian cities and a typical European city have been given in table.

CHEMICAL CHARACTERISTICS

Information on the chemical composition of solid wastes is important in evaluating alternative processing and energy recovery options. If solid wastes are to be used as fuel, the four most important determinations/analyses to be made are:

1. Proximate analysis
   a) Moisture (loss at 105°C for 1hour)
   b) Volatile matter (additional loss, on ignition at 950°C)
   c) Ash (residue after burning)
   d) Fixed carbon (remainder)
2. Fusing point of ash
3. Ultimate analysis, i.e., the determination of the percentage of carbon, hydrogen, oxygen, nitrogen, sulphur, and ash.

4. Heating value (energy value)

The important properties of a solid waste, typically used as fuel, are given in the table.

**Properties of solid waste typically used fuel**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Property</th>
<th>Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Range</td>
</tr>
<tr>
<td>1</td>
<td>By proximate analysis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) Moisture</td>
<td>15-40</td>
</tr>
<tr>
<td></td>
<td>b) Volatile</td>
<td>40-60</td>
</tr>
<tr>
<td></td>
<td>c) Fixed carbon</td>
<td>5-12</td>
</tr>
<tr>
<td></td>
<td>d) Non-combustibles</td>
<td>15-30</td>
</tr>
<tr>
<td>2</td>
<td>By ultimate analysis, content of –</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) Carbon</td>
<td>40-60</td>
</tr>
<tr>
<td></td>
<td>b) Hydrogen</td>
<td>4-8</td>
</tr>
<tr>
<td></td>
<td>c) Oxygen</td>
<td>30-50</td>
</tr>
<tr>
<td></td>
<td>d) Nitrogen</td>
<td>0.2-1.0</td>
</tr>
<tr>
<td></td>
<td>e) Sulphur</td>
<td>0.05-0.3</td>
</tr>
<tr>
<td></td>
<td>f) Ash</td>
<td>1-10</td>
</tr>
<tr>
<td>3</td>
<td>Heating value</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) Organic fraction (kJ/kg)</td>
<td>12000-16000</td>
</tr>
<tr>
<td></td>
<td>b) Total (kJ/kg)</td>
<td>8000-12000</td>
</tr>
</tbody>
</table>

**Density and moisture content**

The density of solid waste varies with its composition, its moisture content and its degree of compaction. It shows figures for waste density. Food wastes range from 100 to 500 kg/m³ with corresponding moisture contents at 50 to 80 per cent. MSW normally compacted in landfill has a density of 200 to 400 kg/m³ with a moisture content of 15 to 40 per cent. Further densities and moisture contents on other wastes are found in Tchobanoglous et al., (1993). Moisture content of wastes are relevant when estimating the calorific value, landfill sizing, reactor sizing, etc.
Density and moisture content of municipal solid waste

<table>
<thead>
<tr>
<th>Waste source</th>
<th>Component of waste</th>
<th>Density (kg/m³)</th>
<th>Moisture content (% by weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>Food</td>
<td>290</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Paper and cardboard</td>
<td>70</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Plastics</td>
<td>60</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Glass</td>
<td>200</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Metals</td>
<td>200</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Clothing/textiles</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Ashes, dust</td>
<td>500</td>
<td>8</td>
</tr>
<tr>
<td>Municipal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncompacted</td>
<td></td>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>In compaction truck</td>
<td></td>
<td>300</td>
<td>20</td>
</tr>
<tr>
<td>Normally compacted in</td>
<td></td>
<td>500</td>
<td>25</td>
</tr>
<tr>
<td>landfill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well compacted in landfill</td>
<td></td>
<td>600</td>
<td>25</td>
</tr>
</tbody>
</table>

GENERATION, STORAGE, COLLECTION & TRANSPORTATION OF SOLID WASTE MANAGEMENT

After estimating the quantity of solid wastes, likely to be generated in a particular locality, the next step towards solid waste management is the proper planning of the integrated system of storage, collection and transportation.

SOLID WASTE GENERATION RATES

In general, solid waste generation and its composition in the developing Asian countries vary widely due to different cultural practices, living standards and climatic conditions (AIT, 2004). As for the case of Thimpu (Bhutan), it generates about 10 tons/day (UNEP 2001a) and Dhaka (Bangladesh) generates as high as 4,364 tons of waste daily (Iftekhar et al., 2005). Average daily solid waste generation in Kabul city (Afghanistan) is 1,080 tons out of which only 250 ton is collected (UNEP, 2003). In New Delhi (India) 3,880 tons of solid waste is generated each day of which only 2,420 tons is collected for disposal (UNEP, 2001c). In Karachi (Pakistan), everyday around 7,000 tons of mixed garbage is
generated and its generation rate is increasing by 2.4% per year (WWF-Pakistan, 2001). In Kathmandu Metropolitan City (KMC), Nepal, daily garbage flow is 944 m^3, approximately 300 tons (Manandhar, 2002) whereas, in Colombo (Sri Lanka) the MSW generation is 2,927 ton/day (AIT, 2004).

Waste generation rates are usually calculated on a kg/capita/day basis. The domestic refuse generation rate varies from 0.3 kg/capita/day to 1.8 kg/capita/day throughout the world. Waste generation ought to be different for rural and urban categories: however, for rural areas no literature pertaining to waste generation is available. For urban areas, the waste generation rates stand tabulated on the basis of the economic standard of a country and the source of generation in table.

**Urban refuse generation rates (kg/captia/day)**

<table>
<thead>
<tr>
<th>Industrial Countries</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>New York, U.S.A</td>
<td>2.4</td>
</tr>
<tr>
<td>Hemburg</td>
<td>0.85</td>
</tr>
<tr>
<td>Japan</td>
<td>0.94</td>
</tr>
<tr>
<td>Great Britain</td>
<td>0.74</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Middle Income Countries</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>0.87</td>
</tr>
<tr>
<td>Phillipines</td>
<td>0.50</td>
</tr>
<tr>
<td>Egypt</td>
<td>0.50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Low Income Countries</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td>0.6</td>
</tr>
<tr>
<td>Pakistan</td>
<td>0.6</td>
</tr>
<tr>
<td>India</td>
<td>0.5</td>
</tr>
</tbody>
</table>
The following generation rates are for the municipal refuse on the basis of its source.

**Generation rates for municipal refuse (kg/capita/day)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential Refuse</td>
<td>0.3 to 0.6</td>
</tr>
<tr>
<td>Commercial Refuse</td>
<td>0.1 to 0.2</td>
</tr>
<tr>
<td>Street Sweeping</td>
<td>0.05 to 0.2</td>
</tr>
<tr>
<td>Institutional Refuse</td>
<td>0.05 to 0.2</td>
</tr>
<tr>
<td>Industrial Waste</td>
<td>0.1 to 1.0</td>
</tr>
</tbody>
</table>

As indicated in the Manual on Municipal Solid waste Management published by CPHEEO, Ministry of Urban Development ([http://cpheeo.nic.in](http://cpheeo.nic.in)) and Report of the Technology Advisory Group on Solid Waste Management constituted by Ministry of Urban Development, New Delhi, the per capita waste generation varies from 0.2 to 0.6kg per day in cities with a population ranging from 0.1 million and above. Due to increase in per capita waste generation of about 1.3% per year, and growth of urban population between 3% to 3.5% per annum, yearly increase in the overall quantity of solid waste generation in the cities averages about 5%. The waste generation rates and physical and chemical characteristics of 59 cities covered under JnNURM are given as under.
NORMS FOR GENERATION OF GARBAGE

Norms for Garbage generation

<table>
<thead>
<tr>
<th>Garbage generated</th>
<th>Average Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Population range upto 1 lakh</td>
<td>0.27 Kg per person per day</td>
</tr>
<tr>
<td>(2) Population range 1 to 5 lakh</td>
<td>0.31 Kg per person per day</td>
</tr>
<tr>
<td>(3) Population range 5 to 10 lakh</td>
<td>0.45 Kg per person per day</td>
</tr>
<tr>
<td>(4) Population range 10 to 20 lakh</td>
<td>0.67 Kg per person per day</td>
</tr>
<tr>
<td>Street sweepings and drain silt</td>
<td>0.10 Kg per person per day</td>
</tr>
<tr>
<td>Slaughter House:</td>
<td></td>
</tr>
<tr>
<td>(1) Small slaughter house</td>
<td>0.5 to 1.0 ton per day</td>
</tr>
<tr>
<td>(2) Medium slaughter house</td>
<td>2 to 6 ton per day</td>
</tr>
<tr>
<td>(3) Large slaughter house</td>
<td>6 to 7 ton per day</td>
</tr>
<tr>
<td>Domestic waste from Hospitals/ Clinics</td>
<td>1.1 Kg per bed per day</td>
</tr>
</tbody>
</table>

The per capita generation of the above combined waste would not be more than 405 gm/capita/day in areas with a density of population less than 20000/sq.km. In sewered areas, the quantity of waste may be higher due to the presence of surface drain sludge. The Local Body has to arrange for the primary collection from the different places where the solid waste is generated and stored and this collection is to be done on a daily basis by different methods.

Factors Affecting the Solid Waste Generation Rates

The factors that influence the quantity of solid waste generated include the following:

1. Geographic location
2. Season of the year
3. Collection frequency (affects amounts collected)
4. Use of waste grinders
5. Characteristics of populace, (standard of living, consumer and cultural habits)
6. Extent of salvaging and recycling public attitudes
7. Legislation

SEGREGATION AND STORAGE AT SOURCE

Storage of waste at source is the first essential step of Solid Waste Management. Every household, shop and establishment generates solid waste on day to day basis. The waste should normally be stored at the source of waste generation till collected for its disposal. In India, such a habit has not been formed and in the absence of system of storage of waste at source, the waste is thrown on the streets, treating streets as receptacles of waste. Generally no bins for storage of domestic, trade or institutional waste are kept at source. Very few people keep personal bins for storage of domestic, trade or institutional waste at source.

Waste from shops, offices and establishments including hospitals, nursing homes, hotels, restaurants, construction and demolition wastes, etc., come on the streets or is disposed of unauthorized on public or private open plots or even discharged in the drains or water bodies nearby resulting in clogging of drains, pollution of water resources and increase in insanitary conditions in the urban areas. Some towns in TamilNadu such as Namakkal, have educated the public through intensive Information Education and Communication (IEC) activities which can be adopted in other towns. Some types of receptables presently used for storage are as under:

- Buckets
- Plastic/HDPE/MDPE bins
- Plastic bags
- Metal bins with or without lids
The segregation and storage of solid waste is the most critical component in the whole process of Municipal Solid Waste Management, which helps in handling solid waste leading to ultimate success of MSWM in terms of the achievements of objectives laid down in the MSW Rules, 2000. 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 Governments” as the compliance criteria on the part of urban local bodies.

In order to achieve these compliance criteria, the segregation and storage at source becomes the first touchstone for effective management of municipal solid waste. Segregation and storage of solid waste at source will differ from type of solid waste generated by the producers.

Broadly the type of solid waste generated can be put into four categories.
(a) Domestic and Trade waste,
(b) Construction waste,
(c) Bio-medical waste, and
(d) Industrial waste.

There are separate guidelines formed by different enforcement agencies like Pollution Control Board etc., for dealing with the bio-medical waste and the industrial waste. The present guidelines/Ready Reckoner will be dealing only with the domestic waste, trade MSWM. The generation of awareness among the producers and creation of an enabling environment is the key to success towards proper segregation and storage at source. Therefore, the first step would be to have extensive awareness and education campaign to make households realize that the segregation of garbage at source is the best key to solid waste management.
Collection of Solid Wastes

Collection and Transfer Operations

The collection of solid wastes and their transport to incinerators and landfills accounts for roughly three-fourths of the total cost of refuse service. In the past, collection and transport decisions by professionals involved in solid waste management were focused on selecting the proper number and size of trucks, choosing the most efficient collection routes and schedules, locating transfer stations if they were to be used, and administering the whole system. With the growing importance of recycling and composting, those basic operations have become more complicated. Now a municipality may have separate trucks, routes, schedules, and destinations for recyclables and compostable materials—all of which need to be coordinated with already existing refuse collection systems.

Various types of collection services and collection systems, which are in use, will be discussed in this section.

1) Municipal Collection Services

Although, a variety of municipal collection services are employed in developed countries like United States, England, etc., however, the most common method, which suits the Indian conditions also, involves the use of large containers (silos) which can be emptied mechanically with an articulated container pick-up mechanism. It is normally accomplished by a fleet of trucks and crew that operate together as collection systems. The crew truck system collects wastes from households or commercial establishment, on a regular schedule, over assigned routes.

2) Commercial-Industrial Collection Services

The collection service, provided to large apartment buildings, residential complexes and commercial and industrial activities, typically, is centered on the use of large movable and stationary containers and large stationary compactors.
Compactors are of the type that can be used to compress the material directly into large containers or to form balls, which are then placed in large containers. The frequency of collection depends on the character of the waste, climate, cost of collection and the waste generation characteristics.

**Types of Collection Systems**

**Containers**

The starting point for the manipulation of solid-waste is the deposit of waste in containers. For many years, galvanized steel barrels of 10 to 40-gallon capacity have been the most used officially authorized domestic container. Many of the local environmental problems of solid wastes have started at the mouth of the container, because of the inevitable practice of collectors of inverting the barrels and banging them on the rim of the collection-vehicle hopper to jerk out.

This treatment usually puts a dent in the rim of the barrel, so that subsequently the lid will not fit. Thereafter flies breed in the contents of the barrel, and rats can easily climb in. the problem is accelerated because refuse tends to stick inside a barrel with a dented rim, and at the next collection the barrel has to be banged somewhat harder to get the refuse to fall out.

The use of light-gauge metal barrels should, therefore, be banned, along with the officially discouraged but usually tolerated use of open ended drums of from 10- to 55-gallon capacities. Some metal barrels have successfully resisted rough treatment either through heavier-gauge rims or by the use of rubber buffers. However, the introduction of plastic barrels, particularly those of the tougher materials such as high-density polyethylene, has overcome most of the disadvantages of metal barrels.

The substitution of paper sacks for barrels, which started in Scandinavia, strong challenge. Apart from the obvious advantage of cleanliness, sacks have
the overwhelming virtue of requiring no replacement to the roadside and later return to the residence. As the weight of a refuse barrel is eliminated, the older’s job can be greatly speeded up. Sacks have often enabled the crew size to be reduced to one loader and one driver, indeed, in certain areas of the United States; one-man operation of the vehicle has been achieved and found to be cost-effective. With an open cab and the capability of front-end loading of the compactor body, the driver can reach out for a bundle or sack sometimes without even stopping the vehicle.

If, however, sacks are left out long enough to be attacked by dogs, rats, or other animals, the result can be very discouraging.

**Direct Haul System**

We can use some simple estimates to help gain a sense of how truck sizes and collection patterns might be planned. A basic collection system consisting of the garage, where collection vehicles are parked overnight, the collection route, and the disposal site, where refuse is deposited. Later, the possibility of incorporating a transfer station between the collection route and the disposal site to reduce lost time by the collection vehicles will be introduced.

To work up a basic plan for refuse collection, let us introduce the following notation:

\[
\begin{align*}
  t_1 &= \text{time to drive from garage to beginning of collection route} \\
  t_2 &= \text{time to drive between collection route and disposal site} \\
  t_3 &= \text{time to drive from disposal site back to garage at end of day} \\
  t_c &= \text{total time spent collecting refuse} \\
  t_d &= \text{time spent at the disposal site dropping one truck load} \\
  t_b &= \text{time per workday spent on breaks, etc} \\
  T_t &= \text{total time for one day of refuse collection} \\
  n &= \text{number of runs from the collection route to the disposal site}
\end{align*}
\]
No matter what, each day’s collection requires at least a drive from the garage to the collection route, time spent on the route, a run to the disposal site, time spent there unloading, and a drive back from the disposal site to the garage. More than one run may be made between the collection route and the disposal site, depending on how big the truck is how many pick-ups are to be made, and how much refuse is picked up at each stop. The following describes a single day of collection:

\[ T_t = t_1 + t_c + t_2 + t_d + (n-1)(2t_2 + t_d) + t_3 + t_b \]
\[ T_t = t_1 + (2n-1)t_2 + nt_d + t_3 + t_b + t_c \]

**Hauled-Container System (HCS):**

Collection, systems, in which the containers used for the storage of wastes, are hauled to the processing, transfer or disposal site, emptied and returned to either their original location or some other location are defined as hauled container systems. These can be of the tilt, frame container or trash, trailer type. The collector is responsible for the vehicle, loading the container and unloading the contents at the disposal site. In some cases, for safety reasons, both a driver and a helper are used.

Systems that use tilt-frame loaded vehicles and large container, often called drop boxes, are ideally suited for the collection of all types of solid wastes and rubbish from locations where the generation rate warrants the use of large containers. Open-top containers are used routinely at waste houses and construction sites. Large containers, used in conjunction with stationary compactors are common at commercial and industrial services and at transfer stations. Because of the large volume that can be hauled, the use of tilt-frame container systems has become widespread, especially among private collectors servicing industrial complexes.
The application of trash-trailer is similar to that of the tilt-frame container systems. Trash-trailers are better for collection of heavy rubbish, such as sand, timber, metal scrap, etc. and are often used for the collection of demolition wastes at construction sites.

**Semi-Automatic Collection**

The favorable response to the use of sacks for collection has accelerated work on development of vehicles which exploit some of the advantages of sack collection. Most present collection vehicles employ a periodic compaction cycle. The pickup of sacks can be so rapid that a continuous-compaction arrangement is desirable. Compaction systems operating on various modifications of the meat-grinder principle have been found effective and three seems likely to be a revival of some recently abandoned systems using drag conveyors.

The possibilities of one-man collection opened up by the use of sacks have led to several proposals for collection trucks having a mechanical pickup controlled from the cab. The collection vehicle becomes analogous to a wheat-harvester. Although there have been some recent developments of machines which pick up barrels by driver control, the need to have to replace the barrels results in a time penalty not faced by automatic bag collectors.

A further possible development is that all households will eventually be required to use household waste compactors, so that the collection vehicles can be further greatly simplified in having to pick up only compacted boundless falling within certain size and weight limits.

**Containerized collection**

Most commercial collection is made in containers of from 1 to 20 cubic yards. The containers are adapted so that they may be picked up by special vehicles, some having compaction arrangements on the vehicles, usually with only the driver of the vehicle being needed to effect the transfer. The system is
so efficient, in comparison with one which requires men to transfer small quantities manually into trucks, that it is being adopted in some cities and towns for domestic pickup, if not for all categories of waste then at least for bulk waste such as furniture.

The simplest arrangement is the rear-end loader, which is usually a simple adaptation of a standard compaction truck with a hook to catch the lip of the container and a hoist so that the container may be tipped up into hopper. Normally the containers are on casters and must be manually moved into place by the operator, who has a set of controls at the rear of the truck.

The front-end loader can be somewhat more automated than the rear-end loader, because the operator simply drives his vehicle up to the container, extends a forklift which then raises the container over the top of the cab, inverts it into a hopper, and then lowers the container back to its previous place. The operation can therefore be much more rapid than for the rear-end loader, but there are many routes where front-end-loading equipment cannot be used because of height restrictions (over-head wires being a special problem) and limits on the maneuvering space required to line up the vehicle with the container.

For cases in which the volume of pickup in any one location is large (on the order of 10 to 20 cubic yards), it is more appropriate that the complete container be taken, rather than being simply emptied and returned. The trucks used are of the flatbed variety, and the normal operation is for the truck to arrive with an empty container which it then “rolls off” and winches on the full container in its place. Because of these operations, the operation is known as a “roll-on roll-off” system.
Economics of Collection

To decide on the truck size that would provide the cheapest waste transport, we need to know the annual cost of owning and operating trucks, including the cost of the crew that makes the pick-ups. Finding the annualized cost of each truck involves using an engineering economy calculation in which the capital cost, amortized over the lifetime of the vehicle, is added to the estimated annual maintenance and fuel costs. The relationship between the purchase price of capital equipment, such as trucks, and the amortized yearly costs is given by

\[ A = P \left( \frac{i(1+i)m}{(1+i)n-1} \right) \]

where,

- \( A \) = annual cost ($/yr)
- \( P \) = purchase price ($)
- \( i \) = discount factor (yr\(^{-1}\))
- \( n \) = amortization period (yr)

Stationary – Container System (SCS)

Collection systems in which the containers are used for the storage of waste remains at the point of waste generation, except when moved for collection are defined as stationary-container systems. Labour requirement for the mechanically loaded stationary-container systems are essentially the same as for the hauled-container systems.
<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Collection container type</th>
<th>Range of container capacities (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hauled-container system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Tilt-frame</td>
<td>Open top, also called debris boxes</td>
<td>8-40</td>
</tr>
<tr>
<td></td>
<td>Used in conjunction with stationary compactor</td>
<td>10-30</td>
</tr>
<tr>
<td></td>
<td>Equipped with self-contained compaction mechanism</td>
<td>15-30</td>
</tr>
<tr>
<td>b) Truck-tractor</td>
<td>Open top trash trailers</td>
<td>10-30</td>
</tr>
<tr>
<td></td>
<td>Enclosed trailer-mounted containers, equipped with self-</td>
<td>15-30</td>
</tr>
<tr>
<td></td>
<td>contained compaction mechanism</td>
<td></td>
</tr>
<tr>
<td>Stationary-container systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Compactor,</td>
<td>Open top and enclosed top and side loading</td>
<td>0.6-0.8</td>
</tr>
<tr>
<td>mechanically loaded</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Compactor,</td>
<td>Small plastic or galvanized metal containers, disposable</td>
<td>75-200</td>
</tr>
<tr>
<td>manually loaded</td>
<td>paper and plastic bags.</td>
<td></td>
</tr>
</tbody>
</table>

Container size and utilization are not as critical in stationary-containers systems using self-loading collection vehicles equipped with a compaction mechanism, as they are in the hauled-container system. Trips to the disposal site, transfer station or processing station are made after the contents of a number of locations have been collected and compacted and the collection vehicle is full. Because a variety of container sizes and types are available, these systems may be used for the collection of all types of wastes.

The major application of manual transfer and loading methods is in the collection of residential wastes and litter. Manual methods are used for collection of industrial wastes where pick-up points are inaccessible to the collection vehicle.
Cranes

Until automatic conveying systems become able to handle raw refuse from the point of dumping from collection vehicles, the input end of a solid-waste treatment facility-incinerator compost/or reclamation plant, transfer station, and so or must in general contain either a crane or a front-end loader. The cranes used are virtually always of the traveling type. This means that the main crane runs on overhead rails fixed to columns which may be part of the building. Occasionally, traveling cranes run on rails set in the ground, in which case the whole support structure of the crane must move with it. The winding gear is contained in a carriage which can be moved laterally along the main crane jib. Control is usually carried out from an overhead cabin, although ground control through a suspended control until or through a radio connection is possible.

The most common form of grab for solid waste is the clamshell bucket. With it the operator can select or even mix up refuse if, for instance, he notes a large mass of, perhaps, plastics scrap which might cause problems if loaded at one time into a furnace.

However, because of the storing bargaining position and resulting high wage rates which crane operators in many area have obtained, a greater degree of automation in crane control can be expected in the future. There is no fundamental reason why cranes should not operate with less human attention than conveyors.

Refuse-Duct systems

The simplest dust system for solid waste is the refuse chute, which uses gravity as the motive power. All that need be said about it here is that it can be extremely useful, but it can also get foul and can form a serious fire danger. Therefore, a refuse chute should be designed with suitable entry chambers, plus
intermediate and final traps, to avoid the possibility of it becoming a chimney for the spread of fire. Incidentally, since a refuse chute smelling of rancid animal far or sticky with molasses is not a source of pride, potentially contaminating wastes should be wrapped before being impacted.

Gravity chutes on elevators can provide for vertical movement. But the most difficult problem in planning movement of material within building complexes is to achieve satisfactory horizontal movement. Solid wastes, for instance can be moved through pipes in a liquid or air stream. Systems employing these principles have been available for decades, but only recently have changing economies of capital and labour costs swung sharply in favour of these capital-intensive arrangements.

**Hydraulic –duct systems**

The Garchey system was first introduced in Paris in 1927. It consists essentially of substituting for regular sink outlets and drains a flushing unit and larger pipes so that newspapers, bottles, cans, and so on, can flushed away into the waste system. These solid materials are conveyed by water to an underground collection chamber, which can be emptied on a regular basis by a special tanker. The overflow from the chamber goes to the sewer in the normal way.

A more recent development of this principle, but one which limits the types of wastes which can be accepted, is to grind the material to a pulp in the sink unit. In this country the Wascon and the Somat Corporations make systems of this type. The pulped wastes are taken to a hydro extractor where the non-soluble wastes are pressed against screens and delivered to a container for collection as a compacted semi-dry pulp.

These systems are obviously more suitable for kitchen wastes, including milk cartons, plastic cutlery and so on, rather than bulkier wastes such as
newspapers and magazines which have first to be reduced in size before they can be inserted into the sink chamber.

**Transportation**

Principally, there are two methods of transporting the solid waste from sources of production to the size of disposal.

1. Direct method
2. Indirect method

**Direct method of transportation**

In this method, the collection vehicle collects the solid waste from the sources of generation as the vehicle gets filled to its capacity; it proceeds directly to the site of disposal. After emptying, it comes back and collects the solid waste from the remaining area.

Herein, the time of traveling to and fro between area of collection and site of disposal is very important and may be substantially affected by the prevailing traffic conditions. In big cities, the suitable sites of disposal are far away from the city centres and, thereby, it requires more travel time. This means that in this method, more time, equipment and manpower will be required in solid waste transportation and thereby less time, equipment and manpower will be available for collection. In order to maintain the frequency and quality of service additional equipment and manpower will be required, which will increase the cost of transport and hence, the overall cost of solid waste management.

**Indirect method of transportation**

In this method, small vehicles collect the solid waste and transport it to a central location, called transfer station. From the transfer stations, larger and more efficient tractor-trailer rigs take over the function of transporting solid
waste to the site of disposal. The following factors should be investigated before adopting this method.

i) Efficiency of the systems
ii) Distance and time of travel to the site of disposal
iii) Suitability of transfer operations to the area
iv) Overall cost analysis

However, after investigating above factors, if significant savings cannot be demonstrated, there is no advantage in adopting this method of transportation.

Transfer Stations

As convenient local landfills close, it is often the case that the replacement site is located many miles away from the community that is being served. As that distance from the collection area increases, it takes more and more time to haul the refuse to the disposal site, which leaves less and less time for each truck to collect the wastes. At some point, it is better to construct a facility close to town, called a transfer station that acts as a temporary repository for wastes dropped off by local garbage trucks. Larger, long-haul trucks are then used to transport wastes from the transfer station to the disposal site.

Comparison of costs for Trucks Making One, Two, or Three Trips per Day to the Disposal Site under Conditions

<table>
<thead>
<tr>
<th>Number of trips per day</th>
<th>House served per truck</th>
<th>Minimum truck size (m³)</th>
<th>Annualized Costs</th>
<th>Cost per household ($/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Trucks ($/yr)</td>
<td>Labour ($/yr)</td>
</tr>
<tr>
<td>1</td>
<td>1725</td>
<td>24.6</td>
<td>108,570</td>
<td>62,400</td>
</tr>
<tr>
<td>2</td>
<td>1425</td>
<td>10.2</td>
<td>50,710</td>
<td>62,400</td>
</tr>
<tr>
<td>3</td>
<td>1125</td>
<td>5.4</td>
<td>31,430</td>
<td>62,400</td>
</tr>
</tbody>
</table>

The table above shows the comparison of costs for different numbers of trips per day. The costs include both the annualized costs for trucks and labour, as well as the cost per household. As the number of trips per day decreases, the overall cost per household also decreases, indicating a potential cost savings with a decrease in the number of trips per day.
Again, a design decision must be made: At what point is the disposal site so far away that the added costs of a transfer station are justified? The problem we need to analyze. The procedure for deriving the cost versus distance, corresponding to a direct haul by the collection vehicles, has already been demonstrated. Example of what that might look like. What needs to be done now is an analysis of the transfer station and its associated fleet of long-haul trucks.

The cost of a transfer station itself depends on many factors, including its size, local construction costs, and the price of land. In addition, transfer stations can employ a variety of technological features that also contribute to costs. Simple transfer stations may consist of just a lightweight building shell with a thick concrete slab called a tipping floor. Collection vehicles drop their refuse onto the tipping floor while a front loader scoops it up and loads the transfer vehicles. More complex facilities may include hoppers for direct deposit of refuse from collection vehicles into transfer vehicles. They may also have compaction equipment to compress the wastes before loading. Some transfer stations compress wastes into dense bales (600kg/m$^3$) that can be loaded with forklifts onto flatbed trucks. Baled refuse is especially convenient for or barge transport.

Trucks that haul wastes from transfer stations to the disposal site are usually large tractor-trailer vehicles. The trailers may open topped or closed, but closed trailers are preferred since they are less likely to spread debris along the highway and the wastes can be more easily compacted in the trailer. Open trailers carry on the order of 30 to 100m$^3$ of refuse with densities of 120 to 180kg/m$^3$. Since the density of wastes in closed trailers may be higher (300 to 500 kg/m$^3$), closed trailers are usually smaller (30 to 60 m$^3$) to keep the total vehicle weight below highway load limits.
CONVEYORS FOR SOLID WASTES

Conveyors are made in such a wide variety of types that all that can be attempted here is to give an idea of the range of options available.

It is not possible to be categorical in recommending one type over another. Almost the only definite statement one can make about the mechanical conveying of solid wastes is that it is an extraordinarily difficult area of design. Domestic waste comes in component sizes from dust and ashes to furniture and refrigerators. It may contain soft pillows and toughened-steel-wire bedsprings. Many components will be dry and hard; others will be wet and sticky. Within the range of possible sizes of storage piles, refuse hoppers, and conveyor belts, solid waste may have an “angle of repose” (the angle of the sides of a freely formed heap of material) of greater than 90 degrees. It tends to “bridge” over hoppers and belts. It can gum up or become entangled with drives. Man incinerator-feeding arrangements which were built with plate conveyors at the bottom of receiving hoppers and designed to work automatically have operated only with the constant attention of a man with a long-handled fork, whose job it is to break down bridges in the refuse and to remove other sources of blockage.

Some feeding arrangements have, however, worked successfully. In other words, the human intervention required is occasional rather than constant. At this time it is not possible to state the reasons why some installations work and others do not. However, two tentative conclusions can be drawn.

1. As domestic refuse has a fairly characteristic range of sizes of components with a definite upper limit (set by the size of the collection-vehicle hopper), large-capacity or wide conveyors perform better than do low-capacity or narrow conveyors.

2. Vibratory feeding arrangements in hoppers and elsewhere are desirable.
Flat-belt Conveyors: Flat belts are used to move airline luggage and parcel post, but would be suitable only for presorted components of domestic refuse, for instance, the larger items.

It is comparatively simple to arrange diverters to switch items from a flat belt, making it attractive for use in a recycling plant. Curved portions may be used to allow bends to be incorporated.

Conveyor belts are useful for distances of a few feet up to 100 km (a 100 km belt is being planned for use in the Sahara).

Dished Belts: Belts are more usually fished when bulk material, such as ashes or compost, is to be carried.

Apron and Pan Conveyors: An alternative to dishing is to have vertical sides to a flat-belt or flat-plate conveyor or to have the belt composed of pans having sides and ends.

Ribs and Cleats: various forms of retainers may be used when materials are to be lifted or lowered up or down inclines. Examples are ribs, cleats and studs.

Snaking Belts: When continuous smooth curves in the layout of the conveyor are needed, the belt material must be capable of lateral deformation. Wire-mesh and corrugated-composition belts are the principal candidates.

Drag Conveyors and Flight Feeders: With relatively homogeneous materials such as sewage sludge and incinerator ash, it is possible to allow the material to be supported in a stationary channel and to move it by means of two chains or wire ropes having cross links or plates.

Bucket Elevators and Belts: If the pan in a pan conveyor is pivoted so that it will hang vertically whatever the angle of the chain or belt, it is termed a bucket belt or elevator. Bucket elevators are also mounted on wheels for moving bulk materials.
**Squeeze Conveyors:** Sometimes two ribbed flat-belt conveyors, one inverted, with a decreasing gap between them in the direction of motion, are used to compress and feed refuse to, for instance a baling press.

**Vibrating Conveyors:** In vibratory conveyors the material is thrown into the air (or at least, it is moved vertically with sufficient acceleration for the reaction between it and the surface to decrease substantially) and the surface is then moved sharply backwards. When the material is coming down and the conveyor surface is going up, the surface is moved forwards.

The motion of the conveying surface may be set by a “forced” vibration, as by a cam or crank, or it may be a free vibration, from the action of one or more out-of-balance masses on a spring-mounted conveyor. In this case, the motion may occur at a natural frequency of vibration, when it is likely to be of relatively large amplitude (some inches) or may be well below or above the natural frequency, with amplitude of a few hundredths of an inch.

The motions produced in the conveyor may be circular, elliptical, or other. Vibratory conveyors form expensive methods of moving materials long distances, but they may be very effective for breaking down voids and bridges, for spreading material across a subsequent flat dished belt or, or for simultaneously moving and screening materials.

**Worm or Screw Conveyors:** A screw turning inside a barrel can move materials small distance, and are popular as feeders. Refuse will become crushed-partially comminuted-during this motion and some refuse compactors and collection vehicles rely entirely on this action to provide compaction.

**Overhead Conveyors:** All of the conveyors mentioned to this point except the screw conveyor have the refuse carried over the conveying system. It is also possible to have the conveyor overhead and to suspend materials from it. Such an arrangement is obviously suitable only for certain components of refuse. For instance, in one projected reclamation plant an overhead conveyor I the
receiving area will be used to take large pieces or bundles of cardboard and newspapers to a pulper.

A special form of overhead conveyor is usually used in a reclamation plant-the overhead magnet for separating ferrous materials.

**Merits and demerits of direct and indirect methods of transportation**

i) Direct method is economical, when the area being served is small.

ii) Direct method is suitable, if sufficient sites of disposal are available closely.

iii) In indirect method more distant sites of disposal can be used economically.

iv) By indirect method, collection capacity of a fixed number of collection vehicles effectively increases as the vehicles are free from direct transportation.

v) By using transfer stations, efficient use of equipment and personnel can be made. This reduces the overall cost of transportation.

**CURRENT DISPOSAL METHODS OF SOLID WASTE MANAGEMENT**

The final functional element in the solid waste management system depicted in is disposal. Disposal is the ultimate fate of all solids wastes, whether they are wastes collected and transported directly to a landfill site, semi-solid waste (sludge) from industrial treatment plants, incinerator residue, compost, or other substances from various solid-waste-processing plants that are of no further use.

A number of different collection and disposal methods are in use in the United States and will be discussed in this section. Fairly recent data are available from the Nation Solid Wastes Survey. It estimates of the approximate fractions of household, commercial, and municipal wastes actually collected that were disposed of by the various methods are given below.
77 per cent in open dumps (including landfills covered less frequently than once a day)
13 per cent in sanitary landfills
8 per cent in municipal incinerators
2 per cent by miscellaneous methods (composting, hog feeding, ocean dumping, salvage operations)

The drive to close open dumps and replace them by sanitary landfills has probably reduced the open dumps to about 60 per cent and increased the sanitary landfills to about 30 per cent.

**Hog feeding**

Hogs were once extensively used for garbage disposal. In colonial times hogs wandering the streets were scavengers of the wastes in the gutters. As urban areas developed, nearby hog farmers found it desirable to collect urban garbage for feeding hogs. A 1941 survey of the 412 U.S cities with a population of 25,000 or more in the 1940 censure found that 2 million metric tons of the 7 million metric tones of garbage produced and collected in those cities were used for feeding hogs. Experiments showed that a gain of 100 kg live weight could result from the feeding of 6 metric tons of garbage, and that the resulting pork would amount to 55 kg. complete use of all U.S. urban garbage for feeding hogs would have provided pork equivalent to only about 2 per cent of 1940 U.S. production, however, so that this use was not major threat to other sources of hog feed.

**Open dumps**

Disposing of solid wastes in open dumps is the most common waste disposal method used in the United States. Much of the uncollected refuse is disposed of privately in a similar manner in ravines, swamps, and other locations. Open dumps, which produce health and air pollution problems and are an aesthetic insult, are not an acceptable method of disposal. They can cause public
health problems by encouraging the growth of populations of files (which can transmit typhoid fever, cholera, dysentery, tuberculosis, anthrax, and other diseases), rats (which can transmit plague, murine typhus fever, leptospirosis, rabies, rickettsialpox, and other diseases), cockroaches, mosquitoes (which can transmit malaria, yellow fever, dengue, mosquito borne encephalitis, and filariasis), and other pests. Air pollution problems arise when the dumped wastes are burned in order to reduce their volume and to conserve space or when spontaneous combustion or arson leads to fires.

**Sanitary Landfills**

The sanitary landfill became common after World War II, although its origins date back to pre-world War I days, at least for the disposal of garbage. In sanitary landfill operations, refuse is spread in thin layers that are compacted by heavy bulldozers before another layer is spread. Alter the refuse is perhaps 3 m deep; it is covered by a thin layer of clean earth, which is again compacted. At the end of the day, the fill is topped with another meter of compacted earth. (In some landfills, which are not properly sanitary landfills, covering is less frequent than once a day).
The advantages of a sanitary landfill, as opposed to an open, uncovered dump, are (1) the public health problems are minimized, because flies, rats, and other pests are unable to breed in the covered refuse; (2) there is no air pollution from burning and none from dust or odors; and (3) fire hazards are very small. There is danger of groundwater or surface water pollution, however, if the landfill site is improperly chosen or if it is dug too deep.

**Incineration**

There are several hundred municipal incinerators in use in the United States, accounting for about one hand the tonnage burned, and there are thousands of small, privately owned trash burners. True incineration requires the burning of solid wastes at high temperatures, the remaining ashes, glass, metal, and unburned combustibles amounting to perhaps one-fourth their original weight; this remainder must then be disposed of in a landfill or other dump. Air pollution is often a problem, and New York City has had to legislate the upgrading of incinerators in apartment buildings because of emissions into the atmosphere. Incinerator technology has been developing in recent years, with air pollution control a particular concern. Many of the newer incinerators are designed to recover the heat for useful purposes, such as making of steam.

**Ocean Dumping**

Some coastal cities dump solid wastes into the ocean. New York City formerly dumped wastes off the New Jersey shore but in 1933 New York still dumps wastes over an area several square kilometers in size 20 km out into the Atlantic Ocean; this area has been described by critics as a “dead sea” of muck and black goo, largely because of the sewage sludge disposed there. In 1974 there were 14 active ocean dumping sites for municipal and industrial solid wastes, 53 for sewage sludge, and 89 for dredge spoils. Dumped wastes in 1973 totaled about 5 million metric tons each of industrial waste and sewage sludge, 1 million metric tons of demolition wastes, and 40 million metric tons of dredged
materials. Permits for ocean dumping are issued by the U.S. Environmental Protection Agency under its Ocean Disposal Program.

**Composting**

Another interesting idea for the utilization of municipal refuse is composting, which is practiced on a large scale in some European countries but has not been tried extensively in the United States. Composting involves fermentation of refuses into a product, compost, which supplies valuable humus for the soil. The composting is generally accomplished by heaping the refuse and moistening it, and then letting it ferment for about six months (the decomposition is faster if the refuse is first ground up into smaller particles). The fermentation occurs at 50 to 80°C, which is apparently too high for pathogens to survive, so disease is not of concern. Sewage sludge can also be added to the compostable material. Compost is valuable as a soil conditioner, because no artificial product is capable of adding humus to the soil. Its fertilizer value is very low—typically it contains 0.5 per cent nitrogen, 0.4 per cent phosphorus, and 0.2 per cent potassium.

**Waste Management and 3Rs concept**

In South Asian countries, the promotion of 3R in the Domestic Solid Waste Management over-emphasises “Recycle and Reuse”, and less focus is given to “Reduction”. It is also interesting to note that due to the low purchasing capacity in the developing countries the market is overflowing with low quality and cheap products creating more waste after its short useful life.

Prior to formalising the 3Rs concept in the waste management hierarchy, few financial and economic issues need to be addressed and resolved.

- Is there any budget allocated for 3Rs activities such as awareness, motivation etc?
- How 3R can be used to meet the budget and expenditure of local governments?
How to link the 3R financing and environmental benefits?

As for Japan, 3R activities are promoted under the concept of “Sound Material-Cycle Society”. Both treatment and 3R technology are well developed and implemented as part of the solid waste management program. Several cities and towns get together and constitute one wide area over which an efficient 3R system is planned and implemented. An integrated system with various facilities for the 3Rs, such as biomass utilization, recycling, waste power plants, asbestos treatment and so on, are formulated under close collaboration among cities and towns.

Reduction in waste generation

“Prevention is better than cure”, so goes an old adage, and it is one of the best method to deal with the problem of solid waste. By preventing (reducing) the generation of waste itself, we can minimize other problems (namely, disposal) related to waste to a great extent. In order to reduce waste generation several methods or tool can be applied, some of which may be:

- Enacting public policies that discourage the production, sale and consumption of products containing unnecessary packaging material. Places where flow of products cannot be controlled appropriate policy measures (extended producers responsibility, taxes, economic incentives etc) should be put in place to discourage unnecessary waste generation. Policies should also look into the aspect of encouraging reusable and recyclable products instead of disposable products (Medina 2002).
- Promotion of local grown products and less reliance on packaged food products go a long way in reducing wastes.
- Education can play a critical role by creating awareness regarding the waste and related issues among the masses.

In a developing country framework, reduction in waste generation should be targeted towards producers; because of excessive packaging, more waste is created. From the consumers’ side, reduction in waste can be generated by
educating the consumers on ways to prevent waste; for instance asking the consumers to use a reusable bag for shopping rather than rely on goods being bagged in numerous poly bags, can significantly reduce the use of poly bags which are the main source of waste in numerous developing countries.

**Reuse and repair**

Reusing relates to the recovery of items to be used again. Reusing ensures reduction in raw material consumption saves energy and water, reduces pollution and prevents the generation of waste. Medina (2003) regards reuse of materials and products as more socially desirable than recycling the same materials. For instance, in India, soft-drinks (Coke, Pepsi etc) are sold in glass bottles and a deposit-refund system operates. A person deposits some amount of money on purchase of the soft drink, which he/she gets back on depositing the bottle, thus enabling the producer to regulate his supply of container without having to produce new ones. Products, such as office furniture and appliances, can also be reused. For instance Manitoba Hydro donated their old office furniture and building waste to Manitoba eco-network, which was used to build a new office for the network; thus saving both time and valuable resources for both Manitoba Hydro and Eco-network. A reuse program not only saves money, it also can be a source of revenue for the companies/households that implement it. The best example would be Interface, which reuses old carpets to produce new ones, thus saving valuable resources and promoting sustainability at the same time. Public policies that provide incentives for businesses and individuals to engage in reuse can have a significant and positive economic and environmental impact (Sudhir et al. 1997, Medina 2002, Zerboc 2003). In a developing country framework, it is to be noted that due to poor economic conditions, repairing and reusing of materials and products is a standard practice, and generally people in the developing countries reuse much more than people living in the developed countries.
Recycling

After source reduction, which is given the highest priority in the solid waste management hierarchy, the recovery of materials for recycling and composting is generally thought to be the next most important component of integrated solid waste management programs. Resource recovery means that the materials have not only been removed from the municipal waste streams, but they also must be, in essence, purchased by an end user. That distinction, for example, means yard trimmings composted at home are considered to be source reduction, not recycling. On the other hand, yard trimmings that are delivered to an off-site composting facility and then sold are considered to be recovered or recycling materials.

The term recycling is often misconstrued to include activities such as refilling bottles for reuse and remanufacturing products for resale to consumers, but it is better to use the term recycling only when materials are collected and used as raw material for new products. The process of recycling includes collecting recyclables, separating them by type, processing them into new forms that are sold to manufacturers, and finally, purchasing and using goods made with reprocessed materials.

The rate of recovery of materials from the waste stream, as reported by the Environmental Protection Agency, has increased dramatically in the last decade or so. Resource recovery grew from less than 10 percent of all municipal solid waste in 1980 to 22 percent in 1993. Most of that increase is attributable to greater rates of recovery composting of paper and paperboard and increase composting of yard trimmings. U.S. recovery rates for a number of categories of MSW. Notice how dominant the paper and paperboard category is in terms of total tones of materials recovered [almost 60 percent], which tends to mask the importance of recovery rates for other materials. For example, recovered aluminum is only about 3 percent of the total mass of recovered materials, but in terms of its total economic value it far exceeds the paper products category.
Examples of products that can be recycled and typical applications of the materials that are so produced. Details of the products,

![a) recyclable](image1.png)

![b) Recycled](image2.png)

Labels on paper products designating the product as being recyclable after use or made predominately from recycled materials.

### GENERATION AND RECOVERY OF MATERIALS MSW IN THE UNITED STATES, 1993 [Millions of tones]

<table>
<thead>
<tr>
<th>Types of materials</th>
<th>Amount Generated</th>
<th>Amount Recovered</th>
<th>Percent Recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper and paperboard</td>
<td>70.6</td>
<td>24.0</td>
<td>34.1</td>
</tr>
<tr>
<td>Glass</td>
<td>12.4</td>
<td>2.7</td>
<td>22.0</td>
</tr>
<tr>
<td>Metals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferrous metals</td>
<td>11.7</td>
<td>3.1</td>
<td>26.1</td>
</tr>
<tr>
<td>Aluminum</td>
<td>2.7</td>
<td>1.0</td>
<td>35.4</td>
</tr>
<tr>
<td>Other nonferrous metals</td>
<td>1.1</td>
<td>0.7</td>
<td>62.9</td>
</tr>
<tr>
<td>Total metals</td>
<td>15.5</td>
<td>4.7</td>
<td>30.0</td>
</tr>
<tr>
<td>Plastics</td>
<td>17.5</td>
<td>0.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Rubber and leather</td>
<td>5.6</td>
<td>0.4</td>
<td>5.9</td>
</tr>
<tr>
<td>Textiles</td>
<td>5.5</td>
<td>0.6</td>
<td>11.7</td>
</tr>
<tr>
<td>Wood</td>
<td>12.4</td>
<td>1.2</td>
<td>9.6</td>
</tr>
<tr>
<td>Other materials</td>
<td>3.0</td>
<td>0.6</td>
<td>22.1</td>
</tr>
<tr>
<td>Total materials is products</td>
<td>142.7</td>
<td>34.9</td>
<td>24.5</td>
</tr>
<tr>
<td>Other wastes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food wastes</td>
<td>12.5</td>
<td>Negligible</td>
<td>Negligible</td>
</tr>
<tr>
<td>Yard trimmings</td>
<td>29.8</td>
<td>5.9</td>
<td>19.8</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inorganic wastes</td>
<td>2.8</td>
<td>Negligible</td>
<td>Negligible</td>
</tr>
<tr>
<td>Total other wastes</td>
<td>45.1</td>
<td>5.9</td>
<td>13.1</td>
</tr>
<tr>
<td>Total municipal solid waste</td>
<td>187.7</td>
<td>40.8</td>
<td>21.7</td>
</tr>
</tbody>
</table>

Source: U.S. EPA 1994g
Economics of Recycling

While the environmental and resource value of recycling is clear, the economic viability under current market and regulatory conditions is less certain. To make an economic assessment, we need to explore the collection costs, the cost of materials processing, the market value of recycled materials, and the tipping fees avoided by reduction the amount of waste that ends up at the local landfill or incinerator.

To a significant extent, there is a tradeoff between the cost of collection and the cost of processing. For example, separate collection of source-separated recyclables is expensive, but the processing that follows collection is relatively cheap. Moreover, overall resource recovery rates may be lower if consumers balk at being asked to do most of the source separation. At the other extreme, using the same packer to pick up recyclables and mixed waste cuts collection costs, but raises the cost of processing. In this case, everyone participates
whether they like it or not, so potential recovery rates are high. Also complicating the economics is the tradeoff between extensive and sorting at the materials recovery facility, common when volumes are low, and mechanized sorting, which predominates in larger operations. Finally, data on costs are hard to come by, difficult to interpret, and often based on widely varying assumptions and accounting practices.

**Resource Recovery**

In recent years dozens of communities have launched programs to recover resources present in the solid wastes. Resource recovery appears to be one of the most important ideas for solid waste management in the future and is discussed further in a later section.

**For discarding wastes the following methods can be adopted:**

  (i) **Sanitary landfill:** In a sanitary landfill, garbage is spread out in thin layers, compacted and covered with clay or plastic foam.

  In the modern landfills the bottom is covered with an impermeable liner, usually several layers of clay, thick plastic and sand. The liner protects the ground water from being contaminated due to percolation of leachate. Leachate from bottom is pumped and sent for treatment. When landfill is full it is covered with clay, sand, gravel and top soil to prevent seepage of water. Several wells are drilled near the landfill site to monitor if any leakage is contaminating ground water. Methane produced by anaerobic decomposition is collected and burnt to produce electricity or heat.

  (ii) **Composting:** Due to shortage of space for landfill in bigger cities, the biodegradable yard waste (kept separate from the municipal waste) is allowed to degrade or decompose in an oxygen rich medium. A good quality nutrient rich and environmental friendly manure is formed which improves the soil conditions and fertility.
(iii)Incineration: Incinerators are burning plants capable of burning a large amount of materials at high temperature. The initial cost is very high. During incineration high levels of dioxins, furans, lead and cadmium may be emitted with the fly ash of incinerator. Dioxin level may reach many times more than in the ambient environment. For incineration of materials, it is better to remove batteries containing heavy metals and plastic containing chlorine before burning the material. Prior removal of plastics will reduce emissions of dioxins and polychlorinated biphenyls (PCBs).

Materials Recovery Facilities

Recyclable materials need to be sorted to separate the glass, plastics, newspaper, cans, and so forth. If a community has a recycling system in place, some of this separation is usually done by consumers, some may be done by the crew of the recycling truck as they make their pick-ups, and some is typically done at a Materials Recovery Facility (MRF). If there is no recycling system geared toward consumers (that is materials that could be recycled are mixed in with all of the other refuse collected), there still may be some attempt at recovery. A facility that tries to recover recyclable materials that are mixed in with all the usual municipal solid waste is referred to as a Waste Processing Facility (WPF) or sometimes as a front-end processing system. These definitions are not precise; for example, a not uncommon collection system has consumers put their commingled recyclables into separate (usually blue) bags, which are tossed into the truck with the rest of the mixed waste. The blue color of those bags helps them stand out visually from dark green, plastic garbage bags, which facilitates their removal at a processing facility.

The primary function of a materials recovery facility is to separate bottles by color, plastics by resin, cans by their metal content, as well as old newspapers (ONP), old corrugated containers (OCC), and compostable organics. The second
function is to density those separated materials so that they can be more easily shipped to end users. Densification includes crushing bottles, flattening metal cans, granulating and baling plastics, and baling waste paper.

Since different communities have differing degrees of preseparation by consumers and truck crews, materials recovery facilities also have a range of equipment and processes. Almost all will include a significant amount of hand separation supplemented by varying amounts of automated equipment. Smaller facilities tend to use more labour since they may not process enough waste to justify the cost of automated equipment, but even large facilities use workers for some amount of handpicking and quality control.

The usual MRF is designed to receive old newspapers and corrugated cardboard that have already been separated from the bottles, cans, plastics, and glass. This not only simplifies processing, but it helps reduce contamination of paper products from food and chemical wastes that may accompany the other recyclables. A separate area of the tipping floor, with its own conveyor belt, receives newspapers and cardboard. Sorters stand by the conveyors belt, removing cardboard, which will be baled later, along with paper and plastic bags, string, and other foreign materials, which are discarded. Newspapers remain on the belt and are fed into a bailer that compact them and wraps them with wire to form bales. A typical bale is approximately 0.75m by 1.2 m by 1.5m (30x48x60 inches). The same baler can be used to make bales of corrugated cardboard, PET, HDPE, aluminum, or ferrous metals. The removal of specific items, such as cardboard, from the conveyor is referred to as positive sorting, to distinguish it from negative sorting, in which the product in question (say newspaper) is left on the conveyor belt.
COMPOSTING

Yard trimmings and food waste account for almost one-fourth of the mass of all municipal solid waste generated in the United States. Prior to the 1990s, essentially all of that ended up as discards sent to the local landfill or incinerator. As the limited remaining life of landfills becomes more critical, it is apparent that source reduction and recycling programs should be implemented for these wastes as well as all the others. In fact, by the mid-1990s, over half of the U.S. population lived in states having regulations restricting disposal of yard trimmings (U.S. EPA, 1994b). The impact of those programs is beginning to be felt. The generation rate of yard trimmings is dropping as more and more households implement backyard composting, and the recovery rate for yard trimmings is increasing rapidly as municipalities implement their own composting programs. The number of facilities in the United States that handle yard trimmings has grown rapidly, from around 800 in 1988 to over 3200 in 1994 (Steuteville, 1995). Notice the distinction between backyard composting, which is a form of source reduction since it reduces the amount of waste that has to be collected, and municipal composting, which is considered a form of recycling since it creates a marketable product out of collected wastes.

Temperature

In the early stages of decomposition, mesophilic microorganisms (bacteria and fungi that grow best at temperatures between 25 and 45°C) generate heat while they metabolize the waste, which raises the temperature of the pile. When temperatures reach temperatures between 45 and 70°C, take over the decomposition. Inside the compost pile, temperatures continue to increase as long as nutrient and energy sources are plentiful for the thermopiles. If the pile temperature stays above 55°C for more than 72 hours, most pathogens and weed seeds will be destroyed, making a more marketable end product. Eventually, the nutrient supply drops, thermopiles die off, the temperature falls, and mesophilic
micro organism once again dominate the decomposition process until stable end products are formed.

**pH**

In the early stages of decomposition, organic acids are formed, which cause the pH of the pile to drop to about 5. When the pH is this low, acid-tolerating fungi dominate. Eventually microorganisms break down the organic acids and the pile pH rises.

**Nutrient levels**

A number of nutrients must be available to the microorganisms that are attacking and degrading the compost pile. The most important nutrients needed are carbon for energy, nitrogen for protein synthesis, and phosphorus and potassium for cell reproduction and metabolism. In addition, a number of nutrients are needed in trace amounts, including calcium, cobalt, copper, magnesium, and manganese.

One of the best indicators of the likely health of microorganism is the ratio of carbon to nitrogen available to them. An ideal C:N ratio is roughly 25 to 35 parts of available carbon to available nitrogen. High C:N ratios inhibit the growth of microorganisms, slowing the decomposition. Low C:N ratios accelerate the rate of decomposition, but may cause loss of nitrogen as ammonia gas and may cause rapid depletion of the available oxygen supply, leading to foul-smelling anaerobic conditions. Leaves, cornstalks, rice hulls, and paper are examples of materials that have high C:N ratios, while grass clippings and sewage sludge have low C:N ratios. Examples of high carbon content and high nitrogen content feedstock.
### Carbon-To-Nitrogen Ratios of Various Materials

<table>
<thead>
<tr>
<th>Types of Feedstock’s</th>
<th>C:N Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn stalks</td>
<td>High Carbon Content</td>
</tr>
<tr>
<td>Foliage</td>
<td>60:1</td>
</tr>
<tr>
<td>Dry leaves and weeds</td>
<td>40-80:1</td>
</tr>
<tr>
<td>Mixed MSW</td>
<td>90:1</td>
</tr>
<tr>
<td>Sawdust</td>
<td>50-60:1</td>
</tr>
<tr>
<td>Cow manure</td>
<td>500:1</td>
</tr>
<tr>
<td>Food scraps</td>
<td>High Nitrogen Content</td>
</tr>
<tr>
<td>Grass clippings</td>
<td>18:1</td>
</tr>
<tr>
<td>Humus</td>
<td>15:1</td>
</tr>
<tr>
<td>Fresh leaves</td>
<td>12-20:1</td>
</tr>
<tr>
<td>Nonlegume vegetable scraps</td>
<td>10:1</td>
</tr>
<tr>
<td></td>
<td>30-40:1</td>
</tr>
<tr>
<td></td>
<td>12:1</td>
</tr>
</tbody>
</table>

Source: U.S. EPA, 1994b

By properly combining different kinds of solid wastes, the C:N ratio can be brought into the desired range. Mixing dry leaves with grass clippings, for example, helps balance the ratio, leading to rapid decomposition without foul odors. Sewage sludge, which is high in water as well as nitrogen, nicely complements municipal solid waste, which tends to be low in moisture and nitrogen. When composted properly, high compost temperatures not only kill pathogens but promote the drying of sewage sludge, which helps reduce the cost of sludge dewatering.

#### Oxygen

As aerobic microbes degrade waste, they remove oxygen from the pile. If the supply of oxygen is insufficient to meet their needs, anaerobic microorganisms will take their place, slowing the degradation process and
producing undesirable odors. Oxygen can be supplied by simply mixing or turning the pile every so often, or piles can be aerated with forced ventilation.

Compost piles that are aerated by mixing need to be turned anywhere from once or twice a week to once per year. More frequent turning speeds the composting process and helps prevent anaerobic conditions, but it may cause the pile to dry out or cool down too much. Such turned windrows can complete the composting of yard trimmings in roughly three months to one year. Composting can be speeded up (which also reduces the land area required), by incorporating a force aeration system. Wastes are stacked on top of a grid of perforated pipes and a blower forces air through the pipes and composting materials. Composting can be completed in as little as three to six months using this method (U.S. EPA, 1994b).

**Discarded Materials**

Recall the definitions used to describe the flow of solid waste materials through our society. Source reduction (e.g., lightening containers) and reuse (e.g. refilling glass bottles) are activities that reduce the amount of materials that enter the municipal waste stream. What remains are referred to as MSW materials generated. Some of those materials are recovered from the waste stream and recycled or composted, leaving materials that are discarded. Those remaining discards are burned or buried.

**Waste-To-Energy Combustion**

The history of combustion of solid wastes in the United States clearly demonstrates the controversial nature of this method of waste disposal. In 1960 a little over 30 percent of MSW was burned. That percentage dropped rapidly during the 1960s and 1970s, reaching a low a of less than 10 percent in 1980. With increased emphasis on avoiding landfilling, with better emission control systems and with better incinerators that were designed to allow the recovery of energy along with volume reduction, combustion of MSW increased to about 16
percent of MSW generation by 1990. EPA projections suggest that incineration will remain in the 15 percent range though the year 2000, with almost all of that (93 percent) utilizing energy recovery.

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper and paperboard</td>
<td>22.2</td>
<td>33.3</td>
<td>38.8</td>
<td>47.4</td>
<td>46.5</td>
</tr>
<tr>
<td>Yard trimmings</td>
<td>18.1</td>
<td>21.0</td>
<td>24.9</td>
<td>27.9</td>
<td>23.8</td>
</tr>
<tr>
<td>Plastics</td>
<td>0.4</td>
<td>2.8</td>
<td>7.1</td>
<td>14.9</td>
<td>16.9</td>
</tr>
<tr>
<td>Food wastes</td>
<td>11.0</td>
<td>11.6</td>
<td>11.9</td>
<td>11.9</td>
<td>12.5</td>
</tr>
<tr>
<td>Wood</td>
<td>2.7</td>
<td>3.6</td>
<td>6.1</td>
<td>10.8</td>
<td>11.2</td>
</tr>
<tr>
<td>Metals</td>
<td>9.4</td>
<td>12.3</td>
<td>12.0</td>
<td>11.7</td>
<td>10.8</td>
</tr>
<tr>
<td>Glass</td>
<td>6.0</td>
<td>11.3</td>
<td>12.9</td>
<td>9.5</td>
<td>9.6</td>
</tr>
<tr>
<td>Rubber and leather</td>
<td>1.5</td>
<td>2.7</td>
<td>3.8</td>
<td>5.1</td>
<td>5.3</td>
</tr>
<tr>
<td>Textiles</td>
<td>1.6</td>
<td>1.8</td>
<td>2.3</td>
<td>5.3</td>
<td>4.9</td>
</tr>
<tr>
<td>Other</td>
<td>1.2</td>
<td>2.1</td>
<td>4.2</td>
<td>4.9</td>
<td>5.1</td>
</tr>
<tr>
<td>Total</td>
<td>74.1</td>
<td>102.5</td>
<td>124.0</td>
<td>149.5</td>
<td>146.6</td>
</tr>
</tbody>
</table>


Material Discarded in the Municipal Waste Stream, 1960 to 1993 (millions of tones per year) of developed countries around the world rely much more heavily on incineration than does the United States—especially if they have high population densities. Japan, for instance, burns almost two-thirds of its wastes, while Germany and France burn 30 and 41 percent, respectively.

In the early 1990s, the United States had 190 combustion facilities in operation that burned just under 30 million tonnes of waste. Most of these plants are located in the eastern part of the United States. Of these, 158 facilities were waste-to-energy plants, and all of those proposed for the future take advantage of energy recovery (Steuteville, 1995).

Incineration of MSW as a method of waste disposal has a number of favorable attributes, including volume reduction, immediate disposal without waiting for slow biological processes to do the job, much less land area requirements, destruction of hazardous materials, and the possibility of
recovering useful energy. There are trade-offs. For example, it is reasonable to question whether burning paper for its energy value or recycling it to reduce the environmental impacts of virgin pulping is the higher use for the material.

**Energy Content of MSW**

The energy content of municipal solid waste depends on the mix of materials that it contains as well as its moisture content. The standard test used to determine the heating value of a material involves completely burning a sample in a bomb calorimeter and then measuring the rise in temperature of a surrounding water bath. The result obtained is known as the higher heat value (HHV), or gloss heat value. Included in the HHV is energy contained in the vaporized water that is produced. Since this vapor is not usually condensed, that energy is lost and a more realistic estimate of the energy that can be recovered during combustion results, which is known as the lower heat value (LHV), or net energy. Table gives example higher heating values of various components of municipal solid waste “as received”—that is, without any particular effort to remove the moisture. For comparison, the energy content of fossil fuels is included.

<table>
<thead>
<tr>
<th>Material</th>
<th>kg</th>
<th>KJ/kg</th>
<th>kJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper and paperboard</td>
<td>31.7</td>
<td>15,800</td>
<td>500,860</td>
</tr>
<tr>
<td>Yard trimmings</td>
<td>16.2</td>
<td>6,300</td>
<td>102,060</td>
</tr>
<tr>
<td>Plastics</td>
<td>11.5</td>
<td>32,800</td>
<td>377,200</td>
</tr>
<tr>
<td>Food wastes</td>
<td>8.5</td>
<td>5,500</td>
<td>46,750</td>
</tr>
<tr>
<td>Wood</td>
<td>7.6</td>
<td>16,000</td>
<td>121,600</td>
</tr>
<tr>
<td>Metals</td>
<td>7.4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Glass</td>
<td>6.6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rubber and leather</td>
<td>3.6</td>
<td>22,300</td>
<td>80,280</td>
</tr>
<tr>
<td>Textiles</td>
<td>3.3</td>
<td>18,700</td>
<td>61,710</td>
</tr>
<tr>
<td>Miscellaneous other</td>
<td>3.6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td></td>
<td>1,290,460</td>
</tr>
</tbody>
</table>
Thus, typical discarded solid waste has an energy content of approximately 12,900 KJ/Kg (5,550 Btu/lb), which is a little less than half the energy content of coal and roughly 30 percent of the energy content of fuel oil.

The composition of MSW varies considerably around the world and so does its energy content. In developing countries, a relatively small fraction of the waste consists of manufactured materials such as paper, metals, plastic and glass, which means that the percentage that is food waste is high—usually over 50 percent. Since food waste has relatively low energy content, the heating value of MSW in the developing world tends to be lower than that of more industrialized countries. Khan and Abu-Ghararah (1991) have developed an equation that attempts to predict the heating value of MSW based on the paper and food fractions plus a term that accounts for plastic, leather, and rubber.

\[
\text{HHV (kJ/kg)} = 53.5(F + 3.6 CP) + 372 \text{ PLR}
\]

where \( F \) is the mass percent of food, \( CP \) is the mass percent of cardboard and paper, and \( \text{PLR} \) is the mass percent of plastic, rubber, and leather in the waste mixture.

Only in unusual circumstances can the HHV of a fuel be captured. Usually the latent heat contained in water vapor is lost to the atmosphere rather than being captured by the power plant. There are two possible sources of that water vapor loss: moisture in the wastes, and hydrogen in the waste that can react with oxygen to form water. Using 2440 kJ/kg as the latent heat of vaporization for water (at 25°C), each kg of moisture that is vaporized and lost contains 2440kJ/kg of energy. In addition, each kg of hydrogen in the waste itself can produce another 9 kg of water vapor. The total energy lost in vaporized water is therefore,

\[
Q_L = 2440(W + 9H)
\]

where
$$Q_L = \text{latent heat of water vapor released (KJ)}$$

$$W = \text{kg of moisture in the waste}$$

$$H = \text{kg of hydrogen in dry waste}$$

Estimated High Heating Value of MSW for various countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Paper (%)</th>
<th>Metals (%)</th>
<th>Glass (%)</th>
<th>Food (%)</th>
<th>PLRa (%)</th>
<th>HHV (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>38</td>
<td>11</td>
<td>18</td>
<td>13</td>
<td>0.1</td>
<td>8.1</td>
</tr>
<tr>
<td>Colombia</td>
<td>22</td>
<td>1</td>
<td>2</td>
<td>56</td>
<td>5</td>
<td>9.1</td>
</tr>
<tr>
<td>Czechoslovakia</td>
<td>13.4</td>
<td>6.2</td>
<td>6.6</td>
<td>41.8</td>
<td>4.2</td>
<td>6.4</td>
</tr>
<tr>
<td>England</td>
<td>37</td>
<td>8</td>
<td>8</td>
<td>28</td>
<td>2</td>
<td>9.4</td>
</tr>
<tr>
<td>France</td>
<td>30</td>
<td>4</td>
<td>4</td>
<td>30</td>
<td>1</td>
<td>7.8</td>
</tr>
<tr>
<td>Germany</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>21</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td>India</td>
<td>3</td>
<td>1</td>
<td>8</td>
<td>36</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>Iran</td>
<td>17.2</td>
<td>1.8</td>
<td>2.1</td>
<td>69.8</td>
<td>3.8</td>
<td>8.5</td>
</tr>
<tr>
<td>Japan</td>
<td>21</td>
<td>5.7</td>
<td>3.9</td>
<td>50.0</td>
<td>6.2</td>
<td>9.0</td>
</tr>
<tr>
<td>Kenya</td>
<td>12.2</td>
<td>2.7</td>
<td>1.3</td>
<td>42.6</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Sweden</td>
<td>50</td>
<td>7.0</td>
<td>8.0</td>
<td>15</td>
<td>8.0</td>
<td>13.4</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>31.7</td>
<td>7.4</td>
<td>6.6</td>
<td>8.5</td>
<td>15.1</td>
<td>12.9</td>
</tr>
</tbody>
</table>

*PLR means plastic, leather, rubber.


**Mass Burn and Refuse-Derived Fuel**

Combustion for energy recovery is typically done in one of two ways: Either MSW is sent directly to a mass-urn incinerator, or it is preprocessed to produce a more homogeneous product called refuse-derived fuel (RDF) that has much better combustion characteristics. As of 1988, 77 percent of the capacity of municipal waste combustors in the United States was mass burn, while the
remaining 23 percent utilized RDFs. That ratio is shifting, however, with one-third of the capacity additions being RDF facilities (Denison and Ruston, 1990).

High and low heating values of combustible components of MSW

<table>
<thead>
<tr>
<th>Material</th>
<th>Moisture&lt;sup&gt;a&lt;/sup&gt; (%)</th>
<th>H&lt;sup&gt;b&lt;/sup&gt; (%)</th>
<th>HHV (KJ/kg)</th>
<th>LHV&lt;sup&gt;c&lt;/sup&gt; (KJ/Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed paper</td>
<td>10.2</td>
<td>5.8</td>
<td>15,800</td>
<td>14,400</td>
</tr>
<tr>
<td>Mixed food waste</td>
<td>72.0</td>
<td>6.4</td>
<td>5,500</td>
<td>3,400</td>
</tr>
<tr>
<td>Mixed green yard waste</td>
<td>62.0</td>
<td>5.6</td>
<td>6,300</td>
<td>4,300</td>
</tr>
<tr>
<td>Mixed plastics</td>
<td>2.0</td>
<td>7.2</td>
<td>32,800</td>
<td>31,200</td>
</tr>
<tr>
<td>Rubber</td>
<td>1.2</td>
<td>10.4</td>
<td>26,100</td>
<td>23,800</td>
</tr>
<tr>
<td>Leather</td>
<td>10.0</td>
<td>8.0</td>
<td>18,500</td>
<td>16,700</td>
</tr>
<tr>
<td>Textiles</td>
<td>22.0</td>
<td>6.4</td>
<td>18,700</td>
<td>17,100</td>
</tr>
<tr>
<td>Demolition softwood</td>
<td>7.7</td>
<td>6.2</td>
<td>17,000</td>
<td>15,500</td>
</tr>
<tr>
<td>Waste hardwood</td>
<td>12.0</td>
<td>6.1</td>
<td>15,000</td>
<td>13,500</td>
</tr>
</tbody>
</table>

<sup>a</sup>percent moisture is as received, by weight

<sup>b</sup>H is percent hydrogen in dry mass

<sup>c</sup>LHV is computed from (9.8)

Source: Based on data given in Niessen (1997)

A sketch of a mass-burn, rotary-kiln furnace receiving refuse directly from a packer truck. Heat recovery from the water walls, convection tubes, and super heater provides steam that can be used for process heat or space heating in nearby industrial facilities, or the steam can be used to generate electricity, which can be transported more easily over long distances.

**BETTER SOLID WASTE MANAGEMENT**

Solid wastes have been defined as “resources out of place”. It has long been known that valuable materials can be recovered from solid wastes, thereby lessening disposal problems and reducing costs. Over the years, the practice of
salvaging of materials from solid wastes has occasionally been followed, been abandoned when it became uneconomical, and sometimes been revived, items, that have had resale value at some time include rags, newspapers, cardboard, bottles, rubber, tin cans, ferrous metals, nonferrous metals, and glass. At one time some cities (such as Washington, D.C., in the 1920s) passed their refuse onto a continually moving belt from which salvageable materials could be picked off. Increasing labor costs, depressed scrap markets, and a general trend toward unconcern about the possible waste of natural resources made recovery less common until interest renewed in the late 1960s.

Better solid waste management in the future must require a combination of resource recovery and source reduction. “Resource recovery” is the term generally applied to methods in which some of the valuables from solid wastes are recovered rather than simply discarded. “Source reduction” refers to avoidance of solid wastes by better design of products that could (or have) become wastes.

There are three different approaches to resource recovery. Utilization involves taking solid wastes and finding a new use for them, one that is generally unrelated to the origin of the wastes. Reuse involves using items that are (or could be) in the solid waste stream for exactly the same purpose as they were used initially. Recycling refers to using the resources as raw materials again, for the same or a different purpose.

**Utilization**

Some solid wastes can be put to direct use. Fly and bottom ash from industrial installations in the United States now total about 30 million metric tons annually, of which only some 5 to 10 per cent is used commercially, largely as a cement substitute in concrete for dams, highways, and other major construction.
These fractions are much less than those in some foreign countries; for example, some 50 per cent of the fly ash in France and 40 per cent in Great Britain find commercial application and do not need to be treated as solid waste. New uses are being developed for fly ash in the United States and other countries; to make brick, to dewater industrial waste water sludge, as a land cover, and for other uses.

Ordinary municipal wastes can also be burned to produce heat or electricity. They typically have a heat of combustion of about $1.2 \times 10^9$ J/kg (5000 btu/lb) and may have 20 per cent more if the inorganic wastes have been removed. Paper and plastics are responsible for much of this heat content. The wastes can be burned in special water-wall incinerators to produce steam or can (after appropriate treatment) be burned along with coal in the furnace of a steam-electric plant. With a heating value of one-third to one-half that of coal, depending on the nature and treatment of the wastes, the solid wastes for a typical American community could provide approximately 10 per cent of its electric power requirements.

Several European cities, as well as others elsewhere, have built incinerators to produce steam. An incinerator Montreal put into operation in the early 1970s to burn 1100 metric tons of refuse daily to produce stream. Several U.S. communities began doing the same thing during the 1970s, and some private concerns have followed suit, contracting with communities to take their solid wastes.

Beginning in 1972 the major test of burning wastes along with coal was carried out by the Union Electric Company in cooperation with the U.S. Environmental Protection Agency and the city of St. Louis, Missouri. Part of the refuse form St. Louise was added to pulverized coal fuel for modified steam
boilers. The success of the experiment led the utility to announce in 1974 that it would construct a solid wastes utilization system to handle all the wastes of the St. Louis metropolitan area, amounting to approximately 2.5 million metric tons annually. When the system is completed, private and public collectors will bring the wastes to six collection/transfer centers from which they will be taken by rail to processing facilities at two power plant sites. The wastes will be shredded to about 2.5 cm (1 inch), and then separated into combustibles and noncombustible. Metals will be recovered and sold, the combustibles will be burned with coal, and other residue will go to a landfill. Union Electric expects its $70 million capital costs and $11 million annual operating costs to be covered by the heat value of the refuse, the sale of salvaged materials, and the dumping fees paid by the waste collectors. A similar but smaller system is in operation in Ames, Iowa.

SOLID WASTE MANAGEMENT

The problem of solid waste management encompasses both the urban and rural spheres. This malaise needs to be looked into and considered urgently, lest it should become an uncontrolled proposition in the near future, threatening the generations to come.

The day-to-day management of municipal solid wastes is a complex and a costly task. Direct activities, that must be considered and coordinated on a daily basis include-the generation rates, on-site storage, collection, transfer and transport, processing and disposal of wastes. These activities are associated directly with the management of solid wastes. Indirect activities that are also an important part of a solid management programme, include-financing operations equipment and personnel; cost accounting and budgeting, contract administration, ordinances and guidelines and public communications.
In short, the solid waste management imbibes in itself:

i) Effective refuse solid waste collection, storage and disposal.

ii) Determining a suitable technology toward recycling of solid wastes, with due consideration given to the economic constraints and environmental aspects.

ENGINEERED SYSTEMS FOR SOLID WASTE MANAGEMENT

The management of solid waste can be conceptualized as a multi-disciplinary activity, involving engineering principles, economics, urban and regional planning, management techniques and social sciences, to minimize overall wastivity of materials and maintain viable quality of environment, in a city or area. The activities involved with the management of solid wastes, from the point of generation to final disposal, have been grouped into six functional elements, viz.,

1. Waste generation;
2. On-site handling, storage and processing,
3. Collection;
4. Transfer and transport;
5. Processing and recovery; and
6. Disposal

These functional elements are described in table
### Functional elements governing the solid waste management

<table>
<thead>
<tr>
<th>S. No</th>
<th>Functional element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Waste generation</td>
<td>Those activities, in which materials are identified as no longer being of value and, are either thrown away or gathered together for disposal.</td>
</tr>
<tr>
<td>2.</td>
<td>On-site handling, storage and</td>
<td>Those activities, which are associated with the handling, storage and processing of solid wastes, at or near the point of generation.</td>
</tr>
<tr>
<td>3.</td>
<td>Collection</td>
<td>Those activities, which are associated with the gathering of solid wastes and the hauling of wastes, after collection, to where the collection vehicle is emptied.</td>
</tr>
</tbody>
</table>
| 4.    | Transfer and transport                | Those activities associated with  
   i) The transfer of wastes from the smaller collection vehicle to the larger transport equipment, and  
   ii) The subsequent transport of the wastes usually over a long distance to the disposal site.                                                                                                      |
| 5.    | Processing and recovery               | Those techniques, equipments and facilities, used both to improve the efficiency of the other functional elements and to recover usable materials, conversion products or energy from solid wastes.             |
| 6.    | Disposal                              | Those activities, which are associated with ultimate disposal of solid wastes, including those which are collected and transported directly to a landfill site, semi-solid wastes (sludge) from waste water treatment plant, incinerator residue, compost or other substances from the various solid waste processing plants that are of no further use. |

### COST OF SOLID WASTES

The social costs of solid wastes are not easy to determine. Open dumps may be responsible for a small amount of disease, and incinerators add to the air pollution costs of a community. Most disposal methods contribute to some aesthetic displeasure. In rare circumstances the costs can be much higher. On October 21, 1966, some 145 persons, mostly children, were killed at Aberfan, Wales, when an avalanche of 2 million tons of rain-soaked coal wastes slipped 150 meters down a mountainside and buried a school and over a dozen cottages.
The slag heap was 120 meters high and had been begun in 1870; the villagers had complained in 1964 that the heap was dangerous and should be investigated, but the National Coal Board had taken no action.

Litter along American roadsides constitutes a solid waste problem with much psychological impact, judging from the interest in antilitter and highway beautification programs. Occasional massive efforts are made to pick up litter along highways, generally resulting in the recovery of several hundred kilograms per kilometer. Since there are approximately 5 million km of roads in the United States, highway litter might amount to roughly 1 million metric tons at present—a small but important part of the solid waste problem and one generally believed to be growing.

The major cost of solid waste disposal in the United States currently comes from the collection, transportation, and transfer of the wastes, not from the final stages of disposal. The National Solid Wastes Survey found that the average per capita annual expense for all communities amounted to $6.81, of which $5.39 was spent for collection ($0.53 capital costs and $4.86 operating costs) and $1.42 for disposal ($0.25 capital costs and $1.17 operating costs). This survey showed that 80 percent of total expense is for collection and only 20 percent for final disposal; this ratio demonstrates emphasis on collection services and neglect of proper disposal practices by the United States.

The per ton disposal costs of solid wastes by the different methods vary widely from one locality to another, because they depend on many factors. The total amount of the wastes is important; large systems generally have lower per ton costs. The nature of the wastes is also significant; for example, some wastes have more combustible materials and are easier to incinerate. The geographical
location also has an effect, with high land costs in some places working against landfills.

In general, however, the per ton costs increase in the following order: open dumps, controlled burning dumps, ordinary refuse landfills, sanitary landfills, and incineration. The costs associated with resource recovery are hard to estimate, but some resource recovery systems are expected to show a profit.

The 1970 cost of solid waste management programs in the United States was estimated by the Council on Environmental Quality as $5.7 billion, or about $27 per person annually. The council recently estimated that the incremental pollution control expenditures made necessary by recent federal legislation would amount to a total of $7.9 billion in the decade 1975-1984, of which $3.4 billion would be spent by the public sector and $4.5 billion by the private sector. The annual incremental costs would rise from $0.7 billion in 1975 to $1.3 billion by 1984.

**Effects of Solid Wastes**

Municipal solid wastes heap up on the roads due to improper disposal system. People clean their own houses and litter their immediate surroundings which affect the community including themselves. This type of dumping allows biodegradable materials to decompose under uncontrolled and unhygienic conditions. This produces foul smell and breeds various types of insects and infectious organisms besides spoiling the aesthetics of the site.

Industrial solid wastes are sources of toxic metals and hazardous wastes, which may spread on land and can cause changes in physic-chemical and biological characteristics thereby affecting productivity of soils. Toxic substances may leaches or percolates to contaminate the ground water.
In refuse mixing the hazardous wastes are mixed with garbage and other combustible waste. This makes segregation and disposal all the more difficult and risky. Various types of wastes like can pesticides, cleaning solvents, batteries (zinc, lead or mercury) radioactive materials, plastics are mixed up with paper, scraps and other non-toxic materials which could be recycled. Burning of some of these materials produce dioxins, furans and polychlorinated biphenyls, which have the potential to cause various types of ailments including cancer.

**Effects of Labour Costs**

When materials are valuable in relation to the cost of an hour of a man’s labour the volume of refuse is bound to the comparatively small and the cost of hand sorting can be absorbed without any special efforts being made to increase productivity. The coming of the industrial revolution seems to have made little change in this general pattern, at least as regards municipal refuse, because early production was predominantly in capital goods. Industrial wastes, however, began to become all too obvious in the form of slag heaps.

**Impacts of solid waste on health**

The group at risk from the unscientific disposal of solid waste include-the population in areas where there is no proper waste disposal method, especially the pre-school children; waste workers; and workers in facilities producing toxic and infectious material. Other high-risk group includes population living close to a waste dump and those, whose water supply has become contaminated either due to waste dumping or leakage from landfill sites. Uncollected solid waste also increases risk of injury, and infection.

In particular, organic domestic waste poses a serious threat, since they ferment, creating conditions favorable to the survival and growth of microbial pathogens. Direct handling of solid waste can result in various types of infectious
and chronic diseases with the waste workers and the rag pickers being the most vulnerable.

Exposure to hazardous waste can affect human health, children being more vulnerable to these pollutants. In fact, direct exposure can lead to diseases through chemical exposure as the release of chemical waste into the environment leads to chemical poisoning. Many studies have been carried out in various parts of the world to establish a connection between health and hazardous waste.

Waste from agriculture and industries can also cause serious health risks. Other than this, co-disposal of industrial hazardous waste with municipal waste can expose people to chemical and radioactive hazards. Uncollected solid waste can also obstruct storm water runoff, resulting in the forming of stagnant water bodies that become the breeding ground of disease. Waste dumped near a water source also causes contamination of the water body or the ground water source. Direct dumping of untreated waste in rivers, seas, and lakes results in the accumulation of toxic substances in the food chain through the plants and animals that feed on it.

Disposal of hospital and other medical waste requires special attention since this can create major health hazards. This waste generated from the hospitals, health care centres, medical laboratories, and research centres such as discarded syringe needles, bandages, swabs, plasters, and other types of infectious waste are often disposed with the regular non-infectious waste.

Waste treatment and disposal sites can also create health hazards for the neighbourhood. Improperly operated incineration plants cause air pollution and improperly managed and designed landfills attract all types of insects and rodents that spread disease. Ideally these sites should be located at a safe distance from
all human settlement. Landfill sites should be well lined and walled to ensure that there is no leakage into the nearby ground water sources.

Until recently, sanitation was mainly centered on the disposal of human excreta, while the disposal and management of other solid wastes remained neglected. Much of the ill health in our country can be attributed to the defective sanitation systems. The insanitary conditions, their impacts and hazards related to them can be grouped under two main headings, as:

(A) Hazards Related to Improper Excreta Disposal

These are further grouped as:
(i) Spread of intestinal diseases and infections,
(ii) Soil/land pollution,
(iii) Water pollution,
(iv) Contamination of food, and
(v) Propagation by flies.

(B) Hazards Related to Accumulation of Solid Wastes

Improper collection and disposal of solid wastes can cause serious problems such as:
(i) The organic portion of solid wastes favours fly-breeding.
(ii) The garbage, in the refuse, attracts rats and rodents.
(iii) The pathogens may be conveyed to man through flies and dust.
(iv) There is always a possibility of water pollution, if rainwater passes through the deposits of fermenting refuse.
(v) There is a risk of air pollution, loss of property and life, if there is accidental combustion of inflammable refuse.
(vi) Heaps of refuse are a nuisance from an aesthetic point of view.

Recycling too carries health risks if proper precautions are not taken. Workers working with waste containing chemical and metals may experience toxic exposure. Disposal of healthcare wastes require special attention since it can create major health hazards, such as Hepatitis B and C, through wounds
caused by discarded syringes. Rag pickers and others, who are involved in scavenging in the waste dumps for items that can be recycled, may sustain injuries and come into direct contact with these infectious items.

**Occupational Hazards Associated With Waste Handling**

**Infections**

- SKIN and blood infections resulting from direct contact with waste, and from infected wounds.
- Eye and respiratory infections resulting from exposure to infected dust, especially during landfill operations.
- Different diseases that results from the bites of animals feeding on the waste.
- Intestinal infections that are transmitted by flies feeding on the waste.

**Chronic diseases**

- Incineration operators are at risk of chronic respiratory diseases, including cancers resulting from exposure to dust and hazardous compounds.

**Accidents**

- Bone and muscle disorders resulting from the handling of heavy containers.
- Infecting wounds resulting from contact with sharp objects.
- Poisoning and chemical burns resulting from contact with small amounts of hazardous chemical waste mixed with general waste.
- Burns and other injuries resulting from occupational accidents at waste disposal sites or from methane gas explosion at landfill sites.

Source – Adapted from UNEP report, 1996.
Diseases

Certain chemicals if released untreated, e.g. cyanides, mercury, and polychlorinated biphenyls are highly toxic and exposure can lead to disease or death. Some studies have detected excesses of cancer in residents exposed to hazardous waste. Many studies have been carried out in various parts of the world to establish a connection between health and hazardous waste.

Public Health Aspects of Solid Waste Management

Solid waste may contain:

- Human pathogens–diapers, handkerchiefs, contained food and surgical dressings.
- Animal pathogens–waste from pets.
- Soil pathogens–garden waste.

Inadequate storage of such wastes provides breeding ground for vermin, flies, cockroaches and birds (seagulls), which may act as passive vectors in disease transmission. The general public, but more particularly the solid waste employees, are at risk. The pathogens that can cause faecal–related diseases are shown. These pathogens include viruses, bacteria, protozoa and helminthes.

Introduction to Chikungunya

Chikungunya fever is a viral disease transmitted to humans by the bite of infected *Aedes Aegypti* mosquitoes. Chikungunya virus (CHIKV) is a member of the genus *Alphavirus*, in the family *Togaviridae*. CHIKV was first isolated from the blood of a febrile patient in Tanzania in 1953, and has since been identified repeatedly in west, central and southern Africa and many areas of Asia, and has been cited as the cause of numerous human epidemics in those areas since that time. The virus circulates throughout much of Africa, with transmission thought to occur mainly between mosquitoes and monkeys.
**Symptoms of Chikungunya**

Symptoms of Chikungunya includes fever, debilitating arthralgia (joint pain), swelling of joints, stiffness of joints, myalgia (muscular pain), headache, fatigue (weakness), nausea, vomiting and rash.

The incubation period (time from infection to illness) can be 2-12 days, but is usually 3-7 days. "Silent" CHIKV infections (infections without illness) do occur; but how commonly this happens is not yet known.

Acute chikungunya fever typically lasts a few days to a couple of weeks, but some patients have prolonged fatigue lasting several weeks. Additionally, some patients have reported incapacitating joint pain, or arthritis which may last for weeks or months. No deaths, neuro-invasive cases, or hemorrhagic cases related to CHIKV infection have been conclusively documented in the scientific literature.

**Preventive measures**

Proper methods of waste disposal have to be undertaken to ensure that it does not affect the environment around the area or cause health hazards to the people living there.

At the household-level proper segregation of waste has to be done and it should be ensured that all organic matter is kept aside for composting, which is undoubtedly the best method for the correct disposal of this segment of the waste. In fact, the organic part of the waste that is generated decomposes more easily, attracts insects and causes disease. Organic waste can be composted and then used as a fertilizer.
The type of litter we generate and the approximate time it takes to degenerate.

<table>
<thead>
<tr>
<th>Type of litter</th>
<th>Approximate time it takes to degenerate the litter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic waste such as vegetable and fruit peels, leftover foodstuff, etc.</td>
<td>A week or two.</td>
</tr>
<tr>
<td>Paper</td>
<td>10-30 days</td>
</tr>
<tr>
<td>Cotton cloth</td>
<td>2-5 months</td>
</tr>
<tr>
<td>Wood</td>
<td>10-15 years</td>
</tr>
<tr>
<td>Woolen items</td>
<td>1 year</td>
</tr>
<tr>
<td>Tin, aluminum, and other metal items such as cans</td>
<td>100-500 years</td>
</tr>
<tr>
<td>Plastic bags</td>
<td>One million years?</td>
</tr>
<tr>
<td>Glass bottles</td>
<td>undetermined</td>
</tr>
</tbody>
</table>

Problems of solid-waste pollution

Solid wastes are sometimes referred to as “the third pollution”. In some ways the problems of dealing with solid wastes are easier than are those for air and water pollution. Air and water are fluids, and fluids spread. Air pollution originating in Britain is experienced in Sweden. Pesticides used on Midwest farms find their way to the Great Lakes through waister runoff to rivers and eventually traces may be detected in Antarctic penguins.

In contrast, solid wastes tend to stay where they are deposited, apart from the relatively minor problem of blowing paper. For solid wastes in one locality to cause problems elsewhere, they either have to be transported there, or they must be converted to gases through, for instance, combustion, or to liquids through, for example, leachates.

There is a negative side to this argument that solid-waste pollution may be the easiest to overcome. Although some wastes are biodegradable and will, if left long enough, merge imperceptibly into the environment without damage, many other wastes are either inert, like many plastics, or are sufficiently long-
lived or harmful (radioactive wastes may be an extreme example) that each item may require human intervention and treatment for environmental damage to be avoided. In contrast, the atmosphere or a river, if not polluted too severely, can regenerate itself after the source of a polluting flow has been stopped. In the River Thames, which has long been a dead and dirty stream in the vicinity of London, carp and migrant birds are returning enforced on polluters. Present-day solid wastes or at least a large proportion of them do not disappear through natural processes in a period of a few months or years.

The “solid-waste problem” can be regarded as largely a handling and transportation problem. At least, the “visible” cost involved are dominated by the amounts spent on collection and transportation. The “invisible” or difficult-to-quantify social costs have not yet received the attention we believe they should. Their inclusion in the overall accounting would lead to solutions much nearer the optimum than are those presently being pursued. This thesis will be discussed more fully later in this section.

We should like first to review some relevant history of solid-waste treatment, with emphasis on the rapid changes of living habits which have brought about significant trends in the nature of solid wastes and in the way they can be treated. Following this, the social economics of solid wastes will be discussed, and it will be shown that optimum solutions can be arrived at only by full consideration of all costs. The solid waste problems are given to a review of operational treatment of solid wastes treatment at the source; in transportation and mechanical handling; landfilling; incineration; and reclamation. We shall make recommendations of the best available current practice and of action to bring about future improvements.

Some vigorous complaints of the nuisance from the handling, or mishandling, or refuse have been recorded from various articulate Londoners.
Edward III, after “suffering from fumes and other abominable stenches arising from the river during a journey down the Thames in 1357,” asked the mayor and sheriff to forbid the throwing of rubbish or filth into the various watercourses around the city. There has been a legal requirement dating from 1297 on every householder in London to keep the pavement within the frontage of his tenement clear of refuse.

Londoners complained about the smoke from various fires at least from Dr. Johnson’s time, but very little seems to have been done until the last two decades. Likewise the litter, which appears to have been on a grander scale than the scraps of paper and plastic about which we complain today, seems, to have remained as sources of irritation from century to century. As evidence that Edward III hadn’t managed to produce a permanent cure, we have the comments of Lord Tyrconnel in 1741, who described the streets of London as “abounding with such heaps of filth as a savage would look on with amazement”. Then in 1832 some outraged inhabitants wrote to The Times complaining about streets in the vicinity of Westminster Abbey “which were the receptacle of all sorts of rubbish and where refuse of vegetables lay rotting and corrupting, contaminating the air and affording a repast to a herd of swine”.

Some of London’s rubbish was taken downstream in barges to be dumped on the Essex marshes; this is still a popular if misguided practice in many parts of the world. One great heap of refuse remained at the bottom of Grays Inn Lane for a century, until in 1841 the dust was extracted and sold to Russia to make brick for the rebuilding of Moscow after Napoleon’s invasion.

Another example of recycling, less dramatic perhaps but a forceful measure of how our way of life has changed, is the management of the refuse yards of Edinburgh. These stayed the same size, at the same ground level, for
more than a century as the canny Scots who were in charge sold or gave away everything once it had been sorted and separated.

**Potential Environmental Impacts from Solid Waste Management Activities**

The typical municipal solid waste stream will contain general wastes (organics and recyclables), special wastes (household hazardous, medical, and industrial waste), and construction and demolition debris. Most adverse environmental impacts from solid waste management are rooted in inadequate or incomplete collection and recovery of recyclable or reusable wastes, as well as co-disposal of hazardous wastes. These impacts are also due to inappropriate siting, design, operation, or maintenance of dumps and landfills. Improper waste management activities can:

- **Increase disease transmission or otherwise threaten public health.**
  Rotting organic materials pose great public health risks, including, as mentioned above, serving as breeding grounds for disease vectors. Waste handlers and waste pickers are especially vulnerable and may also become vectors, contracting and transmitting diseases when human or animal excreta or medical wastes are in the waste stream. (See the discussion on medical wastes below and the separate section on “Healthcare Waste: Generation, Handling, Treatment, and Disposal” in this volume.) Risks of poisoning, cancer, birth defects, and other ailments are also high.

- **Contaminate ground and surface water.** Municipal solid waste streams can bleed toxic materials and pathogenic organisms into the leachate of dumps and landfills. (Leachate is the liquid discharge of dumps and landfills; it is composed of rotted organic waste, liquid wastes, infiltrated rainwater and extracts of soluble material.) If the landfill is unlined, this runoff can contaminate ground or surface water, depending on the drainage system and the composition of the underlying soils.
Many toxic materials, once placed in the general solid waste stream, can be treated or removed only with expensive advanced technologies. Currently, these are generally not feasible in Africa. Even after organic and biological elements are treated, the final product remains harmful.

- **Create greenhouse gas emissions and other air pollutants.** When organic wastes are disposed of in deep dumps or landfills, they undergo anaerobic degradation and become significant sources of methane, a gas with 21 times the effect of carbon dioxide in trapping heat in the atmosphere.

Garbage is often burned in residential areas and in landfills to reduce volume and uncover metals. Burning creates thick smoke that contains carbon monoxide, soot and nitrogen oxide, all of which are hazardous to human health and degrade urban air quality. Combustion of polyvinyl chlorides (PVCs) generates highly carcinogenic dioxins.

- **Damage ecosystems.** When solid waste is dumped into rivers or streams it can alter aquatic habitats and harm native plants and animals. The high nutrient content in organic wastes can deplete dissolved oxygen in water bodies, denying oxygen to fish and other aquatic life form. Solids can cause sedimentation and change stream flow and bottom habitat. Siting dumps or landfills in sensitive ecosystems may destroy or significantly damage these valuable natural resources and the services they provide.

- **Injure people and property.** In locations where shantytowns or slums exist near open dumps or near badly designed or operated landfills, landslides or fires can destroy homes and injure or kill residents. The accumulation of waste along streets may present physical hazards, clog drains and cause localized flooding.

- **Discourages tourism and other business.** The unpleasant odor and unattractive appearance of piles of uncollected solid waste along streets
and in fields, forests and other natural areas, can discourage tourism and the establishment and/or maintenance of businesses.

Recent Changes in the Character of Solid Wastes

It is only in the last few decades, however, that solid wastes have changed in character very markedly. There have been several trends, some independent and some connected:

1. The mass production of consumer goods vastly increased the products, and therefore the refuse, used and discarded by a large proportion of the population.

2. Medical and public-health advances lowered the death rate and greatly increased the population, and therefore the population density.

3. The agricultural revolution was brought about by the development of control for diseases and pests and of fertilizers, which have become so concentrated and inexpensive that most farmers have given up returning organic material to the land.

4. The large increase in productivity of farmers, which has been continuing since the agricultural revolution, has tended to depopulate rural areas and to increase the size, population, and population density of urban areas.

5. A consumer demand for convenience and cleanliness has been principally responsible for the decline in solid fuels and the almost universal use in homes and commercial establishments of fluid (oil and gas) fuels. This change has led to the virtual elimination of furnace ashes from domestic and commercial solid wastes.

6. The development of large-scale food canning started the move toward factory food processing and resulted in a decrease in the amount of garbage (food wastes) produced in the average home and an increase in the quantity of cans and other packaging wastes. In the last one or two decades frozen and, to a small extent, freeze-dried, foods have pushed this
trend almost to the limit. Families and restaurants can now serve meals which are entirely factory prepared, so that there may be virtually no peel, rinds, pits, and so forth; to appear as solid-waste output in these locations. The food-preparation factories, however, have been faced with serious problems of disposal of large quantities of food wastes.

7. In the last few years (perhaps only since 1965) increasing public concerns over air pollution has led to stringent regulations on the burning of paper, leaves, and garden trimmings, and even of the use of home and apartment incinerators, so that domestic solid wastes have experienced an increasing volume of combustibles.

Social Economics of Solid-Waste Pollution

The economics of our society at this time are such that it is becoming cheaper to make new products but more expensive to recondition or even clean them. Every year in the United States, people throw away 7 million cars, 30 million tons of paper, and 48,000 million tin cans. Significantly, man’s solid wastes are changing from wood, paper, and iron to unrustable alloys, glasses, and plastics which neither rot not burn. In the U.S., domestic waste is being generated at the rate of some 5 lbm (2.5kg), per head per day. Adding industrial waste results in a figure much more than doubled. Agriculture likewise generated wastes on a prodigious scale. Over 100 million head of American cattle each produce 60lbm (30kg) of manure daily and soil a quantity of straw, adding more than 30lbm (15kg) to the daily per-capita figure.

In the past, manure was a valuable commodity. But many of today’s cattle are raised in places bearing resemblance more to a mass-production factory than to a farm, and the economic value of manure is no longer high enough for it to be transported and sold as cheaply as synthetic fertilizers. Thus it can be seen that solid waste are often useful, if not valuable, materials which are simply in
the wrong place; the problem of what to do with them is in consequence largely one of efficient transport and handling. Moreover, the high concentration of wastes near animal “factories” typifies the common situation in which land management, air pollution, and water pollution are interlinked. Wastes dumped on or in the ground may cause water pollution. Wastes burnt may pollute the air—unless they are fired in an incinerator with water washing equipment, in which case the pollution may merely be transferred to the water. It is not unduly pessimistic to claim that in most countries there is little or no coordination between the agencies responsible for air and water pollution and land management. And poor waste management can bring other evils. The insects and vermin that breed on untreated wastes cause disease, and the unsightliness of most of our wastes for example, a carwrecker’s yard—may well is one of the causes, as well as one of the effects, of a neighbourhood becoming “run down”.

Social Costs of treatment Facilities

In most areas of the country, designation of a projected site for a new landfill, incinerator, of transfer station, engenders so such community opposition that more frequently than not the project has to be abandoned. The local residents are objecting to the prospect of a number of real disadvantages. The facility is likely to be unsightly. There may be an odour problem. Vermin and insects may proliferate. Litter is likely to spread. Heavy machinery at the sight may produce noise and smoke, and the incoming wastes will probably be transported by large trucks which will bring more noise, smoke, litter, and danger to the streets. The resistance of local residents is not to be wondered at.

What is actually happening in these circumstances is that the wider community is expecting the local residents to bear social costs which, in the terms just stated, are extremely large. These costs would substantially decrease the standard of living of the local community. Rather than the costs being
compensated for in some way, the market seems to add insult to injury by reducing the value of property in the neighbourhood of such treatment facilities.

This problem, formerly a local problem, is becoming a statewide and even an interstate difficulty in many areas. Philadelphia, Milwaukee, and Boston are three of many recent (as of early 1972) examples where long-distance rail haul has been prevented by protests from communities which had been tentatively selected as containing landfill sites. In the case of Boston, the possibilities that baled compacted refuse should be shipped to Maine or New Hampshire has resulted in hurriedly passed laws or ordinances prohibiting the interstate shipment of refuse.

The thesis advanced here is that these reactions are obvious, realistic, and to be expected so long as the social costs are not paid: If the social costs were to be paid, they might be quite high, and they might change the decision-making process dramatically.

Successful sustainable solid waste management
Social Benefits of Solid-Waste Treatment

If residents are compensated in the way described, it is only fair that they should have to pay something for the converse situation. For instance, if someone buys a house at the edge of a disused gravel quarry half-full of water, he will pay less for that house than if it were at the edge of a golf course. If the quarry then becomes used for refuse filling for a period of year, the value of his home will become further reduced and he should be compensated. After the landfill is completed, however, the area may be converted to a golf course or recreation area, and the value of his house will increase and he should start paying some amount to whatever body provided him with this amenity. The accurate transfer of social costs and benefits therefore provides powerful inducements to keep the landfilling process under tight control and to complete it as rapidly as possible.
Regional Solutions to Solid-Waste Problems

These incentives, incidentally, also act to encourage the formation of regional solutions to solid-waste disposal. The present tendency in most parts of the United States is for individual communities to guard their landfill sites very jealously because they want them to last as long as possible. This means that residents living near these sites are condemned to live with all the problems of an active landfill sometimes for 50 years. However, a regional approach will more likely involve concentration on one landfill at a time, completing each in typically 2 to 5 years and thus providing land useful for reaction and other purposes, sometimes decades before it would otherwise be available. Regional approaches might also favour the setting up of recycling centers. Which need to be of large throughput to be viable?

Solid-Waste Handling

All solid wastes should ideally be transferred to a container that is, to a form of storage at the moment of generation. These containers may be small, such as trash bags in automobiles; wastepaper baskets in homes or offices; or the under-sink closed receptacles for food or sanitary wastes. Or the containers may be large, from the 1 to 5 cubic-yard containers that may be placed at the foot of a refuse Clute in an apartment building, to the roll-off containers of 20 or more cubic yards receiving demolition debris at a construction site.

Waste that does not immediately find its way into such containers but is disposed of into the environment becomes litter or junk. In an ever-moving population, the lack of local loyalty and responsibility is leading to an ever-increasing litter problem. Methods of controlling litter are outside the scope of this Chapter, but they may include the provision of storage containers.
Control of solid Waste Ocean dumping

However, income cases this simple rule may be overridden by consideration of conditions of pickup and set down. In the larger sizes the capacities of various types of mechanical lifting devices will need to be considered. In domestic units, consideration of human capacity dictates a density about half that of water, or 30 to 40lb/ft.

A goal in some large installations has been to exceed the density of water so as to enable the disposal of solid-wastes offshore. However, much offshore dumping has since been controlled, and it is hoped that all ocean dumping will be outlawed. If we kill the sea, we would probably make life virtually impossible anywhere on the globe.

Life-Cycle Assessment

Solid waste management all too often focuses almost entirely on what to do with a given waste stream, with the key decision being whether to incinerate the waste or bury it. As landfills filled up or were closed because they could not meet new environmental regulations, as incinerators were shut down due to poor performance, and as communities became more agitated by the environmental effects of living near either type of facility, a new, broader approach to the problem has emerged. Using energy and materials balance approach at every stage in the life cycle of a product can yield new insights into not only the solid waste problem, but also the problems of air and water pollution already described in this book.

What would the life cycle of municipal waste look like?
Diagram of material and energy life-cycle flows and the associated GHG sources and sinks.5

A simple conceptual diagram for the life-cycle assessment of a product is presented. Inputs include energy and raw materials utilized in each stage of the production, use, and disposal of the product. The central box suggests the various stages in the product life cycle, which includes the acquisition and processing of materials (mining, smelting etc.), the actual manufacturing of the product itself, the packaging and distribution of the product, the use of the product, and, finally, the ultimate disposal of the product. Outputs are the air, water, and solid waste effluents associated with each stage, along with the waste head dissipated in the environment plus energy that may be recovered during disposal.
Some of the terms that is used to describe the potential recovery of materials in the product life cycle.

**Reusing** a product in the same application for which it was originally intended saves energy and resources. For example, a plastic bag can carry groceries home from the market over and over again, and a polystyrene cup might be used several times before disposal. Returnable glass bottles for soft drinks are another example. A product can also be reused for some other purpose, such as occurs when glass jars are reused in a workshop to hold small objects such as screws or nails.

**Remanufacturing** refers to the process of restoring a product to like-new conditions. The restoration begins by completely disassembling the product, cleaning and refurbishing the reusable parts, and then stocking those parts in inventory. That inventory, along with new parts, is used to remanufacture products that are equal in quality to new units. Some distinguish between remanufacturing and repair. **Repair** means that only those parts that have failed are replaced. For example, malfunctioning components on a faulty electronic circuit board might be replaced rather than throwing out the entire product.

**Recycling** is the term used to describe the act of recovering materials from the waste stream and reprocessing them so they become raw materials for new applications.

**Green Product Design Strategies**

Design that concerns itself with reducing the environmental impacts associated with the manufacture, use, and disposal of products is an important part of any pollution prevention strategy. Companies that engage in such green product-design are finding that products that combine environmental advantages with good performance and price have additional market appeal.
The Office of Technology Assessment identifies two complementary goals of green design: waste prevention and better materials management (OTA, 1992). Waste prevention can be achieved by reducing the weight, toxicity, and energy use of products along with increasing the useful life of products. Better materials management facilitates remanufacturing, recycling, and composting along with enhanced energy recovery opportunities.

A number of strategies have been identified that contribute to good green design practices, including the following (Keoleian et al., 1994).

The dual goals of green design (Source: OTA, 1992)

Product System Life Extension. Products that do not wear out as quickly do not have to be replaced as often, which usually means that resources are saved and less waste is generated. Sometimes products are discarded for reasons that have nothing to do with their potential lifetime, such as computers that become obsolete and clothing fashions that change, but many products can continue to remain in service for extended periods of time if they are designed to be durable, reliable, remanufacturable, and repairable.
Extending product life, of course, means that consumers replace their products less often, which translates into decreased sales volume for manufacturers. It is hoped that the temptation toward planned obsolescence will be tempered by the realization that market share in the future may be driven to some extent by consumer demand for greener products. Consumers, of course, must make that happen.

**Material Life Extension.** Once a product has reached the end of its useful life, the materials from which it was made may still have economic value, and additional savings can result from avoiding disposal. The key design parameter for extending the life of materials is the ease with which they can be recycled.

Products that have been designed to be recycled easily are becoming especially common in Germany, where tough recycling requirements are in place. For example, Germany’s requirement that automakers take back and recycle old automobiles has stimulated green design in companies such as BMW and Volkswagen, both of which have built pilot plants to study disassembly and recycling of recovered materials. BMW, which already sells cars with plastic body panels that have been designed for disassembly and that are labeled as to resin type so they may more easily be recycled, has set a goal of learning how to make an automobile entirely out of reusable and recyclable parts by the year 2000 (OTA, 1992).

**Material Selection.** A critical stage in product development is selection of appropriate materials to be used. In green design, attempts are made to evaluate the environmental impacts associated with the acquisition, processing, use, and retirement of the materials under consideration. In some cases substituting one material for another can have a modest impact on the quality and
price of the resulting product but can have a considerable impact on the environmental consequences.

Designers today have a much greater range of materials to choose from in developing their products. Ceramics and composites offer superior strength with lighter weight than traditional materials such as steel and aluminum. High-strength alloys and plastics are quickly displacing the metals used in the past. For example, the telecommunications cables that AT&T used in the 1950s consisted mostly of steel, lead, and copper, with small percentages of aluminum and about 1 percent plastics. By the mid-1980s, polyethylene has replaced virtually all of the lead that had been used in the cables’ sheathing so that the fraction of plastics in now more than 35 percent. If replacing lead sheathing with polyethylene had not occurred, AT&T’s lead requirements might now be close to a billion pounds annually (Ausubel, 1989). Such progress continues with fiber-optic cables that weigh only 3 percent as much as traditional copper cables and that use only 5 percent of the energy to produce (OTA, 1992).

**Example of Toxic Metal Sources in MSW**

<table>
<thead>
<tr>
<th>Metal</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>Wood preservatives, household pesticides</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Rechargeable Ni-Cad batteries: pigments in plastics (kitchenware, etc.), colored printing inks (magazines, catalogs) and enamels (pots, pans, mugs, colored glassware, porcelain, ceramics)</td>
</tr>
<tr>
<td>Lead</td>
<td>Automobile batteries, solder (plumbing, gutters, electronics, food cans): pigments or stabilizers in plastics, glass, ceramics</td>
</tr>
<tr>
<td>Mercury</td>
<td>Batteries: fluorescent lamps: fungicides: paints</td>
</tr>
<tr>
<td>Zinc</td>
<td>Flashlight batteries; rubber products (including tires)</td>
</tr>
</tbody>
</table>
As especially important aspect of materials selection is the need to reduce the toxicity of materials whenever possible. Toxic substances used in products can create serious environmental risks when those products end up in landfills or incinerators. Heavy metals, such as lead, cadmium, chromium, mercury, arsenic, copper, tin, and zinc, are commonly used in consumer products and are especially dangerous when they enter the waste stream. Examples of sources of heavy metals in the municipal waste stream are shown in table.

**Reduced Material Intensiveness.** Green design strategies include reducing the amount, and/or toxicity, of materials required to make a given product while maintaining the product’s usefulness and value. Changes in battery technology provide a good example. In 1974, a typical car battery contained about 30 lb of lead, but modern batteries use less than 20 lb. Common household batteries have also been redesigned to use only 15 percent as much mercury those produced a decade or so ago (OTA, 1992).

**Process Management.** Manufacturing products requires raw materials and energy inputs, both of which often can be managed more efficiently.

The energy required to manufacture a product is an important component of a life-cycle assessment. Process improvements that take advantage of waste-heat recovery, more efficient motors and motor controls, and high-efficiency lighting are almost always very cost effective. Since electric motors account for two-thirds of the electricity used by industry (and half of the electricity used in the United States for all purposes), a good place to look for efficiency improvements is there. It is not uncommon for motors in use to be oversized and to run at constant speed, with both factors contributing to low energy efficiency. When motors are used to pump fluids, the pumping rate is usually controlled by adjusting values or dampers rather than by adjusting the speed of the motor itself.
which wastes electricity. New electronic adjustable-speed drives, coupled with more efficient motors, can often save half of the energy normally used.

**Labeling**

Surveys have consistently shown that American consumers, if given a choice, would purchase products that are environmentally superior to competing products, even if they cost a bit more (U.S. EPA 1991). Attempts by manufacturers to capture that environmental advantage have led to an overuse of poorly defined terms such as recycled, eco-safe, ozone-friendly, and biodegradable on product labels. Unfortunately, without a uniform and consistent standard for such terms, these labels are all too often meaningless or even misleading. For example, all soaps and detergents have “biodegradable” since the 1960s, and “CFC-free, ozone-friendly” aerosols have been the norm in the United States since the banning of CFCs for such applications in 1978. (Such aerosols may, however, use HCFCs, which still have some ozone depletion potential, or pentane, which can contribute to photochemical smog.) Labels claiming a product is “eco-safe” or “environmentally safe” have little meaning since the terms are largely undefined.

Clearly, some sort of credible labeling system certifying that the products and packaging bearing such labels have been independently certified to meet certain environmental standards would be a powerful motivator in the marketplace. To that end there are now several competing eco-labels being promulgated by private organizations in the United States. Green Seal labels provide a simple, overall stamp of approval, analogous to the Underwriter Laboratories (UL) label on electrical appliances or the Good Housekeeping Seal of Approval, while the scientific Certification systems label attempts to use life-cycle analysis to compare products based on resource inputs and waste outputs.
How are wastes managed?

In industrialized countries, household waste is separated into categories such as organic material, paper, glass, other containers, etc. This separation is often done in homes by using different bins for the disposal of different items. In developing countries, waste is not separated, though some cities are trying to persuade the public to separate waste.

The simplest and most common method used in the cities is to collect and dump the waste in a landfill. These landfills are located just outside the city. There are now thousands of landfills in the world with huge piles of waste. In industrialized countries, you can also see separate mountains of used cars and tires. Many countries and cities have run out of space for landfills.

How can solid wastes be recycled?

A good way of dealing with solid waste problem is to recycle it. Recycling is the processing of a used item or any waste into usable form. There is a large global recycling industry. In India, we have a thriving unorganized recycling industry, thanks to the itinerant collector, who buys old newspaper, bottles, used clothes, utensils, scrap, motor oil, etc.

Recycling has multiple benefits:

- By taking away some of the waste, it reduces environmental degradation.
- As against expenditure incurred on disposing of the waste, we now make money out of waste material.
- We save energy that would have gone into waste handling and product manufacturing.

Some specific examples of savings through recycling are:

- When aluminum is resmelted, there is considerable saving in cost. The recycling process is, however, energy-intensive.
Making paper from waste pulp rather than virgin pulp saves 50 per cent energy.

Every ton of recycled glass saves energy equal to 100 liters of oil.

Safe and profitable technologies for recycling paper, glass, metals, and some forms of plastic are available. Biogas can be produced from landfill waste. Paper factories can also recycle their waste.

Recycling is not a solution to managing every kind of waste material. For many items, recycling technologies are unavailable or unsafe. In other cases, the cost of recycling is too high.

**Second Method - Control Measures of Solid Waste**

A key element of the Duales System is the Green Dot (der grüne punkt) label, which identifies packages that can be discarded into special DSD recycling bins. An example of the green dot recycling label (which may not be green in color). DSD charges a licensing fee for use of the Green Dot, which depends on the material and weight of the packaging. Fees, which run as high as 20 pfennig (US $0.12) per package, are expected to raise 4 billion Deutsch marks per year ($2.4 billion) (Steuteville, 1994).

The Green Dot label appears only on one-way packaging, so it is not really an environment label per se. It simply indicates that the packaging will be accepted by the DSD system. Reusable containers, for example, which are usually considered to be the best for the environment, do not use the Green Dot. In spite of that potential confusion, almost all beverages in Germany now come in refillable containers and hefty deposit fees help assure that they will be returned for reuse.
The DSD has to collect and sort packaging waste but is not in the recycling business. The DSD collection system includes bins conveniently located near residences and in stores. And the collection system must harmonize with other local waste management systems, which means the der grune punkt bins sit side by side with recycling bins that accept glass and paper and other recyclables.

The net effect of the Duales system is that management of roughly one-third of all of Germany’s solid waste has been shifted from the taxpayers to the private sector, with the resulting costs being built right into the price of products purchased by consumers. There is concern for international implications of the law since it applies to all products sold in Germany, regardless of their country of origin. Many European countries, including France, Netherlands, and Austria, have put similar programs in place, and the European Community is attempting to implement an EC-eco-label.

SOLID WASTE LEGISLATION

Federal programs dealing with solid wastes were nonexistent before 1965 when the Solid Waste Disposal Act was passed by Congress. Listed below are the two basic federal solid waste laws. To date, funding has been mainly for research and development, for training programs, and for financial assistance to the states. The National Solid Wastes Survey, mentioned earlier, provided the first nationwide collection of scientific data about solid waste production and disposal.

1965 PL 89-272 (Title II): Solid Waste Disposal Act. Began a national research, development and demonstration program on solid wastes and provided financial assistance to interstate, state, and local agencies for planning and establishing solid waste disposal programs. Authorized
increasing amount from $10 million in fiscal year 1966 to $32.5 million in 1969 to be spent by the Department of Health, Education, and Welfare and by the Bureau of Mines in the Department of the Interior. Further appropriations have been made since then for these programs, which are now administered by the Environmental Protection Agency.

1970 PL 91-512: Resource Recovery Act. Provided for extended research into new and improved methods to recover, recycle, and reuse wastes and for financial assistance to the states in the construction of solid waste disposal facilities.

So far there has been no federal legislation setting standards for the collection or disposal of solid wastes. Several state and local governments have passed such legislation, often to prevent air or water pollution problems created by burning at open dumps or improper location of dumps and landfills. In addition, public health laws have sometimes been used against disposal areas with rodent or fly problems.

MSW RULES, 2000 – A BRIEF HISTORY

SUPREME COURT DIRECTIVES

In view of the poor situation of solid waste management practices adopted in the country with no immediate solution, a public interest litigation (Writ Petition No.888 of 1996) was filed in the Hon’ble Supreme Court of India by M/s. Almitra H Patel & another Vs Union of India & Others, seeking directions from the Hon’ble Supreme Court of India to the Urban Local Bodies as well as the Government of India and other State Governments in the country, for improving solid waste management practices expeditiously.
The Hon’ble Supreme Court of India ordered to constitute a committee to look into all aspects of solid waste management and requested to give its report not later than 30th June, 1998.

The TOR (Terms of Reference) for this committee were as under:

1. Examine the existing practices and to suggest hygienic processing and waste disposal practices and proven technologies on the basis of economic feasibility and safety which the ULB may directly or indirectly adopt or sponsor.

2. Examine and suggest ways to improve conditions in the formal and informal sector for promoting ecofriendly sorting, collection, transportation, disposal, recycling and reuse.

3. To review municipal bye-laws and the powers of local bodies and regional planning authorities and suggest necessary modifications to ensure effective budgeting, financing, administration, monitoring and compliance.

4. Examine and formulate standards and regulations for management of urban solid waste, and set time frames which the authorities shall be found to implement the same.

Pursuant to the order of the Hon’ble Supreme Court of India dated 16.1.2008, the Ministry of Urban Affairs and Employment, Government of India issued Order No.Q-11021/1/97-PHE dated 29th January 1998 regarding the constitution of the committee. The Committee had several sittings and identified the deficiencies in the existing solid waste management system and prepared an Interim Report dated 30-6-1998 recommending the steps to be taken by the Urban Local Bodies.

The Committee had suggested amendments in State laws needed to make solid waste management practices effective and had also suggested to the Government of India to keep the SWM services outside the purview of the Contract Labour (Regulation & Abolition) Act 1970, so as to enable public
private partnerships and private sector participation in selected areas of SWM for improving the quality of life in urban areas.

This Committee tabled its report in March, 1999 giving wide ranging recommendations to improve the system of waste management from storage of waste at source to its final disposal. It also covered institutional, financial, legal and health aspects. In view of the serious environmental degradation resulting from the unscientific disposal of MSW, the Ministry of Environment and Forests (MoEF), Government of India, has notified the ‘Municipal Solid Waste (Management and Handling) Rules, 2000’ making it mandatory for ULBs to improve the systems of solid waste management as envisaged in the rules within a given time frame ending 31st December, 2003. These rules layout procedures for waste collection, segregation, storage, transportation, processing and disposal. Further, the rules mandate that all cities set up suitable waste treatment and disposal facilities by December 31, 2003 or earlier. These rules also specify standards for compost quality, health control & management and closure of landfills.

Compliance criteria for each and every stage of waste management—collection, segregation at source, transportation, processing and final disposal are set out in the MSW Rules, which include:

a) Dumping of MSW in Oceans, Rivers, Lakes, Open Spaces and compaction or bailing are not acceptable.

b) The biodegradable waste has to be processed by means of composting, vermi composting, anaerobic digestion or any other appropriate biological processing for stabilization of wastes.

c) Mixed waste containing recoverable resources should be recycled.

In order to understand and implement the guidelines, the definitions of words used, herein, as described in the Municipal Solid Waste (Management and Handling) Rules, 2000.