Introduction to Solid Waste Management

Solid waste management is an essential service in any society. Before introducing the process, however, let's start with a discussion of the material being managed—solid waste.

Solid waste refers to the range of garbage materials—arising from animal and human activities—that are discarded as unwanted and useless. Solid waste is generated from industrial, residential, and commercial activities in a given area, and may be handled in a variety of ways. As such, landfills are typically classified as sanitary, municipal, construction and demolition, or industrial waste sites.

Waste can be categorized based on material, such as plastic, paper, glass, metal, and organic waste. Categorization may also be based on hazard potential, including radioactive, flammable, infectious, toxic, or non-toxic wastes. Categories may also pertain to the origin of the waste, whether industrial, domestic, commercial, institutional, or construction and demolition.

Regardless of the origin, content, or hazard potential, solid waste must be managed systematically to ensure environmental best practices. As solid waste management is a critical aspect of environmental hygiene, it must be incorporated into environmental planning.

Solid waste refers here to all non-liquid wastes. In general, this does not include excreta, although sometimes nappies and the faeces of young children may be mixed with solid waste. Solid waste can create significant health problems and a very unpleasant living environment if not disposed of safely and appropriately. If not correctly disposed of, waste may provide breeding sites for insect-vectors, pests, snakes and vermin (rats) that increase the likelihood of disease transmission. It may also pollute water sources and the environment.

What Is Solid Waste Management?

Solid waste management is defined as the discipline associated with control of generation, storage, collection, transport or transfer, processing and disposal of solid waste materials in a way that best addresses the range of public health, conservation, economic, aesthetic, engineering, and other environmental considerations.

In its scope, solid waste management includes planning, administrative, financial, engineering, and legal functions. Solutions might include complex inter-disciplinary relations among fields such as public health, city and regional planning, political science, geography, sociology, economics, communication and conservation, demography, engineering, and material sciences.

Solid waste management practices can differ for residential and industrial producers, for urban and rural areas, and for developed and developing nations. The administration of non-hazardous waste in metropolitan areas is the job of local government authorities. On the other hand, the management of hazardous waste materials is typically the responsibility of those who generate it, as subject to local, national, and even international authorities.

Objectives of Waste Management

The primary goal of solid waste management is reducing and eliminating adverse impacts of waste materials on human health and the environment to support economic development and superior quality of life. This is to be done in the most efficient manner possible, to keep costs low and prevent waste build up.

Functional Elements of the Waste Management System

There are six functional components of the waste management system, as outlined below:

1. **Waste generation**: This encompasses any activities involved in identifying materials that are no longer usable and are either gathered for systematic disposal or thrown away.
2. **Onsite handling, storage, and processing**: This relates to activities at the point of waste generation, which facilitate easier collection. For example, waste bins are placed at sites that generate sufficient waste.
3. **Waste collection:** A crucial phase of waste management, this includes activities such as placing waste collection bins, collecting waste from those bins, and accumulating trash in the location where the collection vehicles are emptied. Although the collection phase involves transportation, this is typically not the main stage of waste transportation.
4. **Waste transfer and transport:** These are the activities involved in moving waste from the local waste collection locations to the regional waste disposal site in large waste transport vehicles.
5. **Waste processing and recovery**: This refers to the facilities, equipment, and techniques employed to recover reusable or recyclable materials from the waste stream and to improve the effectiveness of other functional elements of waste management.
6. **Disposal**: The final stage of waste management. It involves the activities aimed at the systematic disposal of waste materials in locations such as landfills or waste-to-energy facilities.

Integrated Solid Waste Management (ISWM)

As the field of solid waste management advances, solutions are being looked at more systematically and holistically. (ISWM), for example, is an increasingly important term in the field of waste management. It refers to the selection and use of appropriate management programs, technologies, and techniques to achieve particular waste management goals and objectives.

Sources and types of solid waste

most emergency situations the main sources of solid waste are:

- Medical centres
- Food stores
- Feeding centres
- Food distribution points

- Slaughter areas
- Warehouses
- Markets
- Domestic areas etc.

Appropriate solid waste management strategies may vary for institutional, communal and domestic sources, depending on types and volumes of waste. Waste from medical centres poses specific health risks.

Type and quantity of waste.

The type and quantity of waste generated in emergency situations varies greatly. The main factors affecting these are:

- the geographical region (developed or less-developed country or region);
- socio-cultural practices and material levels among affected population;
- seasonal variations (affecting types of food available);
- the stage of emergency (volume and composition of waste may change over time); and
- the packaging of food rations. In general, the volume of waste generated is likely to be small and largely degradable where the population is of rural origin and the food rations supplied are unpackaged dry food stuffs. Displaced urban populations are more likely to generate larger volumes of non-degradable waste, especially where packaged food rations are provided.

Key components of solid waste management

Solid waste management can be divided into five key components:

- Generation
- Storage
- Collection
- Transportation
- Disposal

Generation of solid waste is the stage at which materials become valueless to the owner and since they have no use for them and require them no longer, they wish to get rid of them. Items which may be valueless to one individual may not necessarily be valueless to another. For example, waste items such as tins and cans may be highly sought after by young children.

Storage is a system for keeping materials after they have been discarded and prior to collection and final disposal. Where on-site disposal systems are implemented, such as where people discard items directly into family pits, storage may not be necessary. In emergency situations, especially in the early stages, it is likely that the affected population will discard domestic waste in poorly defined heaps close to dwelling areas. If this is the case, improved disposal or storage facilities should be provided fairly quickly and these should be located where people are able to use them easily. Improved storage facilities include:

- Small containers: household containers, plastic bins, etc.
- Large containers: communal bins, oil drums, etc.
- Shallow pits
- Communal depots: walled or fenced-in areas.

In determining the size, quantity and distribution of storage facilities the number of users, type of waste and maximum walking distance must be considered. The frequency of emptying must also be determined, and it should be ensured that all facilities are reasonably safe from theft or vandalism.

Collection simply refers to how waste is collected for transportation to the final disposal site. Any collection system should be carefully planned to ensure that storage facilities do not become overloaded. Collection intervals and volumes of collected waste must be estimated carefully.

Transportation: This is the stage when solid waste is transported to the final disposal site. There are various modes of transport which may be adopted and the chosen method depends upon local availability and the volume of waste to be transported. Types of transportation can be divided into three categories:

- Human-powered: open hand-cart, hand-cart with bins, wheelbarrow, tricycle
- Animal-powered: donkey-drawn cart
- Motorised: tractor and trailer, standard truck, tipper-truck

Disposal: The final stage of solid waste management is safe disposal where associated risks are minimised. There are four main methods for the disposal of solid waste:

- Land application: burial or land filling
- Composting
- Burning or incineration
- Recycling (resource recovery)

The most common of these is undoubtedly land application, although all four are commonly applied in emergency situations.

On-site disposal options.

The technology choices outlined below are general guidelines for disposal and storage of waste on-site, these may be adapted for the particular site and situation in question.

Communal pit disposal

Perhaps the simplest solid waste management system is where consumers dispose of waste directly into a communal pit. The size of this pit will depend on the number of people it serves. The long-term recommended objective is six cubic metres per fifty people. The pit should be fenced off to prevent small children falling in and should generally not be more than 100m from the dwellings to be served. Ideally, waste should be covered at least weekly with a thin layer of soil to minimise flies and other pests.

Advantages: It is rapid to implement; and requires little operation and maintenance.

Constraints: The distance to communal pit may cause indiscriminate disposal; and waste workers required to manage pits.

Family pit disposal

Family pits may provide a better long-term option where there is adequate space. These should be fairly shallow (up to 1m deep) and families should be encouraged to regularly cover waste with soil from sweeping or ash from fires used for cooking. This method is best suited where families have large plots and where organic food wastes are the main component of domestic refuse.

Advantages: Families are responsible for managing their own waste; no external waste workers are required; and community mobilisation can be incorporated into hygiene promotion programme.

Constraints: Involves considerable community mobilisation for construction, operation and maintenance of pits; and considerable space is needed.

Communal bins.

Communal bins or containers are designed to collect waste where it will not be dispersed by wind or animals, and where it can easily be removed for transportation and disposal. Plastic containers are generally inappropriate since these may be blown over by the wind, can easily be removed and may be desirable for alternative uses. A popular solution is to provide oil drums cut in half. The bases of these should be perforated to allow liquid to pass out and to prevent their use for other purposes. A lid and handles can be provided if necessary.

In general, a single 100-litre bin should be provided for every fifty people in domestic areas, every one hundred people at feeding centres and every ten market stalls. In general, bins should be emptied daily.
Advantages: Bins are potentially a highly hygienic and sanitary management method; and final disposal of waste well away from dwelling areas.
Constraints: Significant collection, transportation and human resources are required; system takes time to implement; and efficient management is essential.

Family bins.
Family bins are rarely used in emergency situations since they require an intensive collection and transportation system and the number of containers or bins required is likely to be huge. In the later stages of an emergency, however, community members can be encouraged to make their own refuse baskets or pots and to take responsibility to empty these at communal pits or depots.
Advantages: Families are responsible for maintaining collection containers; and potentially a highly sanitary management method.
Constraints: In general, the number of bins required is too large; significant collection, transportation and human resources are required; takes time to implement; and efficient management essential.

Communal disposal without bins.
For some public institutions, such as markets or distribution centres, solid waste management systems without bins can be implemented, whereby users dispose of waste directly on to the

ground. This can only work if cleaners are employed to regularly sweep around market stalls, gather waste together and transport it to a designated off-site disposal site. This is likely to be appropriate for vegetable waste but slaughterhouse waste should be disposed of in liquid-tight containers and buried separately.
Advantages: System rapid to implement; there is minimal reliance on actions of users; and it may be in line with traditional/usual practice.
Constraints: Requires efficient and effective management; and full-time waste workers must be employed.

Transportation options.
Where bins or collection containers require emptying, transportation to the final disposal point is required. As described, waste transportation methods may be human-powered, animal-powered or motorised.
Human-powered
Wheelbarrows are ideal for the transportation of waste around small sites such as markets but are rarely appropriate where waste must be transported considerable distances off-site. Handcarts provide a better solution for longer distances since these can carry significantly more waste and can be pushed by more than one person. Carts may be open or can be fitted with several containers or bins.
Animal-powered.
Animal-powered transportation means such as a horse or donkey with cart are likely to be appropriate where they are commonly used locally. This may be ideal for transportation to middle distance sites.
Motorised.
Where the distance to the final disposal site is great, or where the volume of waste to be transported is high, the use of a motorised vehicle may be the only appropriate option. Options include tractor and trailer, a standard truck, or a tipper-truck, the final choice depending largely on availability and speed of procurement.

Off-site disposal options.
The technology choices outlined below are general options for the final disposal of waste off-site.
Landfilling.
Once solid waste is transported off-site it is normally taken to a landfill site. Here the waste is placed in a large excavation (pit or trench) in the ground, which is back-filled with excavated soil each day waste is tipped. Ideally, about 0.5m of soil should cover the deposited refuse at the end of each day to prevent animals from digging up the waste and flies from breeding. The location of landfill sites should be decided upon through consultation with the local authorities and the affected population. Sites should preferably be fenced, and at least one kilometre downwind of the nearest dwellings.
Advantages: A sanitary disposal method if managed effectively.
Constraints: A reasonably large area is required.

Incineration.
Although burning or incineration is often used for the disposal of combustible waste, this should generally only take place off-site or a considerable distance downwind of dwellings. Burning refuse within dwelling areas may create a significant smoke or fire hazard, especially if several fires are lit simultaneously. Burning may be used to reduce the volume of waste and may be appropriate where there is limited space for burial or landfill. Waste should be ignited

within pits and covered with soil once incinerated, in the same manner as land filling. The same constraints for siting landfill sites should be applied here also.
Advantages: Burning reduces volume of combustible waste considerably; and it is appropriate in off-site pits to reduce scavenging.
Constraints: There can be smoke or fire hazards.

Composting
Simple composting of vegetables and other organic waste can be applied in many situations. Where people have their own gardens or vegetable plots, organic waste can be dug into the soil to add humus and fibre. This makes the waste perfectly safe and also assists the growing process. This should be encouraged wherever possible, particularly in the later stages of an emergency programme. Properly managed composting requires careful monitoring of decomposing waste to control moisture and chemical levels and promote microbial activity. This is designed to produce compost which is safe to handle and which acts as a good fertiliser. Such systems require considerable knowledge and experience and are best managed centrally. In general, they are unlikely to be appropriate in emergencies. Advantages: Composting is environmentally friendly; and beneficial for crops. Constraints: Intensive management and experienced personnel are required for large-scale operations.

Recycling.
Complex recycling systems are unlikely to be appropriate but the recycling of some waste items may be possible on occasions. Plastic bags, containers, tins and glass will often be automatically recycled since they are likely to be scarce commodities in many situations. In most developing country contexts, there exists a strong tradition of recycling leading to lower volumes of waste than in many more developed societies.
Advantages: Recycling is environmentally friendly.
Constraints: There is limited potential in most emergency situations; and it is expensive to set up.

Intervention levels: Table 7.1 indicates general intervention strategies for the storage and disposal of solid waste in different emergency scenarios.

Table 7.1. Recommended interventions for different scenarios

Scenarios and recommended interventions	*The affected population go through a transit camp immediately after a disaster*	*The affected population remain in a temporary location for up to six months*	*The affected population stay in the affected area immediately after a disaster*	*The affected population move to a new area and are likely to remain for more than a year*
Immediate action	■ Clearing of scattered waste ■ Burning and burial of waste on site ■ Temporary communal pits ■ Temporary communal bins and off-site disposal ■ Repairing or upgrading of existing facilities			
Short-term measure	■ Communal pits ■ Family pits ■ Communal bins and off-site disposal			
Long-term measure			■ Communal pits ■ Family pits ■ Communal bins and off-site disposal ■ Repairing or upgrading of existing facilities ■ Recycling	

Protective measures

In order to minimise disease transmission there are several protective measures that can be undertaken. These concern equipment for staff and the siting and management of disposal sites.

Staff.

It is important that workers employed to collect and transport solid waste are provided with appropriate clothing and equipment. Gloves, boots and overalls should be provided wherever possible. Where waste is burned, or is very dusty, workers should have protective masks. Water and soap should be available for hand and face washing, and changing facilities should be provided where appropriate.

Siting of disposal sites.

The location of all disposal sites should be determined through consultation with key stakeholders including local government officials, representatives of local and displaced populations, and other agencies working in the area. Appropriate siting should minimise the effects of odour, smoke, water pollution, insect vectors and animals. On-site disposal is generally preferred since this requires no transportation and staff needs are low. This is appropriate where volumes of waste are relatively small, plenty of space is available and waste is largely organic or recyclable.

If the volumes of waste generated are large, or space within the site is severely limited, it maybe necessary to dispose of waste off-site. Where off-site disposal is to be used the following measures should be taken in selecting and developing an appropriate site:

- Locate sites at least 500m (ideally 1 kilometre) downwind of nearest settlement.
- Locate sites downhill from groundwater sources.
- Locate sites at least 50m from surface water sources.
- Provide a drainage ditch downhill of landfill site on sloping land.
- Fence and secure access to site.

Careful assessment should be made to determine who owns the proposed site and to ensure that apparently unused areas are not in fact someone's farm or back yard.

Resources and References

Ali, S.M., Cotton, A.P., and Westlake, K. 1999. Down to Earth: Solid Waste Disposal for Low-Income Countries, WEDC, Loughborough University, UK.

Ogawa, H. 1989. Selection of Appropriate Technology for Solid Waste Management in Asian Metropolises, An International Journal of Regional

Development Dialogue, UNCRD, Nagoya, Japan, Vol. 10 No.3, Autumn.

Tchobanoglous, G., Theisen, H., and Eliassan, R. 1977. Solid Wastes Engineering Principles and Management Issues, McGraw-Hill Book Company,

New York.

US Environmental Protection Agency. 1989. Decision-Maker's Guide to Solid Waste Management, Vol 1, Washington.

US Environmental Protection Agency. 1995. Decision-Maker's Guide to Solid Waste Management, Vol II, Washington.

Vagale, L. R. 1997. Environment of Urban Areas in India Case Study: Bangalore, ENVIS Journal of Human Settlements, Centre for Environmental Studies, School

of Planning and Architecture, New Delhi, India, November 1997.

Diaz, L.F. and C.G. Golueke, “Solid Waste Management in Developing Countries”, BioCycle, 26:46-52, September 1985.

Japan International Cooperation Agency, Master Plan and Feasibility Study on Seoul Municipal Solid Waste Management System in the Republic of Korea, Draft Final Report,

Tokyo, Japan, 1985.

Scharff, C. and G. Vogel, “A Comparison of Collection Systems in European Cities”, Waste Management & Research, 12(5), October 1994.

CalRecovery, Inc., Criterio de Diseño - Planta de Selección y Recuperación de Subproductos de los Residuos Sólidos Municipales, prepared for Mexico City, Mexico,

December 1992.

CalRecovery, Inc., Handbook of Solid Waste Properties, Governmental Advisory Associates, Inc., New York, New York, USA, 1993.

Morwood, R., “Australian Waste Management - Towards 2000”, Proceedings of 32nd Annual International Solid Waste Exposition, SWANA, San Antonio, Texas, USA, August

1994.

Cal Recovery Systems, Inc., Norconsult A.S., and Engineering-Science, Metro Manila Solid Waste Management Study - Review of Existing Conditions, May 1982.

Cointreau, S. Environmental management of urban solid wastes in developing countries. A project guide. Urban Development Technical Paper No. 5. World Bank, Washington, DC,

1982.

Diaz, L.F., G.M. Savage, and C.G. Golueke, Resource Recovery from Municipal Solid Wastes: Vol. I, Primary Processing, CRC Publishers, Inc., Boca Raton, Florida, USA, 1992.

Moeller, D. W. (2005). Environmental Health (3rd ed.). Cambridge, MA:Harvard University Press

Diaz, L.F., G.M. Savage, L.L. Eggerth, and C.G. Golueke, Composting and Recycling Municipal Solid Waste, Lewis Publishers, Ann Arbor, Michigan, USA, 1993.

Diaz, L.F. and C.G. Golueke, “Solid Waste Management in Developing Countries”, BioCycle, 26:46-52, September 1985.

CalRecovery, Inc., Metro Manila Solid Waste Management Study - Waste Stream Characterization, prepared for Ad Hoc Committee, Republic of the Philippines, May 1982.

Nath, K.J., “Solid Waste Management in the Present Indian Perspective”, proceedings of ISWA 1993 Annual Conference, Jönköping, Sweden, September 1993.

Japan International Cooperation Agency, Master Plan and Feasibility Study on Seoul Municipal Solid Waste Management System in the Republic of Korea, Draft Final Report,

Tokyo, Japan, August 1985.

CalRecovery, Inc., Handbook of Solid Waste Properties, Governmental Advisory Associates, Inc., New York, New York, USA, 1993.

World Health Organization, Regional Office for Europe, Urban Solid Waste Management, edited by Institute for the Promotion of International Health Actions (IRIS), Copenhagen,

Denmark, 1991.

Morwood, R., “Australian Waste Management - Towards 2000”, Proceedings of 32nd Annual International Solid Waste Exposition, SWANA, San Antonio, Texas, USA, August

1994.