LECTURE NOTES

For Environmental Health Science Students

Solid and Hazardous Waste Management

Ethiopia Public Health Training Initiative

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Preface

Inadequate or inappropriate management of solid waste produced in the course of human activities is likely to have serious public health consequences and deleterious effects on the environment.

In this lecture note, the various categories of solid wastes are defined. Considerable emphasis is given to classifications, generation rate and composition of solid waste. Most of the text, however, is devoted to the functional elements of solid waste management programs particularly, to storage, collection and disposal of solid wastes. The various technologies for final disposal of solid wastes are discussed in detail.

For health-care institutions in which resources are severely limited, there is a separate premise on minimal programs; this summarizes the simplest and least costly techniques that can be employed for the safe management of health-care solid wastes.

This lecture note is aimed at environmental health professionals, and public health professionals with an interest in and responsibility for an integrated solid waste management system to minimize or eliminate public and environmental health problems so as to prevent diseases and promote health and well being of the community. Its scope is such that it will find application in diploma and degree students alike. The lecture note has four chapters and each of the chapters has review questions at the end to enhance the teaching/learning process.

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CHAPTER ONE

SOLID WASTE MANAGEMENT

1.1 Learning Objectives

By the end of this chapter, the students will be able to:

1. define solid wastes.
2. describe major sources of solid wastes
3. list types of solid wastes.
4. discuss public health importance of solid wastes
5. mention ecological impacts of solid wastes

1.2 Introduction

Solid wastes are all the wastes arising from human and animal activities that are normally solid and are discarded as useless or unwanted. The term solid waste as used in this text is all- inclusive, encompassing the heterogeneous mass of throwaways from the urban community as well as the more homogeneous accumulation of agricultural, industrial, and mineral wastes. Because of their intrinsic properties, discarded waste materials are often reusable and may be considered as a resource in another setting. Integrated solid waste management is the term applied to all of the activities associated with the management of the community's waste. The basic goal of integrated solid waste management is to manage community waste in a manner that meets public health and environmental concerns and the public's desire to reuse and recycle waste material.

Solid waste today contains many materials such as plastics that are not readily degradable and toxic materials, primarily various types of chemical waste produced by industry. Similarly, the amount of hazardous waste generated has been undergoing dramatic change. In addition, industries increase their annual discharges of toxic chemicals directly into the environment.

Early civilizations did not have a problem with waste because it consisted mainly of organic wastes and the decomposers converted it into useful materials. There were also fewer people, and they generated little waste. The problem became larger with more people generating more and a variety of waste. (chemical, liquid, solid, nuclear, and hazardous). Little of this waste is food for the decomposers. Thus, a variety of methods must be used to manage the waste.

A comprehensive solid waste management program encompasses sweeping, storage, collection, and disposal of solid waste. Proper management in these four areas helps greatly in controlling insects, rodents and filth borne diseases.

In Ethiopia, particularly in Addis Ababa, an agency is responsible for the collection and disposal of solid wastes for the city of Addis Ababa with an estimated total population of 2.9 million in 2000. The agency has a clear mandate from the city administration of Addis Ababa. It has an institutional setup, separate budget, as well as the necessary equipment, manpower and logistics for the task. The activity is now carried out by 10 sub-city administration where a division runs the solid waste management program. At present, the agency has 3000 employees in the street sweeping unit and park development, and 128 permanent employees in the garbage collection units. It had a fleet of 74 heavy-duty trucks, (about 40 on the move) and two bulldozers and one compacter at the landfill site.

The estimated solid waste generation of an Addis Ababa resident was about 0.24 kilogram per capita per day and a total of 163,200 tons per annum. The existing collection capacity covered less than 50 percent of the total wastes generated. The remaining wastes were dumped along the streets, on vacant plots, along streams, in ditches, bridges, etc.

Solid waste management in other urban centers of Ethiopia are under the jurisdiction of Municipal Division of Health. All municipalities (except Addis Ababa) and certified urban centers are mandated by Proc. No. 206 of 1981 to provide, maintain and supervise environmental health services along with their other activities in their municipalities and urban centers. Thus, solid wastes management services are the responsibilities of these municipalities and urban centers. Most of them have no institutional set up and resources for discharging their duties effectively. This is aggravated by the low priority usually accorded to sanitation activities.

The sanitarians assigned to the regional health departments and health centers give technical advice whenever called for besides their routine activities.

Therefore, the material that follows will discuss the major aspects of solid waste management including type, source, and public health and ecological impacts of solid wastes.

1.3 Types of Non-Hazardous Solid Waste

Refuse: Includes all solid wastes. In practice this category includes garbage, rubbish, ashes, and other wastes.

1. **Garbage**: designates putrescible wastes resulting from the growing, handling, preparation, cooking, and serving of food. It attracts insects, rats and rapidly decomposes with production of unpleasant odor.
2. **Rubbish**: This term includes all nonputrescible refuse except ashes. There are two categories of rubbish: combustible and noncombustible.
    a. **Combustible**: This material is primarily organic in nature and includes items such as paper, cardboard, wood and bedding.
    b. **Noncombustible**: This material is primarily inorganic and includes tin cans, metals, glass, ceramics, and other mineral refuse.
3. **Ashes:** Waste products from coal, charcoal, and wood when burned.
4. **Other wastes**: demolished materials, abandoned cars, and construction wastes, are also considered as municipal waste.

1.4 Sources of Solid Wastes

The materials that are collected under the term solid waste include many different substances from a multitude of sources. The sources of solid wastes are dependent on the socioeconomic and technological levels of a society. A small rural community in Ethiopia may have known types of solid waste from known sources. While a big city such as Addis Ababa may have many sources.

Most people can identify solid waste when they empty their trashcans. There are much more household wastes that are considered to be solid waste than realized.

In all cases the following sources are universal:

1. **Residential:** generated from living households (domestic), generally contain non-hazardous solid wastes; kitchen waste, ''Ketema", and ash are common in Ethiopia.
2. **Agricultural**: solid wastes due to agricultural activities: food residues, animal dung, crop residues, etc. Such wastes are usually non-hazardous and negligible in rural Ethiopia.
3. **Commercial:** wastes generated from business establishments: food establishments, shops, etc, that

generate generally non-hazardous waste such as paper, cardboard, wood, metals and plastic.

4. **Industrial wastes:** from various types of industrial processes. The nature of the waste depends on the type of industry and kind of raw material involved. There may be toxic and hazardous wastes that have adverse effects to the environment.
5. **Institutional solid waste**: generating from public and government institutions: offices, religious institutes, schools, universities, etc.; generally not hazardous.
6. **Hospital solid wastes**: discarded, unwanted solid wastes from hospitals. It consists of both non-hazardous and hazardous waste. The above classification helps to identify whether the waste is hazardous or not.

Table 1. Type of waste with respect to its length of storage days

Waste type	Length of storage days	Control guide line (minimum)
Garbage	4	Fly breeding
Residential rubbish	7	Flies, land pollution
Mixed refuse	4	Flies
Street sweeping	7	Unsightliness
Dead animals	1	Flies, animal diseases
Special waste	1	Human diseases
Ashes	14	Air pollution, Unsightliness
Feces	1	Flies, human diseases

1.5. Public Health and Ecological Aspects

The proper storage at the point of generation, collection and disposal of the solid waste is part of the environmental health service program, which must be accomplished effectively in a community.

1. They produce a good breeding place for flies, hence create a favorable conditions for food contamination by flies and other fly-borne diseases.

2. Provide food and shelter for **rats** and **mice,** which are destroyers and contaminants of food and other goods.
3. Under certain conditions, may create suitable breeding place for **mosquitoes.** Subsequently bring in the problem of mosquito-borne diseases, (e.g. malaria, filariasis, etc)
4. May cause **nuisances**- which create aesthetic problem, (e.g. looks unpleasant and has bad smell, etc.)
5. May attract dogs, cats and other scavengers.
6. May cause fire hazards by instantaneous combustion.

The public health and ecological reasons for proper management of solid wastes are:

- an attractive media for the growth and multiplication of flies, and hence, may involve all diseases which are transmitted by flies, (e.g. typhoid fever, cholera, dysenteries. etc);
- a suitable breeding place for mosquitoes, subsequently bringing the problem of mosquito-born diseases;
- a good harborage for rats, which can be an economic as well as health problem;
- from aesthetic point of view , such as bad odor , unsightly conditions etc;
- pollution and contamination of air , land and water;
- possible fire hazards by instantaneous combustion;

Review Questions

1. What is solid waste?
2. Why is the problem of solid waste associated with time?
3. What are the major sources of solid waste?
4. What is the public health importance of solid waste?
5. How can solid waste affect humans from an ecological perspective?

CHAPTER TWO

CLASSIFICATION, GENERATION RATE AND COMPOSITION OF SOLID WASTE

2.1. Learning Objectives

By the end of this chapter, the students will be able to:

1. describe the major classifications of solid waste.
2. define the terms "puterscible" and "non-putrescible" solid waste.
3. describe the advantages of determining the solid waste generation rate.
4. list factors that determine the generation rate of solid waste.
5. determine the quantity and volume of solid wastes.
6. explain the composition of solid wastes.

2.2 Introduction

The characteristics, quantities, volume and composition of solid waste generated may differ from one country to another and between urban and rural areas. It depends mainly upon the customs, climate, living conditions and economic standard of the area.

2.3. Classification of Solid Waste

Solid waste can be classified into two categories by its characteristics. These are:

A. Putrescible solid waste

B. Non-Putrescible solid waste.

A. **Putrescible wastes**

- Are solid wastes that can be easily decomposed by bacterial action
- Result from the growing, handling, preparation, cooking and consumption of food.
- Their quantities are varying throughout the year, being greatest in amount during the summer months when vegetable wastes are more abundant.
- Require careful handling with frequent removal and adequate disposal.
- Are the most valuable component yielding fertilizers, or soil conditioners, through composting processes and used as animal/hog feed (e.g. garbage).

B. **Non putrescible wastes**

- Are solid wastes that cannot be easily decomposed by microbial action
- Consist of both combustible and non-combustible substances, such as cans, paper, brush, glass, cardboard, wood, scrap metals, bedding, yard clippings, crockery, etc.
- Are frequently responsible for the creation of nuisances and esthetic problems when they become scattered by the wind and careless handling (e.g. rubbish).

2.4 Generation Rate of Solid Waste

Determination of the generation rate of solid waste is important to obtain data in order to determine waste volume and for subsequent solid waste management.

Factors to consider for the purpose of determining the generation rate are:

1. Measures of quantities

a. Volume measurement.

b. Weight measurement

Be careful in volume measurement because you need to distinguish wastes which are compacted and loosened. Both have different weight and volume. Weight is the most accurate basis for records regardless of whether the waste is loose or compacted.

2. Statistical Analysis

It is necessary to have some statistical base for solid waste management system development. This includes placement of containers, programming the collection program and allocation of vehicle type. (See chapter 3)

3. Expression of Unit Generation

In addition to knowing the source and composition of solid waste, it is important to have uniform units of expression.

a. Residential and Commercial – kilogram per capita per day (Kg/c/d)
b. Agricultural –Kilogram per hectare per year (kg/ ha/ year)

4. Methods Used to Determine Generation Rate

a. Load count analysis –basically involves counting of the individual loads over a specified time period. If possible, weighing the load will be very important.
b. Weight -volume analysis- measuring the volume of the truck and weight of each load will give ample data.

Although the technique is expensive, it is used to: draw a system boundary round the unit to be studied; identify what occurrences affect generation rates; identify the rate of generation associated with different activities using the data available; determine the quantity of waste generated, stored and collected

5. Typical Generation Rate

This is the rate found by conducting a large survey very representative for a nation, state or locality.

6. Factors Affecting Generation Rates

Factors that affect the generation rate of solid waste include:

a. geographical location – related primarily to the different climate that can influence both the amount generated and collection operation.
b. season of the year
c. frequency of collection
d. characteristics of population
e. extent of salvage and recycling.
f. legislation
g. public attitude

2.5. Composition of Solid Waste

Composition of solid waste depends on the local factors such as time of the year or season, habits of the community, educational status, economic status, geographical location, and population size.

A. Physical Composition

Knowing the physical composition of solid waste is important for the selection and operation of equipment facilities, to assess the possibility or feasibility of energy recovery and to design disposal facilities. Its analysis may contain individual component study, moisture content study and density.

Table 2. Ordinary physical composition of municipal solid waste

Component	Percent by weight	
	Range	Typical
Food waste	6-26	15
Paper	24-45	40
Cardboard	3-15	4
Plastics	2-8	3
Textiles	0-4	2
Rubber	0-2	0.5
Leather	0-2	0.5
Garden trimming	0-20	12
Wood	1-4	7
Glass	4-16	8
Tin cans	2-8	6
Nonferrous metals	0-1	1
Ferrous metals	1-4	2
Dirt, Ash, Brick	0-10	4

Source: Rolf Eliassen et al: Solid Wastes Engineering

B. Chemical Composition

It is very important to study the nature and value of solid waste to plan different disposal and recovery options. These studies include the assessment of moisture content, volatility, ash content, etc. The moisture content of municipal solid wastes varies depending on composition of the waste, the season of the year, humidity and weather condition.

Table 3. Typical data on moisture content of municipal solid waste.

Component	Moisture content by percent	
	Range	Typical
Food waste	50-80	20
Paper	4-15	6
Cardboard	4-8	5
Plastics	1-4	2
Textiles	6-15	10
Rubber	1-4	2
Leather	8-12	10
Garden trimming	30-80	60
Wood	15-40	20
Glass	1-4	2
Tin cans	2-4	3
Nonferrous metals	2-4	3
Ferrous metals	2-6	3
Dirt, Ash, Brick, Stone	6-12	8

Source: Rolf Eliassen et al: Solid Wastes Engineering

2.6 Quantities and Volume of Solid Waste

Various estimates have been made on the quantity of solid waste generated and collected per person per day. The amount of municipal solid waste collected is estimated to be

2.7 kg/capita/day, of which about 0.6 kg is residential. Averages are subject to adjustment depending on many factors: time of the year; habits, education, and economic status of the people; number and type of commercial industrial operations; whether urban or rural area; and location.

Each community should be studied and actual weighing made to obtain representative information for design purposes. Community wastes are not expected to exceed 1000 kg/capita/year. With the emphasis being placed on source reduction such as less packaging, waste recovery and recycling such as of paper, metals, cans, and glass, the amount of solid waste requiring disposal is reduced. The volume occupied by solid waste under certain conditions determines the number and size or type of refuse containers, collection vehicles, and transfer stations. Transportation systems and land requirements for disposal are also affected.

Review Questions

1. What are the major classifications of solid wastes?
2. What are the factors that determine the generation rate of solid waste?
3. Why it is important to determine the generation rate of solid waste?
4. How can you determine the composition of solid waste?
5. What are factors that determine the generation rate of solid waste?

CHAPTER THREE

FUNCTIONAL ELEMENTS OF SOLID WASTE MANAGEMENT SYSTEM

3.1 Learning Objectives

By the end of this chapter, the students will be able to:

1. list functional elements of a solid waste management program.
2. identify requirements of solid waste storage containers.
3. realize that collection process of solid wastes is complex.
4. compare sanitary land fill and incinerators.
5. identify common dead body disposal methods.
6. describe common solid waste disposal methods.

3.2 Introduction

Aesthetics, land use, health, water pollution, air pollution, and economic considerations make proper solid waste storage, collection and disposal of solid wastes (municipal and individual) functions that must be taken seriously. Indiscriminate dumping of solid waste and failure of the collection system in a populated community would soon cause many health problems. Odors, flies, rats, roaches, crickets, wandering dogs and cats, and fires would dispel any remaining doubts of the importance of proper solid waste storage, collection and disposal.

3.3 On-Site Handling, Storage and Processing of Solid Waste

A. On-Site Handling

On-site handling methods and principles involve public attitude and individual belief, and ultimately affects the public health. It is an activity associated with the handling of solid waste until it is placed in the containers used for its storage before collection. This may take place at any time before, during or after storage.

Importance of on-site handling of solid waste:

- reduce volume of waste generated
- alter physical form
- recover usable materials

On- site handling methods:

- sorting
- shredding
- grinding
- composting

Factors that should be considered in evaluation of on site processing include capabilities, reliability, environmental effects, ease of operation, etc.

B. On- Site Storage

The first phase to manage solid waste is at home level. It requires temporary storage of refuse on the premises. The individual householder or businessman has responsibility for onsite storage of solid waste.

For individual homes, industries, and other commercial centers, proper on-site storage of solid waste is the beginning of disposal, because unkept or simple dumps are sources of nuisance, flies, smells and other hazards.

There are four factors that should be considered in the on-site storage of solid waste. These are the type of container to be used, the location where the containers are to be kept, public health, and the collection method and time.

1. Storage containers

Garbage and refuse generated in kitchens and other work areas should be collected and stored in properly designed and constructed water-proof garbage cans (waste bins). The cans or receptacles can be constructed from galvanized iron sheet or plastic materials. They should have tightly fitting covers.

They must be of such size that, when full, they can be lifted easily by one man. They should be located in a cool place on platforms at least 30 centimeters above ground level. After putting in garbage, they should be kept covered. The bins must be emptied at least daily and maintained in clean conditions. A typical example of garbage can, constructed from galvanized iron sheet, dimensions: diameter 45 cm and height 75 cm, is shown in figure 1 below.

An adequate number of suitable containers should be provided with proper platforms with receptacles stand. The number may depend on the amount, type and establishments where the need arises. Suitable containers should be water-tight, rust-resistant, with tight-fitting covers, fire-resistant, adequate in size, light in weight, with side handles and washable.

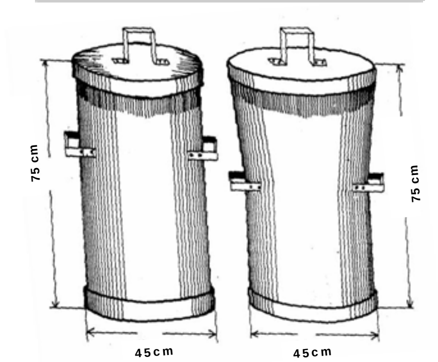
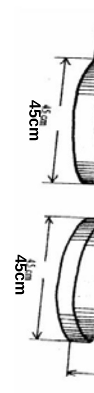


Figure 1. Typical Garbage Can with Tightly Fitting Cover

Source: Gabre-Emanuel Teka (1997): Solid Waste Disposal From Food Premises; In Food Hygiene



2. Container Size (capacity)

Consideration should be given for the size of the loaded container that must be hauled to the collection vehicle or to the disposal site.

Therefore, container size for:-

- ash: up to 80 to 128 liters
- mixed refuse: should not exceed 120 to 128 liters
- rubbish up to 200 liters
- kitchen waste is 40 liters
- garbage is 48 to 80 liters

Plastic liners for cans and wrapping for garbage reduce the need for cleaning of cans and bulk containers, and keep down odors, rat and fly breeding.

Galvanized metal is preferable for garbage storage because it is resistant to corrosion. Plastic cans are light in weight but are easily gnawed by rats.

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

A concrete platform provided with a drain to an approved sewer with a water faucet at the site facilitates cleaning.

On- site processing

Importance of on-site processing:

- reduces volume of waste generated
- alters physical form
- recovers usable materials

Factors that should be considered in evaluating on-site processing are capabilities, reliability, environmental effects, ease of operation, etc.

3.4 Collection of Solid Waste

This is the removal of refuse from collection points to final disposal site. It is the most expensive as compared with other operation and management procedures, because it demands special vehicles, experienced people to manage, more manpower, hand tools, and more funds for fuel, salary, maintenance, gathering or picking up of solid waste from the various sources, taking the collected wastes to the location where it is emptied, and unloading of the collection vehicle.

Collection cost has been estimated to represent about 50% of the total cost of collection when a sanitary landfill is used as means of disposal, and 60% when incineration is used.

Home collection of solid waste generally is done by a private collector or a local government-owned and financed operation.

Private collectors usually charge a fee to each individual homeowner, or a government contract will pay the fees. The government contract enables solid waste collection in a uniform, sanitary manner. Without such a contract, some individuals may be reluctant to pay the collector for the service and the refuse may go uncollected.

1. Collection process

Involves five different phases.

Phase 1 - House to dustbin

Phase 2 - Dustbin to truck

Phase 3 - Truck from house to house

Phase 4 - Truck to transfer station

Phase 5 - Truck to disposal

2. Collection services

People must understand that a good refuse-collection service requires citizen cooperation in the provision and use of proper receptacles in order to keep the community clean and essentially free of rats, flies, and other vermin.

There are four types of collection services:

I. **Curb (curb side):** The home owner is responsible for placing and returning the empty container. Never entirely satisfactory.

II. **Set-out (block collection):** Owner is responsible for returning the container. The full containers are brought or set at the collection site by the crew. Bins are not left out on the street for long periods.

III. **Backyard carrying service (door to door collection**): Collection crews that go along with the collection vehicle are responsible for bringing out stored solid waste from the dwelling units. It is the only satisfactory system in which the householder does not get involved.

IV. **Alleys**: a narrow street or path between buildings in a town. That is difficult to get the container and also to the vehicle that will collect the waste.

Method of loading the solid waste on the vehicle:

a. directly lifting and carrying of container.

b. rolling of loaded containers on their rims.

c. use of small lifts for rolling the containers to the collection vehicle.

d. use of large containers into which wastes from small containers are emptied.

3. Planning of Solid Waste Collection Program.

Routing system of collection

1. Micro-routing is:

- the routing of a vehicle within its assigned collection zone.

- concerned with how to route a truck through a series of one or two way streets so that the total distance traveled is minimized.
- very difficult to design and execute.

2. Macro-routing is:

- large scale routing to the disposal site and the establishment of the individual route boundaries.

Modes of operation in solid waste collection

1. **Hauled container system**- The containers used for the storage of wastes are hauled to the disposal site, emptied and returned.
2. **Stationary container system** - The containers used for the storage of waste remain at the point of generation except for occasional short trips to the collection vehicles.

Unit operations

1. **Pick-up** - refers to the time spent driving to the next container after an empty container has been deposited.
2. **Haul** - represents the time required to reach the disposal site starting after a container whose contents are to be emptied has been loaded on the truck plus the time spent after leaving the disposal site until the truck arrives at the location where the empty container is to be deposited.

3. **At-site-** refers to the time spent at the disposal site and includes the time spent waiting to unload as well as the time spent in loading.
4. **Off-site** - includes the time spent on activities that are non-productive from the point of view of the overall collection system.

3 Frequency of solid waste collection

The frequency of collection depends on the quantity of solid waste, time of year, socioeconomic status of the area served, and municipal or contractor responsibility. In business districts, refuse, including garbage from hotels and restaurants, should be collected daily except on Sundays.

In residential areas, twice-a-week for refuse collection during warm months of the year and once a week at other times should be the maximum permissible interval. Slum areas usually require at least twice-a-week collection. The receptacle should be either emptied directly into the garbage truck or carted away and replaced with a clean container.

Refuse transferred from can to can will cause spilling, which results in pollution of the ground and attraction of flies. If other than curb pickup is provided, the cost of collection will be high. Some property owners are willing to pay for this extra service. Bulky wastes should be collected every 3 months.

Garbage - should be collected at least two times weekly in residential sections in summer and winter. However, most commercial establishments should be accorded daily collection service throughout the year.

Rubbish - is generally collected weekly in residential areas and daily in business sections.

Mixed refuse - should be collected twice daily from most commercial concerns.

The provision of frequent collection services is important in the prevention of fly breeding in garbage, because irregular collections can contribute to the nuisances and hazards which result under poor storage conditions and in chances the amount greater than the expected requirement from households.

4. Collection equipment

Mechanical collection systems have been developed to reduce collection cost. The system requires use of a special container, truck container pick-up equipment, and replacement of the container.

From an economic point of view, such equipment are most unlikely to be applied in Ethiopian situation.

Collection equipment that simplifies the collection of refuse and practically eliminates cause for legitimate complaint is available. The tight-body open truck with a canvas or metal cover has been replaced in most instances by the automatic loading truck with packer to compact refuse dumped in the truck during collection, except for the collection of bulky items. Compaction-type bodies have twice the capacity of open trucks and a convenient loading height. Low-level closed-body trailers to eliminate the strain of lifting cans are also available.

The number and size of the collection vehicles and the number of pickups in residential and business areas for communities of different population will vary with location, affluence, and other factors. The average refuse truck holds 6,000 to 8,000 kilograms.

The solid waste collection vehicle should be covered and able to compact the refuse collected. It may load from the rear, side, or top. The storage areas in these vehicles should be kept relatively clean and water-tight.

5. Organization of solid waste collection program

Many cities and towns require homeowners to use certain types of receptacles. Collectors usually pick up at the curb in front of the dwelling. In some neighborhoods the collectors pick up the receptacles in the backyard, as the people who live there consider receptacles too bulky to handle and unsightly in front of their dwellings.

Haul distance to the disposal facility must be taken into consideration in making a cost analysis. In some highly urbanized areas it is economical to reduce haul distance by providing large, specially designed trailers at transfer stations. In suburban and rural areas, container stations can be established at central locations. These stations may include a stationary compactor for ordinary refuse and a bin for tires and bulky items. Separate bins for paper, glass, and aluminum may also be provided.

Labor requirements for the collection of solid waste depend on both the type of service provided and the collection system used:

1. For hauled container system: one person, two for safety, and a driver to drive the vehicle load and unload containers and empty the container at the disposal site.
2. For stationary container system the labor requirement for mechanically loaded ones are essentially the same with hauled container system. Occasionally, a driver and two helpers are used.

For manually loaded systems, the number of collectors may vary from one to three, depending on the type of service and the type of collection equipment, Curb collection needs less persons than backyard collection, which may require a multi-person crew.

3.5 Transfer and Transport

Transfer stations are used to collect the refuse at a central location and to reload the wastes into a vehicle where the cost per kilogram-kilometer ton-mile will be less for the movement of the ultimate waste to the disposal site. Transfer stations are employed when the disposal site is situated at significant distance from the point of collection.

A transfer station can reduce the cost of transporting refuse by reducing manpower requirement and total kilometers. When a collection vehicle goes directly to the disposal site, the entire crew, driver plus laborers, are idle. For a transfer vehicle, only one driver is needed. As the distance from the centers of solid waste generation increases, the cost of direct haul to a site increases. Ideally, the transfer station should be located at the center of the collection service area.

A transfer station may include stationary compactors, recycling bins, material recovery facility, transfer containers and trailers, transfer packer trailers, or mobile equipment.

A transfer station should be located and designed with drainage of paved areas and adequate water hydrants for maintenance of cleanliness and fire control and other concerns like land scaling, weight scales, traffic, odor, dust, litter, and noise control. Transporting vehicles could be a modern packer truck (trailer), motor-tricycles, animal carts (appropriate for developing countries), hand carts and tractors.

Transfer and transport station should provide welfare facilities for workers (lockers, toilets, showers); small stores for brooms, shovels, cleaning materials, lubricants, parking facilities for hand trucks, sweepers, refuse collectors, and office and telephone for the district inspector.

3.6 Resource Recovery and Processing

Resource recovery is a partial solid waste disposal and reclamation process. It can be expected to achieve about 60% reductions in future landfill volume requirements. Resource recovery must recognize what is worth recovering and the environmental benefits.

Resource recovery and processing is a complex, economical and technical system with social and political implications, all of which require critical analysis and evaluation before a commitment is made. They demand capital cost, operating cost, market value of reclaimed materials and material quality, potential minimum reliable energy sales, assured quantity of solid wastes, continued need for a sanitary landfill for the disposal of excess and remaining unwanted materials and incinerator residue, a site location close to the center of the generators of solid wastes.

Products That Can Be Recycled

1. Plastic

Plastic is not a natural material. It is synthesized from petro-chemicals to create a long, complicated chain of atoms called polymers. Bacteria and fungi that would usually live on the decaying waste of natural food, fauna, and flora cannot digest these recovery polymers.

Instead, toxic cadmium and lead compounds used as binders can leach out of plastics and ooze into groundwater and surface water in unlined or failed landfills. Unfortunately, plastic is one of the most common non-biodegradable wastes deposited in landfills.

There are a number of plastic items that create great decomposition problems. Among them are diapers, grocery bags and balloons. Today only 3% of all plastic containers are recycled.

Plastic threatens the lives of millions of marine animals who get entangled in plastic netting. Autopsied marine animals have revealed that their intestines were full of non-biodegradable plastic. Marine mammals and birds have suffocated, strangled, and been poisoned by the plastic waste such as can rings or balloons that have been expelled into the oceans and into the air. Fishermen currently dump around 175,000 tons of plastic into the oceans each year. It is thought that as many as a million sea birds and 100,000 marine mammals in the Northern Pacific Ocean die each year from eating or becoming entangled in plastic waste.

Many more marine lives are poisoned in the Atlantic Ocean by raw sewage, chemical waste, and pesticide waste flowing from rivers into these water bodies.

2. Tires

Discarded tires pose two particular vector health threats to a community: rats and mosquitoes. Tires create an excellent breeding place for rats and mosquitoes, which in turn carry diseases to humans.

An automobile tire contains about 10 liters of oil, which has the potential to produce enough electricity to serve a small town. Unfortunately, when tires burn in an uncontrolled environment, they are extremely difficult to contain or extinguish.

There are actually some tire graveyards that have been burning for years. Although 15 million old tires are recycled each year, the number of recycled tires is actually going down each year as new blends of rubber and steel-belted tires cannot use recycled tires.

3. Paper

Paper is the single most frequently seen item in most landfills, taking up more land space. It accounts for more than 40% of a landfill's contents. Newspapers alone may take up as much as 13 to 30% of the space in landfills. It is not enough to just change from paper grocery bags to recyclable cloth bags. Garbage archeologists from the University of Arizona have discovered that most materials buried deep in a landfill change very little. Newspapers from the 1950s could still be read in 1992. Paper in landfills does not biodegrade; it mummifies.

Paper may be one of the most recyclable waste products. To establish a newsprint recycling mill, it takes three to five years and costs from $300 to $500 million to build. Can the capital investment be recouped if there is no community plan to market the recycled paper? If economic incentives were given to creative entrepreneurs, more products could easily be developed.

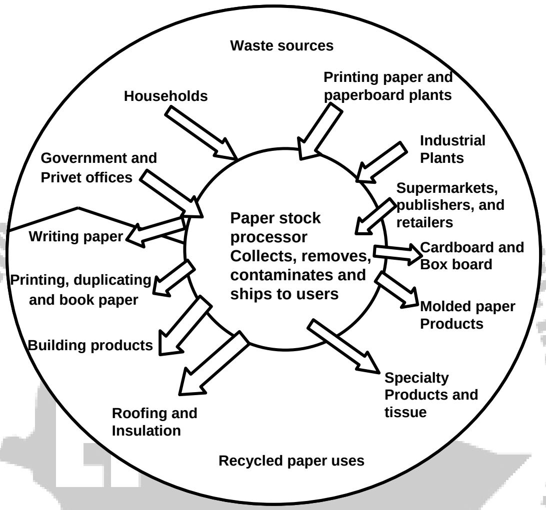


Figure 2. The sources and uses of recycled paper. (Source: World Health Organization (1999) Safe Management of Wastes From Health Care Activities.)

Obstacles to resource recovery

- heterogeneity of the waste
- putrescibility of the waste
- location of the waste
- low value of product
- uncertainty of supply
- unproven technology

- administrative and industrial constraints
- legal restriction
- uncertain market

Techniques involved in resource recovery

1. compaction, which mechanically reduces the volume of solid waste
2. chemical volume reduction by incineration
3. mechanical size reduction by shredding, grinding and milling
4. component separation by hand-sorting, air separation, magnetic separation and screening

3.7 Disposal of Solid Waste

Until relatively recently, solid waste was dumped, buried, or burned, and some of the garbage was fed to animals. The public was not aware of the links of refuse to rats, flies, roaches, mosquitoes, fleas, land pollution, and water pollution. People did not know that solid waste in open dumps and backyard incinerators support breeding of diseases vectors including typhoid fever, endemic typhus fever, yellow fever, dengue fever, malaria, cholera, and others. Thus, the cheapest, quickest, and most convenient means of disposing of the waste were used. Rural areas and small towns utilized the open dump or backyard incinerator. Larger towns and cities used municipal incinerators. Later, land filling became the method of choice for disposing of solid waste.

In solid waste management, disposal is one of basic programs that has to be done with maximum precautions. If it is not done effectively and efficiently, the whole program will not be satisfactory.

Strictly speaking the task of solid wastes disposal is normally handled by municipal, city or town authorities, if such service exists.

Disposal of solid waste has to be accomplished without the creation of nuisance and health hazards in order to fulfill the objectives of solid waste management program. These are:

- improvement of esthetic appearance of the environment
- avoidance of smells and unsightliness.
- reduction of disease by curtailing fly and rodent breeding
- prevention of humans and stray dogs from scavenging

In disposal of solids wastes, it is recommended that the following be done to avoid any risks:

1. The disposal site should be 30 meters from water sources in order to prevent possible contamination
2. Radioactive materials and explosives should not be together.
3. The site should be fenced to keep way scavengers.
4. All surfaces of the dump should be covered.

5. All wastes should be dumped in layers and compacted.
6. The disposal site should be about 500 meters from residential areas.

Generally there are several methods of solid waste disposal that can be utilized. These methods are:

1. Ordinary open dumping
2. Controlled tipping/burial
3. Hog feeding
4. Incineration
5. Sanitary landfill
6. Composting
7. Grinding and discharge into sewer
8. Recycling
9. Dumping into water bodies
10. Disposal of corpses

1. Open Dumping

Some components of solid waste such as street sweepings, ashes and non combustible rubbish are suitable for open dumping. Garbage and any other mixed solid wastes are not fit or suitable because of nuisance and health hazard creation. Generally, solid waste is spread over a large area, providing sources of food and shelter for flies, rats and other vermin. It causes unsightly odor and smoke, nuisance and hazards. Carefully selected rubbish must be disposed in order to prevent fire accidents that might occur. The location of open dumping must be carefully chosen so that there will be a minimum chance of complaints from nearby residents.

Advantages of open dumping

1. It can take care of all types of solid wastes except garbage.
2. It causes less health problems if proper site is selected.
3. It needs less labor and supervision.

Disadvantage of open dumping

1. It attracts flies, mosquitoes and other insects as well as stray dogs, rats, and other animals.
2. It creates breeding sites for rodents, arthropods and other vermin.
3. It creates of smoke, odor and nuisance.
4. It makes the lands and other surrounding areas useless.
5. It leads to cuts and wounds.
6. It attracts scavengers, both humans and animals.

The following points should be kept in mind and must be considered before selection and locating sites for open dumping:

1. Sources of water supply and distance from it
2. Direction of wind
3. Distance from nearest residents, nearby farm areas and main land
4. Distance that flies can travel from disposal site to living quarters as well as the distance that the rodents can travel from disposal areas and living quarters.

Negligence to these and some other factors would lead unforeseen health problems; if at all this method is selected.

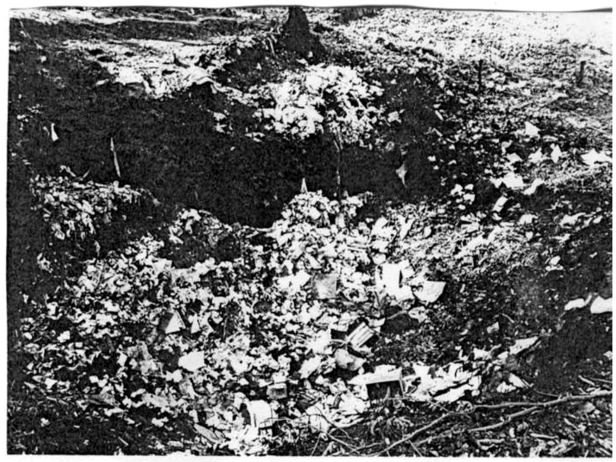


Figure 3. Uncontrolled solid waste disposal. (Source: Sandra J. Cointreau: Environmental Management Of Urban Solid Wastes in Developing Countries.)

2. Controlled tipping/burial

Indiscriminate dumping of garbage and rubbish creates favorable conditions for fly-breeding, shelter and food for rodents, nuisances etc. In order to avoid such problems, garbage and rubbish should be disposed of under sanitary conditions.

One of the simpler and cheaper methods is burning garbage and rubbish under controlled conditions. Controlled or engineered burial is known as Controlled Tipping or Sanitary

Landfill System. In places where there is no organized service, this system can be done by digging shallow trenches, laying down the generated waste in an orderly manner, compacting the waste manually or mechanically, and covering with adequate depth of earth or ash at the end of each day's work. The process is repeated each day systematically at appropriate locations. If properly done, this system can prevent fly-breeding, rodent shelter, mosquito-breeding and nuisances. It can be applied in areas where appropriate land is available for such practice. This system can be considered an adaptation of what is technically called the sanitary landfill system in municipal solid wastes management service. Principally it consists of the following steps:

a. Choosing a suitable site, usually wasteland, to be reclaimed within reasonable distance from habitation.
b. Transporting the generated wastes to the site by appropriately designed vehicles.
c. Laying the wastes in appropriate heap to a pre-determined height.
d. Compacting the layer mechanically.
e. Covering the compacted layer with a thin layer of earth 22 cm depth at the end of each work day. The same steps are repeated for each work period.

3. Hog Feeding

The feeding of garbage to hogs has been practiced for many years in different parts of the world. But there is surprising high incidence of trichinosis among hogs which are fed with uncooked garbage.

Consumption of insufficiently cooked meat from hogs is believed to be the main source of trichinosis. Hogs which are fed on garbage containing hogs' scraps and slaughter-house offal are very likely to be infected. Also rats living around the slaughter-house are infected and there is the possibility that hogs eats dead rats.

The Trichinosis worm is easily killed only at a temperature of 58^0 C. So pork should be cooked until this temperature is obtained. Refrigeration at -35^0C for a period of 30 days will also kill the larva.

Pickling, salting and smoking also kill the larva when done thoroughly. Garbage feeding is profitable if properly handled by farmers and if they are willing to collect it themselves. They should collect it daily and furnish clean cans. While garbage is the most potential valuable element or component of solid waste, it is the most difficult to handle in a sanitary manner and is responsible for the majority of nuisances and health hazards associated with the disease. To use garbage for hog feeding, it has to be cooked at a temperature of $100\ ^0$ C for 30 minutes just to be on safe side. Cooking the garbage before hog feeding will not reduce the food value.

4. Incineration

Incineration is a process of burning the combustible components of garbage and refuse. Disposal of solid waste by incineration can be effectively carried out on a small scale in food service establishments as well as in institutions such as hospitals, schools etc.

The disadvantage of this method is that only combustible materials are incinerated, hence there is a need for separation of the waste into combustible and non-combustible. The non-combustible waste needs separate disposal. Generally there are two types of incinerators, the open and the closed systems.

In the **open** system the refuse is incinerated in a chamber open to the air; while the **closed** system contains a special chamber designed with various parts to facilitate incineration. It requires a chimney of appropriate height to provide a good flow of air through the combustion chamber. There are varieties of designs for small scale incinerators. A typical example of design is shown in Figure 4. The size can be varied depending on the volume of the refuse to be incinerated.

- The combustion chamber is laid with iron grids, at the bottom of which are air inlets in front and at the back.
- The front and back walls are with provision for installing a chimney.
- The feeding door has a baffle wall to facilitate refuse feeding.
- The base below the combustion chamber is for collecting.

On-site Incineration

This term applies to incineration of refuse at home, office, apartment house, commercial building, hospital or industrial site. Refuse collection and disposal could be reduced satisfactorily by using on-site incineration. Generally, air-pollution can be expected.

Advantages of an incinerator

1. Less land is required for landfills
2. A central location is possible, allowing short hauling for the collection service.
3. Ash and other residue produced are free of organic matter, nuisance- free, and acceptable as fill material.
4. Many kinds of refuse can be burned. Even non-combustible materials will be reduced in bulk.
5. Climate or unusual weather does not affect it.
6. Flexibility is possible - no restriction for its operation.
7. Getting income through the sale of waste heat for steam or power is possible.

Disadvantages of an incinerator

1. Initial cost is high during construction.
2. Operating cost is relatively high.
3. Skilled employees are required for operation and maintenance.
4. There may be difficulty in getting a site.

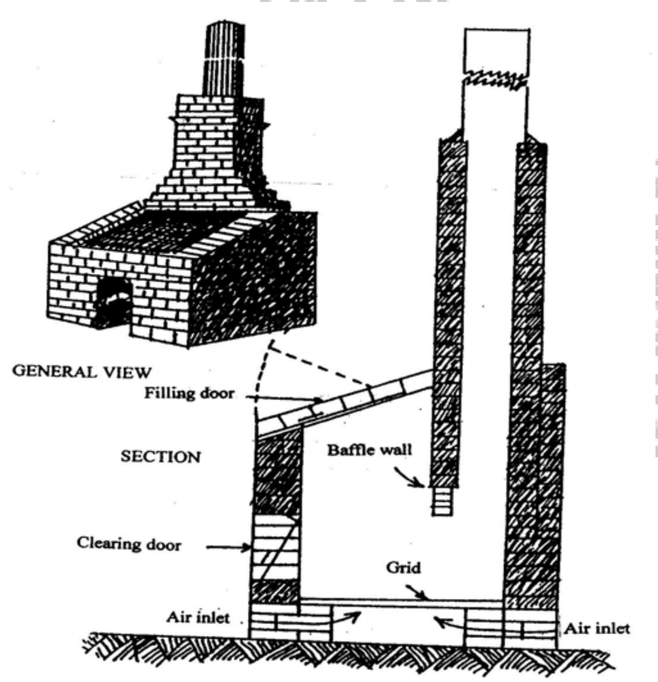


Figure 4. Single chambers onsite Incinerator (Source: Gabre-Emanuel Teka (1997): Solid Waste Disposal From Food Premise, In Food Hygiene.)

An example of this type is commonly seen in some institutions in Ethiopia. A typical design consists of the following dimensions: width = 110 cm; length =110cm; height in front = 135cm; height at back =150cm. Concrete base (chamber)= 60cm by 75cm by 10cm; top fueling door = 60cm by 60cm square, with thickness 5cm. With proper management and little fuel the incinerator can effectively burn dry as well as wet materials.

5. Sanitary Landfill

One of the most widely used means of solid waste disposal is the sanitary landfill. A properly operated sanitary landfill eliminates insects, rodents, safety hazards, fire hazards, and other problems that exist in open dumping.

Sanitary landfill is an effective and proven method for a permanent disposal of refuses. The sanitary landfill method can be used in any community where sufficient suitable land is available. It is especially suitable for cities of less than 100,000 people because sufficient land is more likely to be available in these areas.

The sanitary landfill method of solid waste disposal consists basically of four steps:

1. depositing of refuse in planned and controlled manner
2. compacting the refuse in thin layer to reduce its volume

3. covering the refuse with a layer of earth
4. compacting the earth cover

The sanitary landfill, in most cases, has proved to be the answer for safe and economical solid waste disposal. Refuse should be well compacted in 1.8 to 3.7 meter layers. The fill should not exceed more than 1.8 to 2.4 meter in depth and each day's accumulation of refuse should be sealed with 0.6 meter of cover, and the entire fill finally sealed with 0.67 meter of soil.

A. Site selection for sanitary landfills

The location of sanitary landfill should be based on:

1. distance from the sources of waste so that the hauling distance not too great.
2. availability of suitable access roads and bridges.
3. type of soil for seal (covering) - sand or soil is the most desirable. Avoid rock and clay soil.
4. avoid contact to the water table in order to prevent water contamination.
5. avoid main traffic arteries by trucks.
6. no obstruction of normal drainage channels.
7. avoid areas subjected to flooding.
8. available land areas.
9. impact of processing and resource recovery.

10. soil condition and topography
11. geologic and hydrologic condition
12. surface water hydrology
13. local environmental condition
14. local climatic condition

Final selection of a disposal site usually is based on the result of:

- preliminary study
- engineering design
- cost situations
- environmental impact assessment

B. Location of sanitary landfills

1. 30 meter from all property lines
2. 152 meter from all residences
3. 152 meter from all wells determined to be down gradient and used as a source of drinking water by humans or livestock
4. 61 meter from normal boundaries of springs, lakes, and other bodies of water

C. Method of sanitary landfill construction

Basically, there are two methods and the choice will be made according to the surrounding land available.

1. Area method

The area method is a method where solid waste is dumped, spread, compacted and covered with covering materials. Enough cover should be excavated to provide a 1.8 meter layer daily and a final layer of 7.3 meter, compacted well to eliminate breeding by rodents, flies and other vermin.

2. Trench method

Trench method is used when level ground is available. There are three variations of trench method. These are:

A. Single progressive trench

The trench is dug for one day's solid waste, and cover material is obtained by further trenching.

B. Single trench

One single trench is dug. Excavated material is placed on both sides for use as a cover.

C. Dual trench

One trench is excavated on the length of the site and refuse is dumped into it. Cover materials come from parallel trench excavated two or more meters from the first trench depending on the soil formation.

Trench method operation

a. Dig the trench on the windward side and ramp on the wind ward side of the trench to reduce blowing of papers.

b. The average trench depth is about 2.4 meters to include cover, but may be dug deep (1.8 meter to 3 meter) if the soil is loose and land is scarce.

The trench is usually twice the track width but may be wider, to permit two or more trucks dumping at once.

2. Compaction of sanitary landfills

The objectives of compaction in the trench method are to:

1. reduce settlement problem
2. prevent fire
3. eliminate odor
4. kill flies
5. conserve trench space
6. provide a solid field for truck travel and future use

Methods to obtain the best compaction:

1. Spread refuse thin, and mix garbage with refuse.
2. Hard materials from old furniture leftover, building materials and other bulky materials should be buried deep to eliminate rat shelters.

3. Increase the cover of refuse when the fill is complete (7.3 meter) and daily base 1.8 meter.
4. After the compaction and the fill is established, continuous maintenance program should be carried out to ensure repair crack, erosions and depressions of the surface and side slope.
5. The final level of the fill should be half to one percent slope to allow adequate drainage.
6. Much steeper than a 1% slope should be avoided because it encourages erosion.

Remarks:

1. A separate trench or pit may be desirable for disposal of small dead animals, spoiled food stuffs and other large quantities of untraceable materials.
2. Generally, the rate of decomposition of refuse in a landfill prevents the reuse of the same location for many years. In some areas, decomposition of materials is a achieved after a period of 10 to 15 years, although there are reports of reuse of landfills after a period of about 30 years without insect or odor nuisance.

3. Characteristics of Sanitary Landfills

If the refuse is buried chemical, physical and biological changes occur in about 4 days. After burial about 0.9 meters below the surface, the temperature rises to 54-66 ^{0}C within 60 days. After 10 months, this temperature falls to normal air temperature. Within 12 months, most of the final settlement occurs. By the end of 2 years, most fills complete the settlement process. Among the reactions, the most important are:

- biological decay of organic, putrescible material aerobically or anaerobically with evolution of gases that include air, NH_3, CO_2, CO, H_2, H_2S, CH4, and N_2 and liquids
- chemical oxidation of materials
- the escape of gases from the fill and lateral diffusion of gases through the fill
- the dissolving and leaching of organic and inorganic materials by water and leachate moving through the fill
- the movement of dissolved material by osmotic pressure and concentration gradient
- the uneven settlement caused by consolidation

The decomposition and stabilization in landfill depend on:

- compaction of the waste
- degree of compaction
- amount of moisture present
- presence of inhibiting materials
- rate of water movement
- temperature

4. Landfill Operation Site Layout

In planning the layout of a sanitary landfill site, the location of fill must be determined by:

a. access roads

b. equipment shelters

c. scales to weigh wastes, as needed

d. storage site for special wastes

e. top soil stockpile sites

f. landfill area and extension

A. Operation schedule

- arrival sequence for collection vehicles
- traffic patterns at the site
- time sequence to be followed in the filling operation
- effects of wind and other climatic conditions
- commercial and public access

B. Equipment requirement

The type, size and amount of equipment required for sanitary landfill will be governed by size of community served, the nature of site selected, the size of the landfill and the methods of operation.

The types of equipment that have been used at sanitary landfill include:

1. crawler	2. scrapers
3. compactors	4. water trucks

C. Personnel

If there is advanced mechanical equipment without the facilities for a sanitary landfill serving less than 10,000 persons, the equipment operator would be the only person employed at the site.

On large scale operations, it is desirable to employ a supervisor. In this case, the supervisor should be able to operate the equipment in order to replace the employed operator in case of absence.

D. Accessory Facilities

In addition to the equipment and personnel indicated above, certain facilities are required at the site. These are:

1. shade or shelter for equipment and personnel
2. rest room facilities
3. signs to direct trucks
4. portable or semi portable fencing
5. scale for weighing of trucks
6. hand sprayer for insecticide application
7. portable pump for removal of accumulated surface water

5. Uses of fill lands

Sanitary landfills can be used to improve eroded areas, marshy and other marginal lands. After settling, such lands could be used as parks, golf/sport fields, other recreational areas, and sometimes for airports, parking lots and small construction sites, etc.

6. Leachate in landfills

Leachate may be defined as liquid that has percolated through solid waste and has extracted dissolved and suspended materials from it. In most landfills, a portion of the leachate is composed of the liquid produced from the decomposition of the wastes and liquid that has entered the landfill from external sources, such as surface drainage, rainfall, ground water and water from ground sprays.

In general, it has been found that the leachate increases with the increase of the external water entering the landfills. If a landfill is constructed properly, the production of measurable quantities of leachate can be eliminated. When sewage sludge is to be added to increase Methane gas production, leachate control facilities must be provided.

Advantages of sanitary landfill

1. It is a relatively economical and acceptable method.
2. Initial investment is low compared to other proven methods.
3. The system is flexible; it can accommodate increases in the population.

4. It may result in low collection cost, as it permits continued collection of refuse. All types of refuse may be disposed of.
5. The site may be located close to or in populated areas, thus reducing the hauling cost of collection.
6. It enables the reclaiming of depression and sub-marginal lands for use and benefits of the community.
7. Completed landfill areas can be used for agricultural and other purposes.
8. Unsightliness, health hazards and the nuisance of open dumping can be eliminated.
9. It may be quickly established.
10. Several disposal sites may be used simultaneously.

Disadvantages of Sanitary Landfills:

1. Sometimes suitable land within economical hauling distance may not be available.
2. Relatively large areas of land are required due to slow decomposition of refuse.
3. An adequate supply of good earth cover may not be readily accessible.
4. If not properly located, seepage from landfills into streams may increase the chance for stream pollution.
5. It needs careful and continuous supervision by skilled personnel.

6. If not properly done, it can deteriorate into open dumping. (ordinary dumping)
7. Special equipment is required.

Comparison of Landfills versus Incinerator

Sanitary landfills	**Incinerators**
1. Low initial cost	1. High initial cost
2. May change locations	2. Fixed location
3. Low operational cost	3. Variable, may cost much money
4. Complete and final disposal for all refuses	4. Ash, cans, bottles, etc. disposed of separately
5. Needs large land area	5. Does not need large land area

6. Composting

Composting is an effective method of solid waste disposal. In composting, biodegradable materials break down through natural processes and produce humus. The metabolism of micro-organisms breaks down the waste aerobically or anaerobically.

Materials that are non- biodegradable must be separated from the degradable materials and disposed of in some other manner. Some common non biodegradable materials are glass, plastics, rubber products, and metals. Once non-biodegradable materials have been removed and only biodegradable waste has been established, it is brought to a grinder. Grinding increases the surface area of the waste and enhances biological degradation.

Most modern compost systems are aerobic rather than anaerobic for several reasons:

1. Aerobic processes are not accompanied by the foul stench present at an unsealed anaerobic composting operation
2. In crop production industries, composting is safer because temperatures do not reach that of pasteurization temperatures which exceed the thermal death point of most plants, animals and parasites.
3. Aerobic composting is more rapid than anaerobic composting.

An aerobic compost operation ideally is an optimal environment for the growth of aerobic organisms. The material to be composted is food. Therefore the “food” should have a carbon:nitrogen ratio favorable for decomposition. The microbes require a C: N of 25:1 to 30:1. If the C: N is too low (120:1), the ammonium compounds will volatilize into the air, causing an unpleasant odor. Various groups of organisms have different optimum temperatures (some prefer 25 ^{0}c, some 37 ^{0}c, and others 55 ^{0}c), though the optimal temperature for a process as a whole integrates the optimums of the various microbes.

The pH of aerobic composting varies depending on the organisms' need for oxygen. Aeration is important and is provided by turning the compost mechanically to expose it to oxygen to speed decomposition.

Microbes must have moisture, and such is the case in composting. The amount of moisture needed varies with the composition of the material being composted. The moisture content should be approximately 45% to 50%. If the moisture is too low, microbial activity slows, and biological activity ceases at a moisture content of about 12%. If the moisture content is too high, it reduces the amount of free oxygen present and slows the process so that it may become anaerobic. Many times, sludge is added to waste for composting to provide microbial food and trace elements.

A. Types of Composting

The three main types of composting are: windrow, static pile, and in-vessel.

1. **Windrow:** A sludge/refuse mixture configured in long rows (windrows) that are aerated by convection air movement and diffusion, or by turning periodically through mechanical means to expose the organic matter to ambient oxygen.
2. **Static pile**: A stationary mixture is aerated by a forced aeration system installed under the pile.
3. **In-vessel composting**: Composting takes place in enclosed containers in which environmental conditions can be controlled. The waste decomposes into a harmless organic material that can be used as a soil conditioner and enhancer for agricultural applications.

B. Operation Steps in Composting

1. Removal of non-compostable wastes, (i.e. cans, glasses).
2. Grinding and shredding
   - Helps to speed up bacterial action.
   - Raw refuse is shredded before placed in piles, bins and digested before decomposition.
3. Blenching or proportioning of materials

   - This is also to speed up the bacterial action.
   - The optimum carbon nitrogen has to be 30 - 35:1

- Generally blending is considered to be unnecessary if the ratio is 25 - 30:1
- The optimum moisture content for aerobic composting is 40 - 60% depending on the character of the material.

4. Placement for composting - It can be placed on ground as open piles or windrows in a shallow pit. Height of windrows or piles should not be greater than 1.5 meter to 1.8 meter and not less than 1.07 meter to 1.2 meter. Width at the bottom of the windrow is 2.44 meter to 3.6 meters.
5. Turning - An aerobic condition is maintained by frequent turning. If the moisture content is high, it requires turning every 2 -3 days.
6. Temperature - It is an important factor and should range 50-70 ^{0} C; usually 60^{0}C is satisfactory. Temperature will be the highest in the middle of pile or windrow. Excessive temperature (71^{0}C) is injurious to bacterial action. Excessive temperature is controlled by lowering the height of piles or windrows. If the area is cool, raise the height in order to maintain optimum temperature. If temperatures drop, the condition will be anaerobic.

C. Factors in Composting Operation

The most important factors in composting operations are:

1. segregation of refuse and salvage
2. grinding or shredding of the material
3. carbon-nitrogen ratio

4. blending or proportioning of wastes
5. moisture content
6. placement of materials in the composting pit
7. maintain temperature level to obtain rapid, nuisance-free decomposition
8. aeration to reduce high moisture content in composting materials
9. organisms involved
10. use of inoculate
11. physical or chemical reaction
12. climatic conditions (temperature, wind, rainfall)
13. destruction of pathogenic organisms
14. time required for composting
15. fly control
16. reclamation of nitrogen and other nutrients
17. testing and judging the condition of compost
18. quality of composts, which depends on nature of the material being composted
19. economic aspects of composting

The final product of composting is compost - a mixture composed mainly of decayed organic matter, used as a fertilizer.

D. Uses and Constraints

Compost improves soil moisture retention. It is a good soil conditioner.

Compost, depending on the waste source and its composition, may be used as a soil amendment for agricultural soil and landscaping in municipal parks.

The two most important purposes for composting organic wastes are:

a. reclamation or conservation of the nutrient and fertilizer values of the waste
b. sanitary treatment and disposal to prevent the spread of disease.

Compost is a brown material, the main constituents of which are humus. It has the following physical properties when applied to the soil:

- the lightening of heavy soil
- improvement of the texture of light sandy soil
- increased water retention
- enlarging root systems of plants

Compost may also be used as a landfill cover, land reclamation, animal litter, and possibly animal feed. It may also be used as an additive to fertilizer as fuel, or in building materials.

The presence of toxic levels of pesticides, heavy metals, and pathogens should be determined and evaluated to ensure that the levels are compatible to the intended use of the compost.

The total composting time is determined by the material, process used, and exposure to the elements. Two weeks to as much as 18 months may be required for complete stabilization. For pathogen reduction purposes, the temperature of the mixture must be not less than 55 ^{0}C for at least 3 consecutive days.

E. Moisture Content of the Compost

- Moisture content is a critical factor in aerobic composting.
- If water content falls below 40% the speed of the process declines.
- If it falls below about 20% decomposition ceases.
- If it exceeds 55% water begins to fill the interstices between the particles of wastes, reducing interstitial oxygen and causing anaerobic conditions. This results in a rapid fall in temperature and the production of offensive odors.

F. Character and Value of the Compost

Compost material is stable. It may undergo little or no further decomposition. It has a slightly musty or earthy odor. Color-wise, it must be grayish or blackish. Its value is to serve as soil conditioner, lightness to the soil, promotes aeration and helps retain moisture by adding humus.

G. Health Importance

- Compost presents no health hazards.
- The heat produced will kill pathogenic bacteria and eggs of parasites.
- When composting is processed, fly breeding can be expected due to the mere fact it is done in a slightly open condition.

H. Compost Pit

It can be designed for individual houses or institutions. It is the easiest method of solid waste management system, if it is well managed. It is the most ideal method of dealing with wastes in homes and institutions like schools.

Waste is normally deposited in the pit and covered within 24 hours with a thin layer of earth. When it is full, it is left for bacteria to act upon it, which decomposes leaving humus that can be used as soil conditioner in farms. To be economical, operating a twin pit is the best, as when one fills the other one is used as a component of the first humus.

Table 4. The ideal size of compost pit for home and institutions.

Parameter	Home	Institution
Length	4 meters	6 meters
Width	3 meters	4 meters
Depth	1 meter	1 meter
Volume	12 meter cube	24 meter cube

7. Grinding and Discharge into Sewer Lines

Following are the methods for the disposal of garbage into sewers:

1. Household grinders

They contribute no difficulties in sewer collection systems. Of course it may lead to an increase of solids in sewage treatment plants.

2. Municipal grinding stations

The location of central grinding stations at convenient points along the sewer system or at the sewage treatment plant is required. It requires the separation of garbage from the refuse by households prior to collection to the disposal areas. Central grinding stations should not be objectionable although care should be taken to provide treatment of odor that arises from the accumulated garbage. If at all garbage of all contributing population is discharged into sewer lines, there will be an increase of suspended solids to 50% or less. The water consumption with grinders will be about four liters per capita per day.

8. Recycling

One of the economically feasible and environmentally sound technologies of disposing of solid waste is the recycling method. Recycling can be defined as the process of converting unwanted waste into useful material for re-use. In the recycling method, wastes generated are sorted out into their constituent parts, and then they are recycled into new useful materials.

The recycled goods must be weighed against the additional costs required for organization systems. For example, waste foodstuff and other organic waste can be composted into fertilizer, or processed into animal feeds. Paper, cardboard, glass, metals, rags and other commercial wastes are principal elements of refuse having marketable value from time to time. Even though markets are subject to wide fluctuation, if clean paper can be reclaimed, it can be reused in manufacturing cardboard. Glass has some value, especially if they can be hand sorted according to size and color. The same thing is true for salvageable cloths, leather pieces, wooden materials, cardboard and cartons.

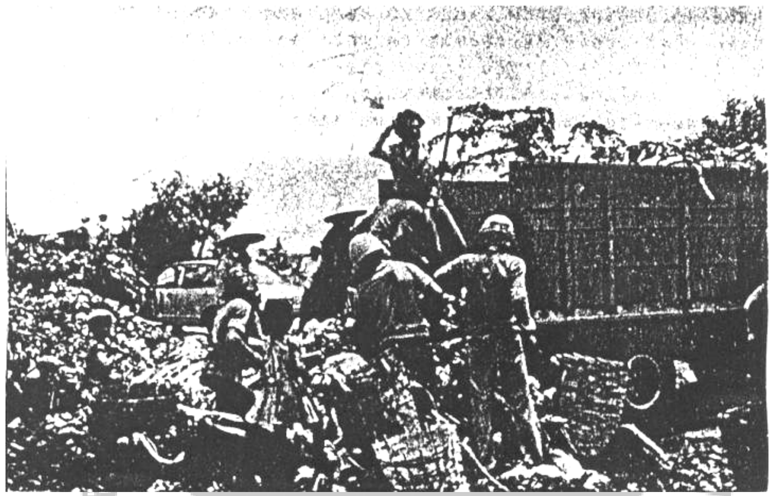


Figure 5. Recycling by Municipal refuse workers and private pickers at dump sites during unloading of collection equipment (Source: Sandra J. Cointreau: Environmental Management of Urban Solid Wastes in Developing Countries)

9. Dumping into Water Bodies

The dumping of solid waste into water bodies such as streams, rivers, lakes, seas, and oceans was once one of the means of disposal. This is still practiced in some cities and towns located on banks of rivers or seashores, even though it can be ineffective due to the washing of the wastes to the shores and interference of sanitation of the bathing area.

Such a disposal method would be effective if the risk to marine life is taken into consideration and direction of wind blow observed before dumping.

10. Disposal of Dead Bodies

There are putrification methods that can be practiced in relation to disposal of dead bodies.

1. Embalming

This delays the decay process of dead bodies by injection of preservatives.

2. Cremating

Burning of dead bodies is practiced in certain religions. It is considered to be the best and most sanitary method. In addition, it helps in conservation of land. It is cheap as far as cost is concerned. It is not an acceptable method culturally in Ethiopia.

3. Disposal into water bodies.

This method is usually practiced by travelers in sea water such as fishermen and naval forces.

4. Ground Burial

This is the most common, old and traditional method practiced in areas where there is no digging or land problem. The minimum depth for such a method is 2 meters. Burial pits should not be used for subsequent burials; new pits should be dug as needed.

Review Questions

1. What problems of waste disposal have been created due to urbanization and industrialization?
2. What are the primary risks to human health associated with solid waste dumping?
3. If you could design a recycling program for your community, what would be the primary components?
4. What would be the personal, political, and social factors associated with changing behavior of others in terms of solid waste disposal?
5. How do you recycle, reuse and reduce solid waste in your community?
6. What are the common solid waste disposal methods that are practiced in your community, college or university?

CHAPTER FOUR

HAZARDOUS WASTE MANAGEMENT

4.1 Learning Objectives

By the end of this chapter, the students will be able to:

1. define hazardous waste.
2. discuss the characteristics of hazardous waste.
3. explain basic control measures for the movement of hazardous wastes.
4. describe disposal methods for hazardous wastes.
5. define health-care institution waste.
6. list the major characteristics of health-care institution waste.
7. list the public health importance of health-care institution waste.
8. describe the treatment and disposal methods for healthcare institution waste.

4.2. Introduction

The concern towards hazardous waste management was stimulated by undesired massive health effects that were noticed in the neighborhood of Niagara Falls in New York State in the United States in the 1970s. Following is a brief history:

1. The Hooker Electrochemical Manufacturing Company bought an abandoned canal called Love Canal (named after the landowner) in 1940.
2. The Company had completed all necessary legal transactions for the permission for dumping toxic wastes arising from the manufacturing of chemicals by 1942.
3. Hooker sold the canal for $1 to the Board of Education in 1953 after dumping about 19,000 tons of chemical wastes contained in metallic drums (55 gallon capacity). Hooker had repeatedly given a written testimony to the Board that the Canal had toxic wastes that would cause health effects if their content were disturbed and exposed to people. The Hooker Company had also declared that it would not take any risks arising from such exposure.
4. Various federal agencies continued to dump additional toxic chemicals in the Canal. The overall cumulative wastes meanwhile grew to 200,000 tons from 82 different chemicals. Health effects from some chemicals wastes

were known: benzene (leukemia and anaemia), chloroform (also carcinogenic), trichloroethylene (toxic to CNS), lindane (CNS, GI tract poison), and many other chemicals.

5. The City of Niagara Falls began to be constructed in 1957. The Board of Education also constructed elementary schools and playgrounds in the vicinity of Love Canal. The dump site of Love Canal was heavily disturbed for the construction of homes, basements, and underground sewerage systems.
6. People around the Love Canal complained of bad unusual odour coming from the Love Canal in 1976. Heavy rain occurred in 1977 that washed the toxic waste into underground water level. The storm water also contaminated the surface area of the buildings, homes, playgrounds.
7. Unusual increased numbers of miscarriages, nerve damage, deformities in newborns, cancer rates, rectal bleedings, skin lesions, epilepsy, etc, were observed among the residents in the Love Canal starting in 1976.
8. The cause of the health crisis was identified to be leakages from the toxic waste drums. There were sharp dialogues between politicians and scientists about the incident.

9. President Carter declared a State of Emergency in the Love Canal in 1976. $37 million were spent for the relocation of families, schools, etc.
10. The Government adopted two strict hazardous waste management regulations in 1976 and 1980.

4.3 The Concern about Hazardous Waste Management

1. cause of mass life and material damage and loss (disability, death, fire, explosion);
2. cause of environmental damages: potential water, solid, and air pollution (underground and surface drinking water);
3. cause of potential increased chemical bioaccumulation that is hard for biodegradability (chlorine containing chemicals);
4. cause of long term irreversible health risks (mutagenicity, teratogenicity, and carcinogenicity)
5. high concern of trans-boundary movement of toxic wastes;
6. cause of massive toxic health damages.

4.4 Characteristics of Hazardous Waste

The Environmental Protection Agency of America (EPA) defines the characteristics of hazardous waste as:

1. Flammability and Ignitability

The waste burns or explodes with the application of fire, friction, electricity spark, or any source of heat; wastes with high ignitable potential and/or which burn vigorously and persistently. Such wastes have a flash point of less than 60^0C. Examples: solvent washes, waste oil, alcohols, aldehydes, paint wastes, petroleum wastes, cleaning solvents, etc. Flash point of a liquid is the lowest temperature at which it gives off enough vapour to form an ignitable mixture with the air in its surface.

2. Corrosivity

It is the ability of the waste to cause skin and mucosal membrane damages: burns and erosions, and dissolves or corrodes metallic surfaces. Such wastes have pH value of: 2.5<pH>12.5 at normal room temperatures (25^0C). The corrosion rate for material damage is at 0.625 meters per year at 55^0C. Examples: acid sludge, battery acid wastes, caustic waste water, alkaline cleaning wastes, rust remover waste, etc.

3. Reactivity

A waste that reacts violently with water with the formation of toxic fumes, gases, or aerosols (Strong acids and HCN when mixed with water); and explodes when mixed with water. Such incidents can also occur when the waste is mixed with other chemicals producing the same effect. Wastes containing unstable chemicals are also in this category. Examples: Cyanide plating wastes, wastes containing strong oxidizers such as chlorine, ozone, peroxides, permanganates, HCl, etc.

4. Toxicity

A waste that is likely to produce mass acute and chronic poisoning; long-term health effects (mutagenicity, teratogenicity, carcinogenicity). The following guideline can be used for determining whether acute and chronic toxicity may occur: if a waste contains an amount greater than ten times its standard in drinking water, or a hundred times more than in its standard in drinking water, or a hundred times more than in its standard for water used for recreational purposes.

5. Infectivity

A waste with a potential cause for infectious diseases, such as hepatitis B. Example: medical wastes containing microbial cultures, pathological wastes, contaminated human blood and its products, sharps, skin-piercing objects, contaminated animal wastes, contaminated exudates and secretions.

6. Radioactivity

Wastes containing radioactive elements. Such wastes are mainly from biomedical training and research institutes. Wastes may include radioactive elements of uranium, molybdenum, cobalt, iodine.

7. Bioaccumulation effect

Wastes that are not easily degraded when exposed with the environment. Examples: polychlorinated biphenyls (PCB), dioxin.

4.5. List of Hazardous Chemicals

The following hazardous chemicals selected as require priority consideration:

1.Arsenic and its compounds 2) Mercury and its compounds; 3) Cadmium and its compounds; 4) Thallium and its compounds 5) Beryllium and its compounds 6) Chromium (VI) compounds; 7) Lead and its compounds; 8) Phenolic compounds; 9) Antimony and its compounds; 10) Cyanide compounds; 11) Isocyanates; 12) Organohalogenated compounds except inert polymeric materials; 13) Chlorinated solvents; 14) Organic solvents; 15) Biocides and phytopharmaceutical substances; 16) Tarry materials from refining and tar residues from distilling; 17) Pharmaceutical compounds; 18) Peroxides, chlorates, perchlorates, and azides 19) Ethers; 20) Chemical laboratory materials, not identifiable and/or new, with unknown effects on the environment; 21) Asbestos 22) Selenium and compounds 23) Tellurium and compounds 24) Polycyclic aromatic hydrocarbons 25) Metal carbonyls 26) Soluble copper compounds 27) Acids and/or basic substances used in the surface treatment and finishing of metals.

4.6. Transportation and Disposal of Hazardous Waste

The transportation of hazardous waste can pose a threat to the public. To promote safety and protect the public's health, companies follow four basic control measures for the movement of hazardous waste from a source to disposal site;

1. Hazardous waste manifest:

The concept of a cradle-to-grave tracking system is considered key to proper management of hazardous waste. Manifest copies accompany each barrel of waste that leaves the site where it is generated, and are signed and mailed to the receiving sites to indicate the transfer of waste from one location to another.

2. Labeling:

Each container is labeled and marked. The transporting vehicle is labelled before waste is transported from the generating site. Companies post warning labels such as: explosive, strong oxidizer, compressed gas, flammable liquid, corrosive material, and poisonous or toxic substances.

3. Haulers:

Because of the dangers involved, haulers of hazardous waste are subject to operator training, insurance coverage, and special registration of vehicles transporting hazardous waste. Handling precautions include restrictive use of the transport trucks and the use of gloves, face masks, and coveralls for the workers' protection.

4. Incident and accident reporting:

Accidents involving hazardous waste must be reported immediately to the state regulatory agency, as well as local health departments. Necessary information that will help responders contains the material that should be made available.

4.7. Control of Hazardous Waste

1. Whom or what to control?

There are five types of hazardous waste generators: (1) the primary generator, (2) the transporter, (3) waste storage, (4) treatment, and (5) disposal facilities. All the producers and the recipients of waste need to follow certain standard operative procedures (SOP) to manage the waste in accordance with the existing law and waste regulations. Basic data/record-keeping, reporting, manifesting, protocols of SOP, and contingency planning in cases of emergency are very essential for waste tracking purpose.

2. How do you classify whether the waste is hazardous or not?

- Use the defined list of criteria.
- Identify the components of the waste.
- Review literature about the inherent characteristics of components of the waste. For example, various WHO documents include: toxic substances registry, environmental health criteria, international chemical safety program documentation, etc.

3. Control approaches

a) Waste management hierarchy includes: source reduction > waste avoidance>waste minimization>waste recycling >

waste treatment>waste disposal. The approach is based on resource use maximization (efficiency) and cost effectiveness.

Waste Minimization Program	
Source reduction • Technological efficiency • Material substitute • Good management practice	**Waste Recycling** • Direct use • Reclamation

b) Government and Public Involvement

- The national and regional governments need to adopt waste management guidelines and regulations. Allocation of adequate resources is also desired.
- The public and the community need to be involved in the waste management hierarchy.
- Public education is important.
- The UN agencies; (WHO, UNIDO, and UNEP) involvement in the adoption of National Waste Management Program and control of transboundary movement of wastes should be appreciated and acknowledged.

4. Hazardous Waste Treatment

Different technical options and alternative methods can be employed for the treatment. The end result needs to focus on making the waste non-harmful or less hazardous, reduce its volume and texture, separate for re-use, and isolate it for final disposal.

Treatment methods include:

A. **Physical methods**: drying, screening, grinding, evaporation, sedimentation, filtration, fixation, etc.
B. **Chemical methods**: Oxidation, reduction, neutralization, hydrolysis, etc.
C. **Biological methods**: composting, aerobic and anaerobic decomposition, activated sludge, enzyme treatment, etc.
D. **Thermal methods**: incineration, boiling, autoclaving, UV treatment, microwave use, etc.

5. Hazardous Waste Disposal:

The hazardous waste, after treatment, can be ultimately disposed using the following methods:

a) **Land farming**: the treated waste can be used as a fertilizer or soil conditioner with the approval of concerned regulatory entities;
b) **Deep well injection**: a special kind of drilled well is prepared for such purposes. Brine (40% salt solution) is

usually disposed in this manner. Precautions for water pollution need to be a concern.

c) **Surface impediment:** encapsulation, fixation, or containment of the waste. This method involves arresting or demobilizing the movement or migration of the waste by containing it in a hard core: clay soil, thermoplastics polymers, non-corrosive metallic containers (carbon-steel tanks), cement, lime, fire glass, rocks.

d) **Ocean dumping**: was mostly practiced from 1945 to the 1970s. Despite the existing public protest, this method continuous to be an alternative for the waste generators.

4.8 Health-Care Institution Solid Waste

1. Classification of health-care institution waste:

Health-care institution waste can be divided into two main categories: regular medical waste and infectious waste. Regular medical wastes is generally everything else used in the facility. This might include administrative waste, paper, or food-waste from cafeterias.

Between 75% and 90% of the waste produced by health-care institution providers is non-risk or "general" health-care institution waste, comparable to domestic waste. The remaining 10 - 25% of health-care institution waste is regarded as hazardous and may create a variety of health risks. This chapter is concerned almost exclusively with hazardous health-care institution waste also known as "health-care institution risk waste".

Infectious waste includes human blood and blood products, cultures, stocks of infectious agents, pathological wastes, contaminated sharps (hypodermic needles, scalpel blades, capillary tubes), contaminated laboratory wastes, contaminated wastes from patient care, discarded biologicals, contaminated animal carcasses and body parts infected with human pathogens such as in research and training, contaminated equipment and miscellaneous infectious waste.

2. Health hazards:

Health-care workers (particularly nurses) are at greatest risk of virus infections such as HIV/AIDS and hepatitis B and C, through injuries from contaminated sharps (largely hypodermic needles). Other hospital workers and waste-management operators outside health-care establishments are also at significant risk, as are individuals who scavenge at waste disposal sites (although these risks are not well documented). The risk of this type of infection among patients and the public is much lower. Certain infections, however, spread through other media or are caused by more resilient agents, may pose a significant risk to the general public and to hospital patients.

Individual cases of accidents and subsequent infections caused by health-care institution waste are well documented. The overall situation, however, remains difficult to assess, especially in developing countries. It is suspected that many cases of infection with a wide variety of pathogens have resulted from exposure to improperly managed health-care institution waste in developing countries.

Table 5. Risk of infection after hypodermic needle puncture

Infection	Risk of infection
HIV	0.3%
Viral hepatitis B	3%
Viral hepatitis C	3-5%

Source: WHO (1999): Safe Management of Waste from Health- Care Activities

There were insufficient data on other infections linked to health-care institution waste to allow any conclusions to be reached. On the basis of the figures for HBV, however, it is recommended that all personnel handling health-care institution waste should be immunized against that disease.

If these data are to be extrapolated to developing countries like Ethiopia, it should be borne in mind that supervision and training of personnel exposed to waste in those countries may be less rigorous, with the result that more people are likely to be exposed to health-care institution wastes, both within and outside health-care establishments.

In any health-care establishment, nurses and housekeeping personnel are the main groups at risk of injuries; annual injury rates are 10-20 per 1000 workers. Highest rates of occupational injury among all workers who may be exposed to health-care institution waste are reported by cleaning personnel and waste handlers; the annual rate in the USA is 180 per 1000. Although most work-related injuries among health-care workers and refuse collectors are sprains and strains caused by overexertion, a significant percentage are cuts and punctures from discarded sharps.

The existence in health-care establishments of bacteria resistant to antibiotics and chemical disinfectants may also contribute to the hazards created by poorly managed health-care waste. It has been demonstrated, for example, that plasmids from laboratory strains contained in health-care waste were transferred to indigenous bacteria via the waste disposal system. Moreover, antibiotic-resistant Escherichia coli have been shown to survive in an activated sludge plant, although there does not seem to be significant transfer of this organism under normal conditions of wastewater disposal and treatment.

Concentrated cultures of pathogens and contaminated sharps (particularly hypodermic needles) are probably the waste items that represent the most acute potential hazards to health.

Sharps may not only cause cuts and punctures but also infect these wounds if they are contaminated with pathogens. Because of this double risk of injury and disease transmission, sharps are considered as a very hazardous waste class. The principal concerns are infections that may be transmitted by subcutaneous introduction of the causative agent (e.g. viral blood infections). Hypodermic needles constitute an important part of the sharps waste category and are particularly hazardous because they are often contaminated with patients' blood.

Many of the chemicals and pharmaceuticals used in health-care establishments are hazardous (e.g. toxic, corrosive, flammable, reactive, explosive, shock-sensitive). These substances are commonly present in small quantities in health-care waste; larger quantities may be found when unwanted or outdated chemicals and pharmaceuticals are disposed of. They may cause intoxication, either by acute or by chronic exposure, and injuries, including burns. Intoxication can result from absorption of a chemical or pharmaceutical through the skin or the mucous membranes, or from inhalation or ingestion. Injuries to the skin, the eyes, or the mucous membranes of the airways can be caused by contact with flammable, corrosive, or reactive chemicals (e.g. formaldehyde and other volatile substances). The most common injuries are burns.

Disinfectants are particularly important members of this group: they are used in large quantities and are often corrosive. It should also be noted that reactive chemicals may form highly toxic secondary compounds.

Obsolete pesticides, stored in leaking drums or torn bags, can directly or indirectly affect the health of anyone who comes into contact with them. During heavy rains, leaked pesticides can seep into the ground and contaminate the groundwater. Poisoning can occur through direct contact with the product, inhalation of vapors, drinking of contaminated water, or eating of contaminated food. Other hazards may include the possibility of fire and contamination as a result of inadequate disposal such as burning or burying.

Chemical residues discharged into the sewerage system may have adverse effects on the operation of biological sewage treatment plants or toxic effects on the natural ecosystems of receiving waters. Similar problems may be caused by pharmaceutical residues, which may include antibiotics and other drugs, heavy metals such as mercury, phenols, and derivatives, and disinfectants and antiseptics.

3. Sources:

a) **Medical wastes:** These wastes are usually produced in patient rooms, treatment rooms and nursing stations. The operating room may also be a contributor, and items include soiled dressings, bandages, catheters, swabs, plaster casts receptacles, and masks. The hazardous waste is generated from both OPD and inpatient wards as a result of diagnosing, treating, or handling the patient.

b) **Surgical and autopsy** (Pathologic wastes): These wastes may be produced in surgical or autopsy rooms. Items that may be included are placenta, tissues and organs, amputated limbs, fetus and similar material.

c) **Laboratory wastes**: These wastes are produced in diagnostic or research laboratories. Items that may be included are cultures, spinal-fluid samples, dead animals, and animal bedding.

d) **Infectious solid wastes**: proportion of medical waste that is infectious (dressings, lab and pathological wastes, contaminated blood, discarded equipments, etc.)

e) **Domestic/general wastes**: offices, kitchen wastes (non-hazardous)

f) **Radioactive wastes**: radiating residues produced as a result of radiotherapy and diagnosis.

4. Management of Health Care Institution Solid Wastes

The need for infectious and medical waste management now reaches beyond hospitals and medical centers to smaller waste generators such as clinics, colleges and universities, diagnostic laboratories, funeral homes, doctors' offices, and other health facilities. Infectious and medical waste produce occupational risks such as direct exposure to blood products, needle sticks, and infectious dressings by patients, visitors, and workers. Environmental risks include the possibility of pollution of groundwater, surface water, or air. Even small amounts of laboratory solvents can leach into drinking water. Incinerated medical waste may not destroy infectious agents, releasing them into the air, in the ash or via scrubber effluent.

A. Waste minimization, recycling, and reuse

1. Waste minimization

Significant reduction of the waste generated in health-care establishments and research facilities may be encouraged by the implementation of certain policies and practices, including the following:

- Source reduction: measures such as purchasing restrictions to ensure the selection of methods or supplies that are less wasteful or generate less hazardous waste.
- Recyclable products: use of materials that may be recycled, either on-site or off-site.
- Good management and control practices: apply particularly to the purchase and use of chemicals and pharmaceuticals.
- Waste segregation: careful segregation (separation) of waste matter into different categories helps to minimize the quantities of hazardous waste.

Careful management of stores will prevent the accumulation of large quantities of outdated chemicals or pharmaceuticals and limit the waste to the packaging (boxes, bottles, etc.) plus residues of the products remaining in the containers. These small amounts of chemical or pharmaceutical waste can be disposed of easily and relatively cheaply, whereas disposing of larger amounts requires costly and specialized treatment, which underlines the importance of waste minimization.

Waste minimization usually benefits the waste producer: cost for both the purchase of goods and for waste treatment and disposal are reduced and the liabilities associated with the disposal of hazardous waste are lessened.

All health-service establishments employees have a role to play in this process and should therefore be trained in waste minimization and the management of hazardous materials. This is particularly important for the staff of departments that generate large quantities of hazardous waste.

Suppliers of chemicals and pharmaceuticals can also become responsible partners in waste minimization program. The health service unit can encourage this by ordering only from suppliers who provide rapid delivery of small orders, who accept the return of unopened stock, and who offer off-site waste management facilities for hazardous wastes.

Reducing the toxicity of waste is also beneficial; by reducing the problems associated with its treatment or disposal.

2. Safe Reuse and Recycling

Medical and other equipment used in a health-care establishment may be reused provided that it is designed for the purpose and will withstand the sterilization process. Reusable items may include certain sharps, such as scalpels and hypodermic needles, syringes, glass bottles and containers, etc. After use, these should be collected separately from non-reusable items, carefully washed and sterilized (particularly in the case of hypodermic needles, in which infectious droplets could be trapped). Although reuse of hypodermic needles is not recommended, it may be necessary in establishments that cannot afford disposable syringes and needles. Plastic syringes and catheters should not be thermally or chemically sterilized; they should be discarded.

Certain types of containers may be reused provided that they are carefully washed and sterilized. Containers of pressurized gas, however, should generally be sent to specialized centers to be refilled. Containers that once held detergent or other liquids may be reused as containers for sharps waste (if purpose-made containers are not affordable) provided that they are puncture-proof and correctly and clearly marked on all sides.

Recycling is usually not practiced by health-care facilities apart, perhaps, from the recovery of silver from fixing baths used in processing X-ray films. However, recycling of materials such as metals, paper, glass, and plastics can result in savings for the health-care facility, either through reduced disposal cost or through payments made by the recycling company.

In temperate climates, the heat generated by on-site incinerators may be an attractive and cost-effective option for heating hospital premises.

In determining the economic viability of recycling, it is important to take into account the cost of alternative disposal methods and not just the cost of the recycling process and the value of the reclaimed material.

B. Handling, Storage, and Transportation of Health-Care Facility Waste

1. Waste segregation and packaging

The key to minimization and effective management of health-care waste is segregation (separation) and identification of the waste. Appropriate handling, treatment, and disposal of waste by type reduce cost and does much to protect public health. Segregation should always be the responsibility of the waste producer, should take place as close as possible to where the waste is generated, and should be maintained in storage areas and during transport. The same system of segregation should be in force throughout the country.

The most appropriate way of identifying the categories of health-care facility waste is by sorting out the waste into color-coded plastic bags or containers.

In addition to the color coding of waste containers, the following practices are recommended:

- General health-care facility waste should be part of the stream of domestic refuse for disposal.
- Sharps should all be collected together, regardless of whether or not they are contaminated. Containers should be puncture-proof (usually made of metal or high-density plastic) and fitted with covers. They should be rigid and impermeable so that they safely retain not only the sharps but also any residual liquids from syringes. To discourage abuse, containers should be tamper-proof (difficult to open or break) and needles and syringes should be rendered unusable. Where plastic or metal containers are unavailable or too costly, containers made of dense cardboard are recommended; these fold for ease of transport and may be supplied with a plastic lining.
- Bags and containers for infectious waste should be marked with the international infectious substance symbol.
- Highly infectious waste should, whenever possible, be sterilized immediately by autoclaving. It therefore needs to be packaged in bags that are compatible with the proposed treatment process: red bags, suitable for autoclaving, are recommended.
- Small amounts of chemical or pharmaceutical waste may be collected together with infectious waste.

- Large quantities of obsolete or expired pharmaceuticals stored in hospital wards or departments should be returned to the pharmacy for proper disposal.

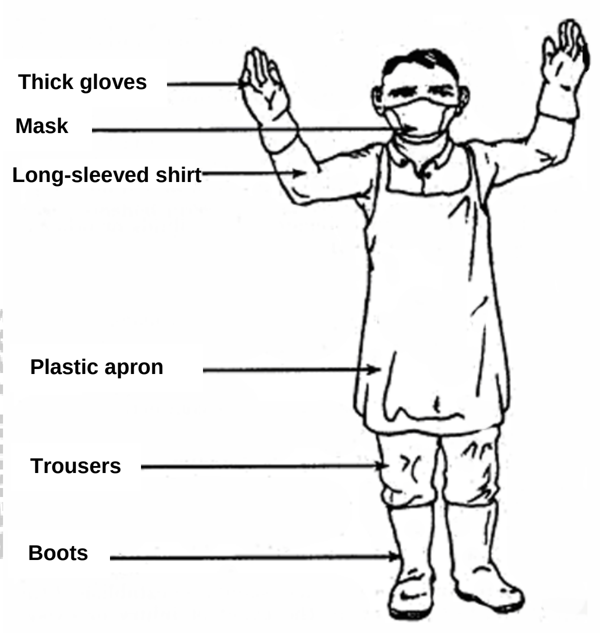


Figure 6. Recommended protective clothing for health care waste transportation. (Source: WHO (1999): Safe Management of Waste From Health Care Facility Activities.)

C. Treatment and Disposal Technologies for Health-Care Facility Waste

The final choice of treatment system should be made carefully, on the basis of various factors, many of which depend on local conditions:

- Disinfection and sterilization efficiency;
- Health and environmental considerations;
- Volume and mass reduction;
- Occupational health and safety considerations;
- Quantity of wastes for treatment and disposal/capacity of the system;
- Types of waste for treatment and disposal;
- Infrastructure requirements;
- Locally available treatment options and technologies;
- Options available for final disposal;
- Training requirements for operation of the method;
- Operation and maintenance consideration;
- Available space;
- Location and surroundings of the treatment site and disposal facility;
- Investment and operating cost;
- Public acceptability;
- Regulatory requirements.

Several treatment technologies are available to dispose of health care establishment waste.

1. Incineration Technology

Incineration uses controlled, high-temperature combustion process to destroy organics in waste materials. Modern incineration systems are well engineered; high-technology processes designed to maximize combustion efficiency and completeness with a minimum of emissions of waste.

2. Open dumps

- uncontrolled and scattered deposit of wastes at a site
- leads to acute pollution problems, fires, high risks of disease transmission, open access to scavengers and animals.

3. Sanitary landfills (see chapter 3)

4. Safe burial on health-care premises

Certain basic rules should be fulfilled:

- Access to the disposal site should be restricted to authorized personnel only.
- The burial site should be lined with a material of low permeability, such as clay.
- Only hazardous health-care facility waste, including placenta, should be buried.
- Large quantities (greater than>1 kg) of chemical wastes should not be buried at one time.
- The burial site should be managed as a landfill process, with each layer of waste being covered with a layer of earth to prevent odors, as well as to prevent rodent and insect breeding.

5. Steam Sterilization

The advantages of steam sterilization, or autoclaving are relatively low capital investment, operating cost, relatively small space requirements, and simplicity of operation. Disadvantages include limited capacity, the requirement of special waste packaging and handling, and odor and drainage problems. Autoclaving is not recommended for pathological wastes, waste with high liquid content, and waste contaminated with volatile chemicals. After autoclaving, the appearance of waste remains unchanged. Although needles, syringes, blood bags, and the like, are sterilized, they also are recognizable. This has the effect of making much of the waste unacceptable for disposal in a landfill or other disposal means. Also, compacting autoclaved waste tends to break open waste bags and other containers, exposing and spilling their contents. Consequently, waste haulers and landfill operators may not be willing to accept autoclaved waste in spite of its sterile condition.

Review Questions

1. What is a hazard?
2. What are the common features of hazardous waste?
3. How does your community assist in the collection and disposal of hazardous wastes found in the home and in the community in general?
4. Are there any hazardous waste sites in your community? Why have they been classified as hazardous waste sites?
5. What precautions should be taken during the transportation of hazardous wastes?
6. How can you dispose of hazardous waste?
7 What is health- care facility waste?
8. What are the type of health care establishment wastes?
9. What are potential health risks that can be associated with handling of health-care facility waste?
10. Who are at risk of health-care waste?
11. How can you dispose of health care waste?

GLOSSARY

Aerobic: organisms which need free oxygen; living or active only in the presence of free oxygen.

Anaerobic: unable to live in the presence of free oxygen, but obtaining oxygen by breaking down complex organic compounds.

Ash residue: waste products of coal and other fuels. They are non putrescible.

Composting: the controlled biological decomposition of organic solid waste under aerobic conditions.

Contamination: the presence of an agent of infection on a body, articles or substance.

Domestic waste: kitchen wastes, ashes from fires, broken utensils and worn-out clothing.

Garbage: putrescible solid waste including animal and vegetable wastes resulting from the handling, storage, sale, preparation, cooking, or serving of foods.

Health-care facility waste: includes all the waste generated by health-care establishments, research facilities, and laboratories. In addition, it includes the waste originating from "minor" or "scattered" sources, such as that produced in the course of health care undertaken in the home.

Incineration: process of burning wastes in an incinerator, to reduce the volume of the waste.

Incinerator: a facility designed to reduce the volume and weight of solid waste by a combustion process with or without a waste heat recovery system. It is an apparatus which enables refuse to be burnt with the minimum expenditure of fuel.

Industrial waste: waste resulting from manufacturing processes. Some of these wastes are putrescible and cause obnoxious odor and may create health hazard.

Infectious waste: a waste (solid), that is suspected to contain pathogens (bacteria, viruses, parasites, or fungi) in sufficient concentration or quantity to cause disease in susceptible hosts.

Integrated solid waste management: a practice of disposing of solid waste that utilizes several complementary components, such as source reduction, recycling, composting, waste - to - energy, and landfill.

Leachate: a liquid resulting from precipitation and percolating through landfills containing water, decomposed waste and bacteria.

Night soil: excreta that have been collected from box, toilets and privies.

Putrescible wastes: wastes that are decomposable by bacterial actions.

Recycling: a resource recovery method involving the collection and treatment of a waste product for use as raw material in the manufacture of the same or another produce.

Refuse: all putrescible or non-putrescible waste material that is discarded or rejected, including garbage, rubbish, incinerator residue, street cleanings, dead animals, and offal.

Resource recovery: a term describing the extraction and utilization of materials that can be used as raw material in the manufacturing of new products, or that can be converted into some form of fuel or energy source.

Rubbish: all non-putrescible wastes except ash. It consists of both combustible and non-combustible wastes.

Sanitary landfill: a method of disposing of refuse on land without creating nuisances or hazards to public health or safety.

Solid waste: are waste materials not including liquid wastes.

Solid waste management: the process by which workable alternative programs and plans are developed to solve solid waste problems.

Source reduction: refers to reducing the amount of waste generated that must eventually to be discarded, including minimizing toxic substances in products, minimizing volume of products, and extending the useful life of products.

Source separation: the segregation of various materials from the waste stream at point of generation for recycling.

Transfer station: a facility with structures, machinery, or devices that receives deliveries of solid waste by local collection vehicles, and provides for transfer to large vehicles that delivers the waste recycling, treatment or disposal site.

Waste: any movable material that is perceived to be of no further use and that is permanently discarded.

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