Paper No: 11 Solid and Hazardous Waste Management

Module: 16 Hazardous waste: Definition, sources, classification, collection, segregation, characterization

athshala पाठशाला
A Gateway to all Post Graduate Courses
MHRD Govt. of India

Development Team

Principal Investigator & Co- Principal Investigator	Prof. R.K. Kohli Prof. V.K. Garg & Prof. Ashok Dhawan Central University of Punjab, Bathinda
Paper Coordinator	Dr. Yogalakshmi K. N., Central University of Punjab, Bathinda
Content Writer	Dr. Yogalakshmi K. N., Central University of Punjab, Bathinda
Content Reviewer	Prof. VK Garg Central University of Punjab, Bathinda
Anchor Institute	Central University of Punjab

Description of Module	
Subject Name	**Environmental Sciences**
Paper Name	Solid and Hazardous Waste Management
Module Name/Title	Hazardous waste: Definition, sources, classification, collection, segregation, characterization
Module Id	EVS/SHWM-XI/16
Pre-requisites	A basic knowledge and interest in understanding hazardous waste
Objectives	1. To understand the definition of hazardous waste and its sources of generation 2. To gain knowledge on the classification of hazardous waste 3. Familiarize the collection methods involved 4. To understand the methods of segregation used
Keywords	Hazardous waste, characteristics, corrosivity, ignitability, toxicity, reactivity, K list, F list, P and U list, segregation, collection and transport

Module 16: Hazardous waste: Definition, sources, classification, collection, segregation, characterization

Objectives:

1. To understand the definition of hazardous waste and its sources of generation
2. To gain knowledge on the classification of hazardous waste
3. Familiarize the collection methods involved
4. To understand the methods of segregation used

1. Introduction

A hazardous substance is defined according to Resource Conservation and Recovery Act (RCRA) as any solid or combination of solids that because of its quantity, concentration, or physical, chemical, or infectious characteristics, may cause or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness, or pose a substantial hazard to human health or the environment when improperly managed.

A hazardous waste is an hazardous substance that

1. Is discarded, accumulated, stored, physically, chemically, or biologically treated prior to being discarded; or
2. Has served its original intended use and sometimes is discarded; or
3. Is a manufacturing or mining by-product and sometimes is discarded.

2. Definition

According to U.S. Resource Conservation and Recovery Act of 1976 (RCRA), any waste that is toxic and/or hazardous if they "cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness; or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed off, or otherwise managed."

The RCRA regulations (40 CFR 261 and 262) specify that a solid waste is a hazardous waste if it is not excluded from regulation, and meets any of the following conditions:

- Exhibits any of the characteristics of a hazardous waste
- Has been named as a hazardous waste and listed as such in the regulations
- Is a mixture containing a listed hazardous waste and a nonhazardous solid waste
- Is a waste derived-from the treatment, storage, or disposal of a listed hazardous waste

Any solid waste that exhibits one or more of these characteristics is classified as hazardous: Ignitability, Corrosivity, Reactivity and Toxicity.

3. Characterization of Hazardous waste:

Table 1 summarizes the characteristics of hazardous waste and the risks associated with it.

Table 1 – Characteristic and risks of a hazardous substance and waste

Characteristics	Relevant features	Associated risk
Ignitability	• A liquid, except aqueous solutions containing less than 24% alcohol that has a flashpoint less than 60°C (140°F) • A nonliquid capable, under normal conditions, of spontaneous and sustained combustion • An ignitable compressed gas per DOT regulations • An oxidizer per DOT regulation	That which identifies wastes that pose a fire hazard during routine management. Fires not only pose immediate dangers of heat and smoke, but also can spread harmful particles over wide areas.
Corrosivity	• An aqueous material with pH less than or equal to 2, or greater than or equal to 12.5 • A liquid that corrodes steel at a rate greater than 0.25 inch per year at a temperature of 55°C (130°F)	That which identifies wastes requiring special containers because of their ability to corrode standard materials, or requiring segregation from other wastes because of their ability to dissolve toxic contaminants.
Reactivity (or explosiveness)	• Normally unstable and reacts violently without detonating	That which identifies wastes that, during routine management, tend to

	• Reacts violently with water • Forms an explosive mixture with water • Generates toxic gases, vapors, or fumes when mixed with water • Contains cyanide or sulfide and generates toxic gases, vapors, or fumes at a pH of between 2 and 12.5 • Capable of detonation if heated under confinement or subjected to strong initiating source • Capable of detonation at standard temperature and pressure • Listed by DOT as Class A or B explosive	react spontaneously, to react vigorously with air or water, to be unstable to shock or heat, to generate toxic gases or to explode.
Toxicity	As determined by the Toxicity Characteristics Leaching Procedure (TCLP), that is designed to produce an extract simulating the leachate that may be produced in a land disposal situation. The extract is then analyzed to determine if it includes any of the toxic contaminants listed in Table 2. If the concentrations of any of the Table 2 constituents exceed the levels listed, the waste is classified as hazardous. Toxicity of a waste may also be declared by the generator based upon knowledge of the waste and/or the generating process.	That which identifies wastes that, when improperly managed, may release toxicants in sufficient quantities to pose a substantial hazard to human health or the environment.

The concentration at which a particular chemical is toxic is summarized in Table 2. Heptachlor is toxic at a minimum concentration of 0.008 mg/L. Cresol and other phenolic compounds show a toxic concentration at 200 mg/L.

Table 2 - Maximum Concentration of Contaminants for the Toxicity Characteristics

Contaminant	Regulatory level (mg/L)
Arsenic	5.0
Barium	100.0
Benzene	0.5
Cadmium	1.0
Carbon tetra chloride	0.5
Chlordane	0.03
Chlorobenzene	100.0
Chloroform	6.0
Chromium	5.0
o-cresol	200.0
m-cresol	200.0
p-cresol	200.0
Cresol	200.0
2,4-D	10.0
1,4-Dichlorobenzene	7.5
1,2-Dichloroethane	0.5
1,1-Dichloroethylene	0.7
2,4-Dinitrotoluene	0.13
Endrin	0.02
Heptachlor (and its epoxide)	0.008
Hexachlorobenzene	0.13
Hexachlorobutadiene	0.5
Hexachloroethane	3.0
Lead	5.0
Lindane	0.4
Mercury	0.2
Methoxychlor	10.0
Methyl ethyl ketone	200.0
Nitrobenzene	2.0
Pentachlorophenol	100.0
Pyridine	5.0
Selenium	1.0
Silver	5.0

Tetrachloroethylene	0.7
Toxaphene	0.5
Trichloroethylene	0.5
2,4,5-Trichlorophenol	400.0
2,4,6-Trichlorophenol	2.0
2,4,5-TP (Silvex)	1.0
Vinyl chloride	0.2

Source: 40 CFR 261.24 (Blackman Jr)

The effect of toxic chemicals in the environment can produce wide range of health effects, such as acute or chronic illness. It depends on the dosage, frequency, duration, concentration etc., which can be determined by carrying out a risk assessment. The purpose of risk assessment is to insure with a reasonable margin of safety, that human health effects do not result from exposures caused by production or waste management practices.

4. Source

The inclusive listing adopted by EPA includes separate lists of nonspecific source wastes, specific source wastes, and commercial chemical products. These lists are described briefly, as follows:

4.1 Nonspecific source wastes:

It is called "F" wastes because their EPA waste identification codes begin with the letter F, are generic wastes, commonly produced by manufacturing and industrial processes. Examples from this list include spent halogenated solvents used in degreasing and wastewater treatment sludge from electroplating processes as well as dioxin wastes, most of which are "acutely hazardous" wastes due to the danger they present to human health and the environment. benzene, methylene chloride, trichloroethylene, carbon tetrachloride are few of the solvents listed in F list. Solvent blends with 10% or greater are included in F list.

4.2 Specific source wastes:

It is called "K" code is from specially identified industries such as wood preserving, petroleum refining, and organic chemical manufacturing. These wastes typically include sludges, still bottoms, waste waters, spent catalysts, and residues, e.g., wastewater treatment sludge from pigment production.

4.3 Commercial chemical products:

It is denoted by "P" and "U" codes and include specific commercial chemical products or manufacturing chemical intermediates. Commercial pure grade chemicals or any formulations with either of chemicals as active ingredient are listed in P and U list. P list is differentiated from U list based on the quantity at which the chemical is regulated. Acute toxic wastes whose accumulation or waste generation exceeds 1 kg per month is categorized under unlike U list whose waste generation 25 kilograms per month. This list includes chemicals such as chloroform and creosote, acids such as sulfuric and hydrochloric, and pesticides such as DDT etc.,

EPA has also ruled that most mixtures of solid wastes and listed hazardous wastes are considered hazardous wastes and must be managed accordingly. This applies regardless of what percentage of the waste mixture is composed of listed hazardous wastes. Without such a regulation, generators could evade RCRA requirements simply by mixing or diluting the listed wastes with nonhazardous solid waste. Wastes derived from hazardous wastes, such as residues from the treatment, storage, and disposal of a listed hazardous waste are considered a hazardous waste as well.

5. Classification

Hazardous waste is classified into six broad categories. Hazardous waste includes a lot more compounds or chemicals either as single or in combinations. The waste categories are detailed below.

- Radioactive wastes: Substances that emit ionizing radiation is called as radioactive substances and the waste generated from these substances are termed as radioactive wastes. Although they are categorized as a separate group still they are studied as hazardous waste due to the harmful effects they cause to living beings. They also persist in the environment for a long period of time. Half life determines their persistence in the environment.
- Biomedical wastes: Toxicity and infectivity are the two important characteristics of biomedical wastes. The toxic nature of biomedical waste place them under hazardous waste category. Biomedical waste is generated from hospitals, health centres and research facilities.

- Chemicals: Chemicals can be organic, synthetic, metals, acidic or basic or salts. They are hazardous when they cause toxicity. A waste stream containing these wastes at levels equal to or greater than threshold values, such streams should be considered hazardous.
- Flammable wastes: Once again dual grouping is done for this particular waste. Flammable substances can be a gas, liquid or solid. Organic sludges, plasticizers, solvents are some of the examples of flammable wastes. These wastes are hazardous and needs special management.
- Explosives: Similar to flammables, they also need special management method. They are produced from ordnance manufacturing and generated from industrial gases.
- Household hazardous wastes: In our everyday life we generate a lot of hazardous substances which is disposed off as commingled waste. They are disposed along with municipal solid waste. Some of the hazardous waste generated from households include oil paints, nail polish, latex, paints, batteries, cleaning chemicals, e waste, pesticides, chlorinated and non chlorinated solvents and many more.

6. Collection and storage

The hazardous waste collection methods and containers mainly depends on the nature and characteristics of waste. Precautionary measures have to be taken while handling, storage and transport of hazardous waste. Moreover, the compatibility of waste need to be assessed before storing them in same container. Collection and storage of hazardous waste also depends on the amount of generation. If waste is generated in less quantity, they can be stored and disposed off at regular intervals. However, large quantity of hazardous waste generation necessitates every day transfer and disposal. The containers used to store or collect hazardous waste includes fibreglass or glass-lined containers for corrosive acids or caustic solutions. Lined containers are used to avoid the reaction of metals with the container. Other containers used include PVC lined containers, single walled drums used as pressure vessels, exotic metal drums made of aluminum, nickel, stainless steel and Laboratory packs used in universities and research laboratories. Single walled drums are filled with nitrogen and used for storing reactive, flammable and explosive wastes. According to EPA guidelines, the containers used for collection and storage of hazardous waste must be closed or sealed except when waste is to be removed or added. Care should be taken to avoid rupture in the containers which might further lead to spillage or leakage issues.

Two types of storage area are designated for hazardous waste: Central accumulation area and satellite accumulation area. Liquid wastes should be collected and stored in a manner to avoid inhalation, accidental spill and vapor build up. To prevent this the containers must either be fitted with drum funnel screw lid or latching drum lids. Drum funnel screw is fitted with closed lid containers and Latch drum lids are for open lid containers. The lids should have a good gasket mechanism to keep the container sealed, leak proof and air tight. Containers filled with solid or semi-solid hazardous waste must be closed with lid with continuous gaskets and fusible plugs. These plugs will help in collecting the vapors escaping from the wastes. All the lids and seals should be checked periodically as the chemicals inside the containers will erode these seals resulting in release of vapours.

Table 3 Collection equipment for various hazardous waste

S. No.	Waste Category	Collection equipment and accessories
1.	Radioactive substances	Various types of trucks and railroad equipment depending on characteristics of wastes; special marking to show safety hazard; heavy loading equipment to handle concrete-encased lead containers.
2.	Toxic chemicals	Flatbed trucks for wastes stored in drums; tractor-trailer tank truck combination for large volumes of wastes; railroad tank cars; special interior linings such as glass, fibre glass or rubber.
3.	Biological wastes	Standard packers' collection truck with some special precautions to prevent contact between wastes and the collector; flatbed trucks for wastes stored in drums.
4.	Flammable wastes	Same as those for toxic chemicals, with special colourings and safety warning printed on vehicles.
5.	Explosives	Same as those for toxic chemicals with some restriction on transport routes, especially through residential areas.

Source: Tchobanoglous, et al., (1977 and 1993); https://nptel.ac.in/courses/120108005/lecture9.pdf

Labelling is very important in hazardous waste collection and storage. Details such as symbol of manufacturer, year of manufacturing, specification, capacity and single trip or multiple trip container. Waste stored in large storage tanks are pumped into the collection vehicle and taken to treatment or disposal. However, sealed containers are transferred to collection vehicle and taken as such to treatment or disposal site. Flatbed trucks are used for short distances and drum storage collection containers. Larger tank trucks, trailers and railroad tank is used for long distance travel.

7. Segregation

The hazardous waste materials are first segregated based upon their physical forms such as organic materials, aqueous materials and sludges. These forms determine the course of action that would be taken in the treatment and disposal of these wastes. The level of segregation of hazardous wastes (Figure 1) that should be followed is very important in the treatment, storage and disposal of different kinds of wastes. It is relatively easy to deal with wastes that are highly segregated.

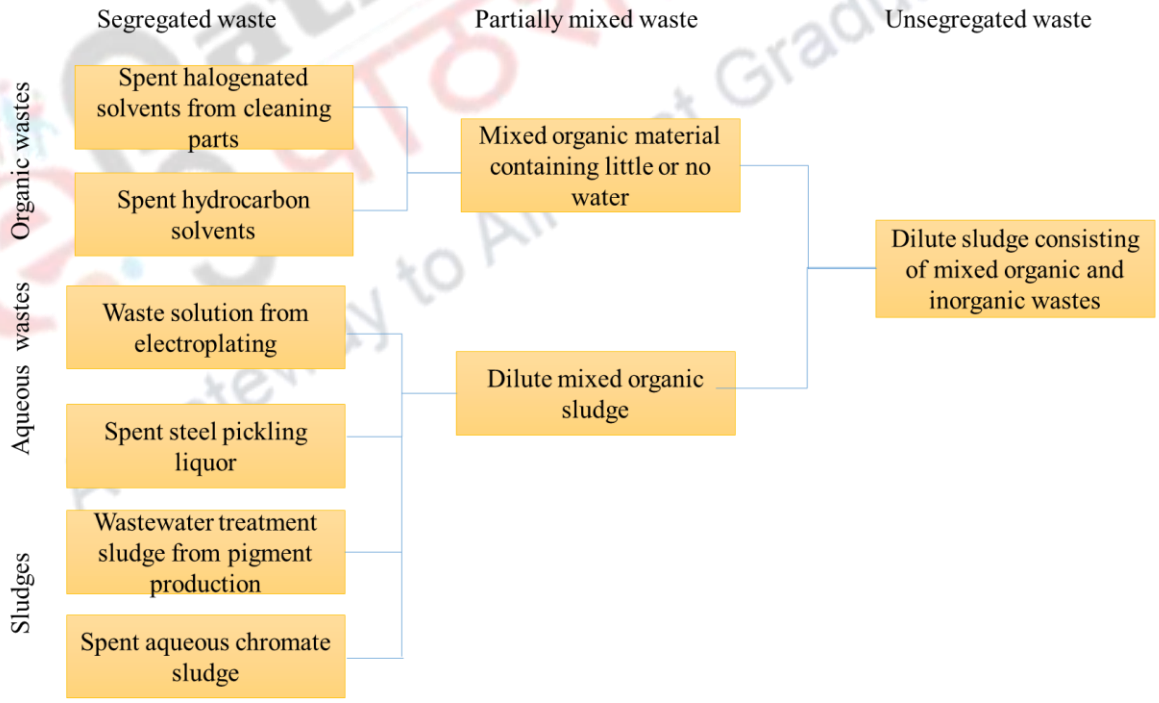

Figure 1 – Illustration of waste segregation (Source: Manahan 1993)

A waste that has been concentrated is generally much easier and more economical to handle than the one that is dispersed in a large quantity of water or soil. Dealing with hazardous wastes is facilitated when the original quantities of wastes are minimized and the wastes remain separated and concentrated.

Once the waste is segregated, it is ideally subjected to treatment and disposal upon further processing. The transport of hazardous substance and waste into the environment is plausible based on the characteristics of the waste itself. The physical properties of hazardous wastes such as volatility and solubility contribute to a large extent to their transport in the environment. Highly volatile hazardous wastes are more likely to be transported through the atmosphere and the more soluble ones will be carried by water.

The compound volatility determines the distribution of hazardous waste constituent between atmosphere, geosphere or hydrosphere. Usually in the hydrosphere, and often in soil, hazardous waste constituents are dissolved in water; therefore, the tendency of water to hold the constituent is a factor of its mobility. For example, although ethyl alcohol has a higher evaporation rate and lower boiling temperature than toluene, the vapor of the latter is more readily evolved from the soil because of its limited solubility in water in comparison with ethanol.

Chemical factors also contribute to the transport of wastes. For example, the clay minerals in the soil tend to bind some elements more strongly (Cd, Hg, Pb, Zn); some elements moderately (K, Mg, Fe, Si) and some other elements (Na, Ca, Mn, B) very poorly. It should be noted that retention of iron and manganese is a strong function of their oxidation state in that the reduced forms of Fe and Mn are poorly retained, whereas the oxidized forms of $Fe_2O_3.xH_2O$ and MnO_2 are insoluble and stay on soil as solids.

8. Transfer station

Unlike municipal solid waste, hazardous waste management does not involve a transfer station. Since the collection vehicles carry the containers with hazardous waste directly to the treatment or disposal site, the requirement of transfer station stays nullified.

Summary

To summarize, at the end of this module we have

- Defined hazardous waste
- Understood the characteristics of hazardous waste
- Identified the sources of generation: Specific, non-specific and commercial chemical products
- Classified hazardous waste
- Familiarized the collection methods, storage and collection containers
- Understood the importance of segregation of hazardous waste.

Reference

- TV Ramachandran (2009), 'Management of Municipal Solid Waste'. Centre for Ecological Sciences, IISc Karnataka research foundation.
- Tchobanoglous, G., Theisen, H. and Eliassan, R. (1977). Solid Waste Engineering, Principles and Management Issues, McGraw-Hill Book Company, New York.
- www.nptel/Municipal solid waste management.com
- https://www.newpig.com/epa-issues-guidance-document-for-closed-containers
- https://www.osha.gov/Publications/complinks/OSHG-HazWaste/11-12.pdf
- https://nepis.epa.gov/