EMT 304: HAZARDOUS SUBSTANCES MANAGEMENT

COURSE UNITS

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Comment [SSO1]: This document is edited in line with British English in all matters of grammar, spelling, punctuation, etc. Merriam Dictionary and WordWeb serve as reference dictionaries. Except specifically noted, the senses implied by the original author of the manuscript are maintained.

1.0 Introduction

The aim of this module is to teach Hazardous Substances Management to students of the National Open University of Nigeria as well as the general public the dangers of hazardous and toxic substances. According to the National Environmental Standards Regulatory and Enforcement Agency (NASREA) of the Federal Ministry of Environment, hazardous and toxic substances are serious threat to the environment and human well-being. NESREA was created in 2007 as an enforcement body of Federal Ministry of Environment (FMEnv) with a mandate that covers, among others, supply, use and management of hazardous and toxic substances including wastes arising from their use.

The content of this module is organized in a logical sequence as to inform better understanding of the issues in the following units:

1. Unit 1: Nature, Origin and Classification of Hazardous Substances
2. Unit 2: Sources and Pathways of Hazardous Substances
3. Unit 3: Disposal methods and technology of hazardous substances
4. Unit 4: Analysis of hazardous and toxic substances, contamination of water bearing strata, soil, plants, food webs and bio-concentration
5. Unit 5: Regulations and laws governing hazardous and toxic substances

UNIT 1:

The Nature, Origin, Identification, and Classification of Hazardous Substances

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Introduction

A hazardous substance is any substance, whether solid, liquid or gas, that may cause harm to your health. Hazardous substances are capable of causing significant adverse effects to the environment or human beings. A hazardous material is a substance or combination of substances which, because of its quantity, concentration, or physical, chemical or infectious characteristics, may either 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 environment when improperly treated, stored, transported or disposed of or otherwise managed (WRSEC, 2014).

Under the Hazardous Substances and New Organisms (HSNO) Act 1996 of New Zealand, a hazardous substance is any substance that has one of the properties, such as an explosive nature,

flammability, ability to oxidize (i.e. to accelerate a fire), corrosiveness, acute or chronic toxicity, ecotoxicity with or without bioaccumulation (i.e., can kill living things either directly or by building up in the environment); or ability to generate a hazardous substance on contact with air or water.

A substance is hazardous only if the level of any of these properties is above a threshold defined in regulations made under section 74 of the Act. Wherever possible, thresholds have been based on internationally recognized measures. The Act also controls compressed gas containers whether or not the gas itself is hazardous.

A good knowledge of hazardous substances involves identification, understanding of their nature, source and their classification.

2.0 Objectives

By the end of this unit, you should be able to:

- Understand the nature of hazardous substances in relation to their management
- Understand the source of hazardous substances and how they can be managed
- Identify hazardous substances
- Classify the various types of hazardous substances

3. Main Content

3.1.Nature, Origin and Classification of Hazardous Substances/Wastes.

Hazardous substances are all-pervasive and are a result of most human activities e.g. agriculture, manufacturing, petroleum refining, hospitals and pharmacies, in the household etc. They come in all shapes and forms: liquid, solids or sludges, and they include expired drugs, pesticides, dry

and wet cell batteries, used engine oils, chlorine bleach, paints, thinners, nail varnish, shoe polish, aerosols, kerosene, gasoline etc. Categories of household hazardous waste includes decorative paints, coatings and related products; garden chemicals and pet-care products; motoring products and household chemicals, materials and appliances.

Hazardous wastes are thus extremely dangerous materials that require the highest degree of care in handling, treatment and disposal. Kiely (1998) observed that the public perception of hazardous wastes is that they are a problem and those that generate hazardous wastes must somehow be stopped from continuing or engaging in this nefarious practice. However, most people fail to reckon with the fact that the generation of hazardous wastes is a part of everyday living in this consumerist society of ours. In other words, the public is afraid of these substances but uses them everyday without realizing it. On the contrary, what appears credible to most people is that hazardous wastes arise from manufacturing operations, petroleum and chemical processing and that they are nowhere related to our common day-to-day activities. This wrong perception of hazardous wastes tends to exacerbate the problem.

Comment [SSO2]: Experience has shown that more scientific literature prefers to use the past in reporting research findings. So, instead of "observes" much of their literature uses "observed".

I have maintained that even though you use present tense to report some scientific findings.

3.2. The nature of hazardous substances

Hazardous substances take various forms. They may take the form of gases, explosives, flammable and combustible solids and liquids. Some hazardous substances take the nature of oxidizing substances organic peroxides, toxic substances, infectious substances and corrosives. Apart from these ones, there are other hazardous substances that do not belong to any of the groups mentioned above. Such hazardous substances are referred to as miscellaneous hazardous substances. Hazardous substances are often known as dangerous goods. Hazardous wastes have also been defined as wastes or a combination of wastes that pose a substantial present or potential hazard to humans or other living organisms because such wastes:

- are non-degradable or persistent in nature;
- can be biologically magnified i.e., their concentration can increase at consecutively higher trophic levels in an ecosystem ;
- can be lethal; or;
- may otherwise cause or tend to cause detrimental cumulative effects.

Cunningham and Saigo (2001) gave a more embracing definition of hazardous wastes. According to them, a hazardous waste means any discarded material containing substances known to be toxic, mutagenic, carcinogenic, or teratogenic i.e. causing birth defects to humans or other life forms. Such material is also ignitable, corrosive, explosive or highly reactive alone or with other materials. Similarly, Osibanjo (1999) referred to hazardous waste as any waste(s) containing significant quantities of a substance or substances which may cause danger:

Comment [SSO3]: Verify this spelling

- to the life of living organisms when released into the environment;
- to the safety of humans or equipment in disposal plants if incorrectly handled; and
- or have the potential for severely polluting and damaging the environment.

All these definitions suggest the ubiquitous nature of hazardous substances. It is found in our homes, factories, workplaces, and farms and in the natural environment (Kiely, 1998).

A hazardous substance is also defined as one that is persistent, bioaccumulative and is toxic, or gives rise to an equivalent concern.A substance is said to be bioaccumulative if the bioconcentration factor for aquatic species on a wet weight basis is greater than 2,000. Toxic substances can be defined as broad group of chemicals capable of causing harm to plants and animals including humans.

Toxic compounds have been grouped into five categories: atmospherically-deposited compounds; organic and inorganic contaminants that result from industrial, manufacturing or other point and non-point discharges from facilities; pesticides; contaminants of emerging concern (CECs); and biological contaminants.
(dec.vermont.gov/sites/dec/files/documents/wsmd_swms_StressorPlan_Toxics).

Infectious substances are substances known or reasonably expected to contain pathogens. Pathogens are defined as micro-organisms (including bacteria, viruses, rickettsiae, parasites, fungi) and other agents, such as prions, which can cause disease in humans or animals. However, corrosives are materials that can attack and chemically destroy exposed body tissues. Corrosives can also damage or even destroy metals. They begin to cause damage as soon as they touch the skin, eyes, respiratory tracts, digestive tracts, or metals. They might be hazardous in other ways, too, depending on the particular corrosive material (www.ccohs.ca/oshanswers).

3.3.Origin of hazardous substances

Hazardous substances are common to find. They are found almost everywhere. Their sources are everywhere around us. They can be found in the home, workplace, roadways, industrial or commercial areas. Even some products we use daily contain some hazardous substances in them. Examples include the kitchen where you have petroleum products, such as kerosene, cooking gas, oven cleaners, drain cleaners, ammonia bleach etc. Other areas are the laundry – bleach, spot removers, cleaners etc. as well as garage- petrol (gasoline), solvents, pesticides, paints, pain removers, thinners etc. These products, when mishandled, constitute household hazards.

According to a study carried out by the Department of Environmental Health and Safety, University of Texas at Dallas in 2012, “almost everyone works with or around chemicals and

chemical products every day. Chemical safety is inherently linked to other safety issues including engineering controls, laboratory procedures, personal protective equipment, electrical safety, fire safety, and hazardous waste disposal. Many chemicals have properties that make them hazardous: they can represent physical hazards (fire, explosion) and/or health hazards (toxicity, chemical burns, and dangerous fumes). However, there are many ways to work with chemicals which can both reduce the probability of an accident and minimize the consequences should an accident occur" (UT Dallas, 2012).

3.4.Identification of hazardous substances

There are a number of ways in which hazardous substances can be identified. To identify if a substance is hazardous, check the product's container label and/or the safety data sheet (SDS) which is available from the supplier. If a product is not classified as a hazardous chemical under the Queensland Work Health and Safety Act 2011, an SDS is not required and, therefore, may not be available. If you are unsure, always check with the product's supplier. The labels of hazardous chemicals usually contain the words 'danger' or 'warning', along with relevant pictograms and details of hazards.

However, in industrial and commercial sites, most buildings that contain hazardous substances are identified by the National Fire Protection Association 704 Diamond system. This is located at entrance to the building. The system is divided into four quadrants. Each has a special meaning and is coded with a colour. The top quadrant is coded red meaning fire hazard, the right is coded yellow for reactivity, the left quadrant is coded blue for health hazards, while the bottom quadrant is coded white for information on special hazards of particular chemicals. Each

coloured quadrant bears numbers from zero to four showing the degrees of hazard from zero to four, with four being the greatest hazard.

Also, to identify a hazardous substance, there should be a careful observation of the container. For hazardous items transported on roadways, they carry a Department of Transportation (DOT) label on the package. The labels bear different colours signifying varying degrees of hazards. Orange colour signifies explosive, red- flammable gas and liquid, white – poison, black/white – corrosive, yellow – oxidizer, green – non-flammable gas, and yellow/white – radioactive.

3.5.Classification of hazardous substances

Hazards posed by hazardous substances may either be safety–related or health–related. The properties that make substances hazardous are related to these hazards. The Occupational Safety and Health Administration (OSHA) defined hazardous substances in terms of health hazards and physical hazards. Health hazard is assessed as either chronic or acute. A chronic health hazard occurs as a result of long-term exposure. On the other hand, an acute health hazard occurs rapidly as a result of short-term exposure. Similarly, a substance poses a physical hazard if there is a scientific evidence that it is a combustible liquid, flammable, explosive or reactive (i.e. unstable).

The definition of properties that renders a substance hazardous is given in Annex III of the EU Hazardous Waste Directive. This contains Fourteen (14) hazard categories (H1 - H14), and they include explosive, oxidizing, flammable, irritant, toxic, corrosive, infectious, teratogenic and mutagenic properties, among others.

A centralized system of classification of hazardous substances based on the Basel Convention (1989) identified forty–five (45) categories of hazardous substances (Y1 – Y45) including clinical, pharmaceutical, used lubrication oils, wood preservatives, wastes from petroleum refining, drilling waste, wastes containing lead, asbestos etc.

Appendix IV of this convention provides for two categories of substances requiring special consideration and they are Y46 (wastes collected from households) and Y47 (residues arising from the incineration of household wastes). These two categories are not specifically labelled 'hazardous wastes', but their hazardous nature is implied.

A comprehensive definition of hazardous substances will, therefore, include the following properties:

- Corrosivity i.e. ability to destroy something progressively by chemical action.
- Explosivity i.e. ability to explode.
- Flammability i.e ability to catch fire.
- Ignitability i.e. tendency to burn.
- Reactivity i.e. tendency to take part in spontaneous chemical reactions.
- Carcinogenicity i.e. capability to induce cancer or increase the incidence of cancer.
- Infectivity i.e. ability to infect or cause infection.
- Irritant properties (allergic response) i.e. causing irritation, especially physical irritation.
- Mutagenicity i.e. ability to induce genetic mutation.

- Toxicity (acute or chronic) i.e. capability to poison a living organism.
- Radioactivity i.e. ability to emit radiation.
- Teratogenicity i.e. ability to induce non-hereditary congenital malformations or increase their incidence in a developing system e.g. foetus.
- Sensitization i.e. to induce undue sensitivity in somebody to a particular substance.

Hazardous substances include gents that can damage body organs and tissues such as the blood, lungs, eyes or skin etc.

Therefore, all hazardous substances are classified based on their properties. There are nine different classes which every hazardous substance must belong. The nine classes are:

a. Class 1: Explosives
b. Class 2: Gases
c. Class 3: Flammable and Combustible Liquids
d. Class 4: Flammable Solids
e. Class 5: Oxidizing Substances, Organic Peroxides
f. Class 6: Toxic Substances and Infectious Substances
g. Class 7: Radioactive Materials
h. Class 8: Corrosives
i. Class 9: Miscellaneous Hazardous Materials

Some of the nine hazard classes are further separated into divisions based on their physical or chemical properties. For instance, explosive substances are further divided into mass explosive

hazard, projection hazard, fire and/or minor blast /minor projection hazard, minor explosive hazard and very insensitive; no mass explosion hazard. The same goes for the rest of the hazardous substances. Having the right information about the various hazardous materials would help in their management.

3.6 Conclusion

This session has shown how the understanding of hazardous substances, their sources, identification and classification can help in handling them. The understanding of the various categories of hazardous substances will enable people to know the appropriate precautionary measures to adopt in managing them.

3.7. Summary

In this unit, we have so far learnt that:

a. Hazardous substances take various forms--ranging from the form of gases, explosives, flammable, combustible solids to liquids.

b. They can be found in the home or workplace, roadways, industrial or commercial areas.

c. They can be identified by a careful observation of their containers and/or buildings where they are kept.

d. Hazardous substances are divided into nine major groups which also have subgroups.

3.8 Tutor Marked Assignments

1. How would your knowledge of hazardous materials aid you in managing chemical spills?

2. How can your knowledge of hazardous substance help you in your activities both at home and workplace?

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UNIT 2:

SOURCES AND PATHWAYS OF HAZARDOUS SUBSTANCES

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1.0 Introduction

This unit describes the various sources of hazardous substances in our environment and the pathways through which they exist. Recall that hazardous substances are those materials that pose a significant threat, both now and in the future, to human health and the environment when improperly managed. Substances considered hazardous are those that are ignitable, corrosive, reactive, toxic, or all of these. Substances designated as 'hazardous' are generated by a wide range of industries of varying sizes. The term hazardous and toxic substances are often used interchangeably to refer to a substance that can be poisonous or can cause health effects. For toxic substances in the environment to exert adverse effects on humans, they must deposit on and/or penetrate through a body surface and reach target sites where they can alter the normal functions and/or structures. The critical pathways and target sites can vary greatly from substance to substance and, for a given substance, can vary with its chemical and physical form. Understanding the sources and pathways of these hazardous substances will help in determining the risk of harmful environmental and health effect from the substances.

2.0. OBJECTIVES

At the end of this unit, the student should be able to:

Explain the two main sources of hazardous substances on the environment

Explain exposure pathways, routes and mediums

3.0 MAIN CONTENT

3.1. Sources of Hazardous Substances

Having identified some of the hazardous and toxic substances in the preceding unit, we now look at where these substances come from. We are going to discuss it using two main identified sources: Natural and Synthetic (Anthropogenic) with more emphasis on the synthetic sources.

3.1.1.Natural Sources of Hazardous Substances

These refer to those substances that occur in nature (i.e. not produced by human activities). They may exist as minerals, metals or gases in different media of the earth surfaces. Their exposure in a dose in a particular area can pose significant hazard to lives and the environment. Examples include what happens when an erupting volcano spews out huge quantities of rocks, ash, chlorine, sulfur dioxide, and other chemicals. Other natural chemicals can pollute too, but sometimes human actions allow natural substances to reach dangerous levels as in the following illustrations: 1. Radon is a naturally radioactive chemical, a gas that arises from transformations occurring in underlying rocks and soil around the world as natural radioactive uranium decays. But, levels of radon in outside air are low. It is when radon seeps up into – and concentrates in – human structures that problems may arise. 2. Arsenic and Asbestos are naturally occurring

chemicals that exist in rocks and soil; when there is high concentration, it may dissolve into water sources, thereby making them toxic to life.

Comment [SSO4]: Suggestions: toxic to human life.
Toxic to both human and animal lives

3.1.2 Synthetic (Anthropogenic) Sources of Hazardous Substances

These are substances created by human activities. In recent times, due to increase in innovations, technological advancement and better quality of life, the number of synthetic substances on the environment has increased tremendously. The produced hazardous substances are mostly used in households, industries, workplaces and agricultural development. A brief description of some of the hazardous substances and where they are mostly found are explained below:

a. **Household hazardous substances**: Majority of the materials used on daily basis at different households, to a large extent, can be classified as being hazardous. They range from paints, electrical and electronics equipment, water storage and treatment materials, lightings, adhesives, solvents etc. For example, paints are among the main sources of lead in the households; most adhesives, solvents, batteries contain zinc, manganese, mercury, copper, lead, cadmium, nickel, acids, arsenic compounds, copper etc. When their concentration exceeds the permissible healthy limit, exposure to these substances may have negative effects on humans and the environment.

b. **Industrial hazardous sources**: Industries and all manufacturing facilities use and release certain hazardous substances into the environment. These releases into the environment may either be routine or accidental. Examples include: all industries that release fumes into the atmosphere through combustion; motor vehicles including cars, buses, airplanes, ships and off-road vehicles; chemical and petroleum refineries; manufacturing facilities; plant generating electric power by burning coal, oil, or natural gas; mining; constructions; military operations;

pharmaceuticals; health; food, etc. On a day- to- day basis, humans produce and interact with hazardous substances.

c. **Agricultural sources**: Most supplements and chemicals used in growing crops and raising animals contain varying concentration of hazardous chemicals. They include agro-chemicals, such as pesticides, herbicides, fertilizers and others.

3.2. Pathways of Hazardous Substances

Hazardous substances seldom stay at the point of release. They move and are transported among the environmental mediums (air, water, soil and sediments, and biota). Pathways refer to the mediums by which hazardous substances get to a living organism and the environment. Examples include the air we breathe, the water we drink, the food we eat, and even the soil we work with, play with and use to grow much of our foods. Understanding these mediums will enable us to mitigate the health and environmental impacts of the identified hazardous substances on human beings. The pathways are as a result of the interaction of these components: exposure pathways, medium of exposure and route of exposure.

3.2.1. **Exposure Pathways**

Humans can be exposed to chemicals and physical agents through various exposure pathways. An exposure pathway describes the course that a substance takes from the source of the hazardous substance or chemical to the exposed individual or environment. Using a human being as an example, an exposure pathway (see Figure 1) generally consists of the following: (1) the source of the chemical; (2) a medium (i.e. soil, water, or air); (3) an exposure point, the potential point of contact between the human and the contaminated medium; and (4) a route of exposure (inhalation, ingestion, dermal absorption), the way in which a substance enters the human body.

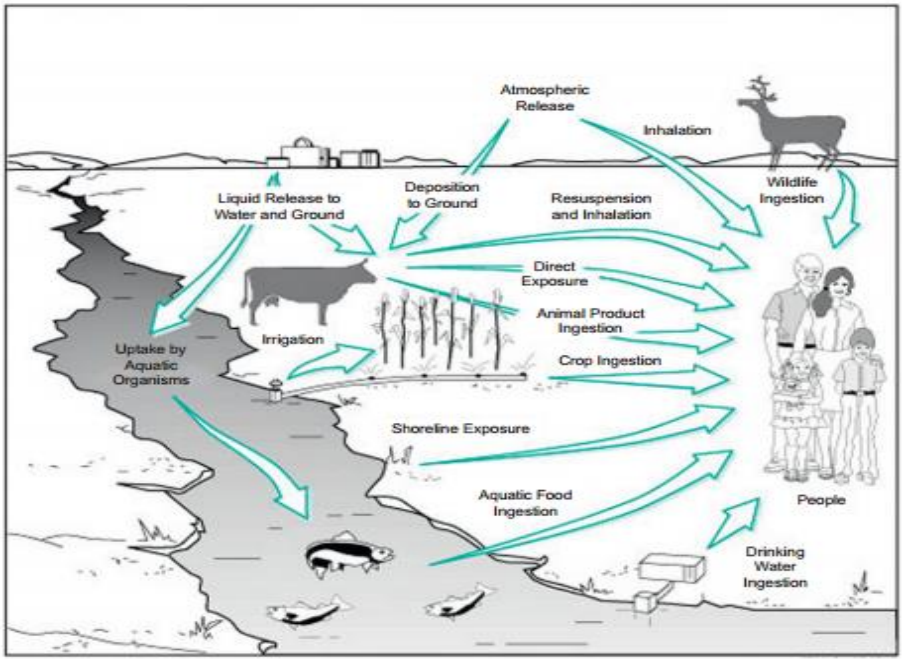

Figure 1: Illustration of exposure pathways

Source: United States Department of Energy, (1989)

3.2.2. Exposure Medium

Humans are exposed to hazardous substances in a number of ways. Sometimes, exposure occurs directly at the source, as in the case of workers, while in some, through contact with a medium. The primary media, soil, water, air, and biota, become contaminated by various mechanisms. Table 1 presents some typical release sources, release mechanisms, and receiving media.

Table 1 Common Mechanisms by Which Contaminants are Released to Media (US EPA, 1997)

Release Source	Release Mechanism	Receiving Medium
Smoke stacks, furnaces	Direct	Air
Vehicles, aircraft, marine vessels		
Surface wastes – lagoons, ponds, pits, spills	Volatilization	
Contaminated surface water		
Contaminated surface soil		
Contaminated wetlands		
Leaking drums		
Contaminated surface soil	Fugitive dust generation	
Landfills, waste piles		
Contaminated surface soil	Surface runoff	Surface water
Lagoon overflow	Episodic overland flow	
Spills, leaking containers		
Contaminated groundwater	Groundwater seepage	
Surface or buried wastes	Leaching	Groundwater
Contaminated soil		
Addition of pesticides, fertilizers	Direct	Soil
Contaminated air	Deposition, rain	
Surface or buried wastes	Leaching	
Contaminated surface soil	Surface runoff	
Lagoon overflow	Episodic overland flow	
Spills, leaking containers		
Contaminated surface soil	Fugitive dust generation/ deposition	
Waste		
Contaminated surface soil	Tracking	
Surface wastes – lagoons, ponds, pits, spills	Surface runoff, episodic overland flow	Sediment
Contaminated surface soil		
Contaminated groundwater	Groundwater seepage	
Surface or buried wastes	Leaching	
Contaminated soil		
Contaminated soil, surface water, sediment, groundwater or air	Uptake	Fruits, vegetables, grains
Contaminated water and sediments	Uptake	Fish and shellfish
Contaminated soil, water, or food	Uptake	Meat and dairy products

Air is the gaseous component of the earth, which serves as a veritable medium for airborne chemicals and hazardous substances to exist in the environment. Exposure to airborne chemicals varies widely among inhalation microenvironments. They can occur virtually everywhere, such as at residence, workplace, outdoor ambient air, transport vehicles, recreational spaces and public spaces.

Water refers to the liquid part of the earth's surface. Water can occur either at the earth's surface or underground. Most hazardous substances released into the environment end up in water bodies, such as rivers, ponds, lakes and underground aquifers. Surface and ground water used for domestic and other production purposes are the most likely exposure medium of hazardous substances for those living near the sites.

Soil and sediments serve as one of the mediums most exposed to deposits of hazardous substances. Although, soil is not ordinarily a direct exposure source for humans, contaminated soil could affect plants and animals and can also transfer the hazardous substances to other mediums, such as water and air.

Biota: plants and animals in the environment also serve as exposure medium as hazardous substances absorbed from the environment can be transmitted to human beings when there is a contact.

3.2.3 **Route of Exposure**

After soil, water, air and biota become contaminated, human exposure to the contaminants can occur through contact with the medium. These potential points of contact are called exposure points. Any sources or contaminated media at a source site can be considered a point of exposure. If contaminants have travelled offsite, significant exposure points would typically be locations close to or down gradient or downwind of the site; however, chemicals can sometimes be transported from a site and deposited in a distant water body. At the point of exposure, chemicals can enter the human body typically through the following exposure routes: inhalation, ingestion, and direct contact.

a. Inhalation

Breathing of gases, vapours, dust or mists is a common route of exposure. Inhalation of polluted air or chemicals in air essentially occurs continuously because ambient air contains a variety of gaseous and particulate pollutants. These substances enter and irritate the nose, air passages, lungs and other regions.

b. Ingestion

Human exposure to toxic substances can occur via ingestion, the process of taking a substance into the body through the mouth. Ingestion of mediums, such as water, food, and soil, can result in the inadvertent consumption of toxic substances. Ingestion of contaminated drinking water, as well as ingestion of contaminated groundwater and surface water (such as during swimming) can result in exposure to toxic chemicals. Ingestion of biota including fruits, vegetables, grains, meats and dairy products, fish and shellfish can all result in chemical exposure. Exposure to chemicals through the ingestion of contaminated soil, although typically inadvertent, occurs frequently with children at greater risk than adults as a result of childhood behaviours (US EPA, 1997).

c. Direct Contact

The skin is generally an effective barrier against the entry of environmental chemicals. Although, skin is relatively impermeable and acts as a barrier, certain chemicals can diffuse through the epidermis. Touching of hazardous substances with the skin or eyes is also a route of exposure and this can occur during various activities. Contact with contaminated water and soil can occur during bathing or swimming, gardening, construction, or recreation or even during the use of domestic or commercial products.

The route of exposure can determine whether or not the hazardous substance will have an effect. For example, inhaling a polluted air can result in health challenges, while touching a lead may not cause any health challenges or physical injury.

4.0 Summary

In this unit we have learnt that:

i. Hazardous substances are found in nature and are produced by various human activities.

ii. Hazardous substances seldom stay at the point of release, they move and are transported among the environmental mediums (air, water, soil and sediments, and biota).

iii. Hazardous substances on the different media enter the human body through three exposure routes namely: inhalation, ingestion and direct contact.

5.0 Tutor Marked Assignment

Explain the major sources of hazardous substances on the environment.

Discuss the various media where hazardous substances are stored in the environment

What the exposure routes through which hazardous substances interact with human beings.

6.0. References and Other Material

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UNIT 3:

HAZARDOUS SUBSTANCE TREATMENT AND DISPOSAL

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1.0 INTRODUCTION

The purpose of this unit is to describe the various options available for the treatment and disposal of hazardous substances/waste. In the preceding chapter, we defined hazardous substances as substances/materials whose nature or/and amount and/or concentration, either directly or indirectly, can pollute or damage the environment, and/or may endanger the environment, human health, and survival of human beings as well as other lives. Substances are classified as hazardous when they display one or more of these characteristics: explosive, oxidizing, flammable, irritant, harmful, toxic, carcinogenic, as well as harmful effects on the environment and human health (Kummer, 1999). These substances generate wastes which are dangerous or difficult to keep, treat, or dispose of without additional precautions. Some are non-degradable, while some are highly toxic and can be biologically magnified.

One of the first principles in waste management is to avoid waste generation in the first instance. But, since generation of hazardous and toxic wastes cannot be avoided because of their nature, proper care is expected to be followed in disposing the toxic wastes and hazardous substances. Disposal is the final stage of the hazardous waste management system.

Blackman (2001) noted that "Disposal of hazardous waste has been accomplished in every mode of behaviour - careful and careless, casual and furtive, clever and mindless, etc. The simple (take it out back and dump it) practice was commonplace. As case histories of contaminated sites continue to be developed, the practice of dumping solvents and other liquid wastes into the ground, into ditches, (incredibly) into drainage wells, into seepage pits, and into trash dumps is often found to have been the mechanism or practice involved."

In hazardous substance/waste management, wastes are separated into three broad groups: radioactive, chemical, and bio-hazardous.

Radioactive waste is classified as either low-level or high-level waste. Low-level waste is typically found in households, medical and research institutions, while high-level waste is typically generated by nuclear reactors.

Chemical waste includes a wide range of materials, such as discarded commercial chemical products, process wastes, and wastewater.

Bio-hazardous waste is a term used to describe different types of waste that might include infectious agents.

2.0 OBJECTIVES

By the end of this unit, the student is expected to:

- Understand the various hazardous and toxic waste treatment methods/technologies
- Understand the various disposal methods employed in hazardous waste management

- Understand the environmental factors affecting choice of disposal sites

3.0 MAIN CONTENT

3.1 Hazardous Substances/Waste Treatment Technologies

The issue of hazardous substance/waste treatment is complex. This is because the selection of treatment technologies requires a great deal of substance characterisation to determine the waste properties and depends on the availability, affordability and need for environmentally friendly technologies. Although, there are rules and guidelines governing disposal of hazardous substances and wastes, these wastes still find their way to public landfills, nearby dumpsites, drainage channels or water ways, raising serious environmental concerns. In order to curtail these concerns, hazardous substances/wastes are first treated so as to reduce their toxic and hazardous nature prior to their ultimate or final disposal. Treatment technologies refer to those techniques which decompose or break down the hazardous substances and their associated waste into non-hazardous constituents. Many waste treatment technologies can provide permanent, immediate, and very high degrees of hazard reduction.

The treatment technologies are divided into four main methods:

1) Biological methods: Composting, aerobic and anaerobic decomposition, activated sludge, enzyme treatment, etc.
2) Physical methods: Drying, screening, grinding, evaporation, sedimentation, filtration, fixation, etc.
3) Chemical Methods: Oxidation, reduction, neutralisation, hydrolysis, etc.
4) Thermal Methods: Incineration, boiling, autoclaving, ultraviolet treatment, microwave treatment etc.

Amongst the treatment methods, thermal method seems to be the preferred and most innovative disposal technique used in treatment and disposal of hazardous substances and wastes.

Incineration

Incineration is the preferred means of treatment and disposal for most organic and selected inorganic hazardous wastes. Incineration is simply the controlled combustion of waste materials in order to reduce them to a non-combustible residue or ash and exhaust gases, i.e., carbon dioxide and water. It is mostly used to treat wastes that cannot be recycled, reused, or disposed of in a landfill site. There are many different types of incineration technology, but the Rotary Kiln, Multiple Hearth and Fluidised Bed Furnaces have been shown to be the most versatile for hazardous substances and waste management. Basic methods of thermal incineration includes: combustion, pyrolysis, gasification, vitrification, detonation.

Boiling, autoclaving, ultraviolet treatment and microwave treatment are also used to treat hazardous substances, especially those from clinical and bio-hazardous wastes, while most chemical wastes are treated using chemical and physical methods.

3.2 Hazardous Waste Disposal

After treatment has been applied to reduce or remove the toxic and hazardous nature of the substance to man and his environment. The final waste has to be discarded and properly disposed in a safe and suitable location. The disposal method is dependent on the nature of the waste as well as the geographical location of the waste generator or treatment plant or the specified disposal location.

Based on this, hazardous substances can be disposed through one of these mediums:

1) Land
2) Water

3) Air

With land being the main disposal medium with significant impact on air and water we will concentrate on those disposals that take place on land.

Open Dumps: They are locations where illegally dumped, abandoned piles of garbage and debris are left in large quantities either on temporary or permanent basis. They have the lowest initial capital investment and operating cost and are generally sited in vacant plots of land. Because they are not controlled, hazardous substances, especially household hazardous wastes, are often disposed in them which often present an increased risk to ground and surface water quality and health risks to surrounding residents.

Landfills: This is the burial of waste in excavated trenches or cells. The waste may be in bulk form or containerized. It has been established that, for most parts, hazardous wastes are treated in unlicensed facilities using conventional methods, such as landfilling (Mmereki, Baldwin, Hong and Li, 2016). Two types of landfills are normally used for hazardous waste disposal, namely, controlled landfills and secured or sanitary landfills.

- ***Controlled Landfills:*** These are non-engineered disposal sites at which wastes are deposited in accordance with minimum prescribed standards of site operation. Typically controlled landfills have minimal site infrastructure with improved operational and management procedures. The site is generally identified on the basis of land availability and convenience and is already being used as an open dump. The site is not earmarked on the basis of technical, environmental or financial criteria.
- ***Secured or Sanitary Landfills:*** A secure landfill is a carefully engineered depression in the ground (or built on top of the ground) consisting of a bottom liner, leachate collection system, cover, and natural hydrogeological setting. The aim is to avoid any

hydraulic (water-related) connection between the wastes and the surrounding environment, particularly groundwater.

Deep-Well Injection*:* This disposal method uses injection wells to place treated or untreated liquid waste into geologic formations that have no potential to allow migration of contaminants into potential potable water aquifers. This method involves pumping liquid waste through a steel casing into a porous layer of limestone or sandstone. High pressures are applied to force the liquid into the pores and fissures of the rock, where it is to be permanently stored. This method is relatively inexpensive and requires little or no pre-treatment of the waste, but it poses a danger of leaking hazardous waste and eventually polluting subsurface water supplies.

Surface Impediment: This method involves arresting or demobilizing the movement or migration of the waste by containing it in a hard core: clay soil, thermoplastic polymers, non-corrosive metallic containers (carbon-steel tanks), cement, lime, fire glass, and/or rocks.

Ocean Dumping: This is a practice where hazardous substances and waste are disposed into water bodies. Despite the existing public protests and regulations against use of this method, waste generators and disposal firms have continued to dump hazardous and other forms of waste into water bodies.

3.3 Environmental Factors Affecting Choice of Disposal Sites

Having identified land as the main disposal medium in waste management identification of the suitability of potential landfill sites requires a comprehensive assessment of site conditions and potential impacts on the environment. Several factors affect the choice of disposal sites especially for hazardous and toxic waste. This is to ensure that proper care is taken to mitigate or minimise the occurrence of adverse effects to man and the ecosystem within the sites.

These factors includes:

- Geology
- Topography
- Soil condition
- Hydrogeology
- Hydrology
- Climate (including air quality and odour modelling)
- Flora and fauna
- Infrastructure
- Accessibility

3.3.1 Geology: Suitable geology is important to ensure containment of leachate in the long term, or in the event of engineered containment systems failing. Geology should be assessed with regards to the movement of leachate and landfill gas.

3.3.2 Topography: Landform in the vicinity of disposal sites will influence drainage, potential ground water problems, soil erosion risk, access, site visibility and protection from prevailing winds. A suitable site will have sufficient grade to provide drainage of surface runoff and adequate level areas to enable excavation of trenches and associated earthworks and the construction of service facilities. Sites with slopes exceeding 1 in 5 are generally not suitable because of soil erosion risk.

Comment [SSO5]: 1 in 5 what? Be specific about the measurement or dimension.

Careful consideration needs to be given to the landforms in the vicinity of the disposal site as they may influence:

- The type of disposal method that can be utilised;
- The suitability of the site for construction of service facilities;
- Surface water drainage management;

- Groundwater conditions;
- Soil erosion risk;
- Access to the site;
- Ability to screen the site from view; and
- The impact of winds on the site.

3.3.3 Soil condition: Soil structure should be suitable for the excavation of landfill cells or trenches and the construction of drainage works and should also be of sufficiently low permeability to slow the passage of leachates from the site. Sites in clay-rich environments are preferable, as their low permeability will allow more time for natural attenuation of leachates to occur. In establishing the suitability of a site, several test pits should be dug to determine the ease of excavation of the in-situ material and the suitability of soil types.

3.3.4 Hydrogeology: A suitable hydrogeological location is important to protect groundwater resources and understand the likely fate and rate of discharge of contaminants which may enter groundwater. Landfills must not be located in the following areas: areas overlying drinking water aquifers; and/or areas where, after taking into account specific design proposals, there could be a risk of causing unacceptable deterioration of the groundwater quality in the locality. The purpose of a hydrogeological assessment is to determine the relationship between the landfill and surrounding hydrogeology in order to ascertain the potential risk the landfill facility will have on the environment.

3.3.5 Hydrology: The pollution of surface water by leachate is one of the principal concerns in relation to landfill location. If landfills are located in close proximity to waterways, there is an increased risk of water pollution through leachates. Leachates are generated by water passing through waste materials in landfills and becoming exposed to and mobilizing a range of

contaminants. The potential impact of water pollution is greater in waterways that are used for drinking water or aquaculture.

3.3.6 Climate (including air quality and odour modelling): Consideration should be given to the local climatic conditions when siting a waste disposal facility. The heavy rainfall situations which can occur in the Northern Territory can cause severe erosion and storm water drainage issues if landfills are not sited and designed in an appropriate manner. Hot, dry windy conditions can cause dust and windblown waste issues. Landfills should be located in an area which facilitates the management of landfill issues.

Comment [SSO6]: Northern Territory where?

3.3.7 Flora and fauna: The development of landfills may impact on the flora and fauna of the local area. The potential impacts on flora and fauna are:

- clearing of vegetation;
- loss of habitat and displacement of fauna;
- loss of biodiversity by impacts on rare or endangered flora and fauna;
- potential for spreading plant diseases and noxious weeds;
- litter from the landfill detrimentally impacting on flora and fauna;
- contamination of sensitive ecosystems, such as wetlands, by leachate;
- creation of new habitats for scavenger and predatory species;
- erosion; and
- alteration of water courses.

3.3.8 Infrastructure: Local infrastructure must be able to sustain the operation of a landfill. Landfilling requires the transportation of waste. As a result, the capacity of the road network to cope safely with a minimum of disturbance to the local community and increased traffic load should be examined. The preferred transportation route should minimise the transport of waste

through residential and other sensitive areas. This consideration may influence the placement of the entrance to the landfill. A transportation study may reveal the need for additional road infrastructure, such as highway interchanges, turning lanes or signals. The availability of services such as reticulated water, sewerage and power will influence the facilities provided for staff at the landfill and, perhaps, indicate a need to provide additional services, namely, water storage for fire-fighting purposes.

3.3.9 Accessibility: A landfill facility must have all weather access. Access roads should be located to minimise erosion and the alteration of drainage systems. This road should be designed to safely accommodate the anticipated volume of vehicular traffic and consist of two lanes of sufficient width and strength to carry the delivery vehicles. The access roads intersection with the existing public road should be carefully designed to reflect traffic volumes and safety requirements.

4.0 Summary

In this unit we have learnt;

i. the various hazardous and toxic waste treatment methods/technologies

ii. the various disposal methods employed in hazardous waste management

iii. the environmental factors affecting choice of disposal sites

5.0. Conclusion

For effective and efficient management of hazardous substances and waste, proper care should be taken to treat the waste using adequate treatment technology and to dispose the waste in a secure and environmentally friendly medium and manner. Proper considerations should be taken when siting a hazardous waste disposal facility.

6.0 Tutor Marked Assignments

1. Discuss the reason why hazardous substances are treated before disposal

2. Using specific examples, assess the disposal method best suitable for hazardous household waste

3. What will you suggest as the best and innovative technology for disposal of hazardous substances and waste?

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UNIT 4:

ANALYSIS OF HAZARDOUS AND TOXIC SUBSTANCES

TABLE OF CONTENTS

1.0.Introduction

As earlier established, hazardous substances are made up of chemical composition or other properties that are capable of causing illness, death, or some harm to humans and other life forms when mismanaged or released into the environment. When these substances are released into the environment, they impact the quality of air we breathe, the quality of water available for human and animal consumption and for plant growth. They also affect underground water table, soil productivity, food webs, bio-concentration, human and animal health.

2.0.Objective

By the end of this unit, students should be able to:

- understand the effects of hazardous substances on the major components of the environment;
- understand how environmental contamination through hazardous and toxic substances affect human health and the functions of the human system;
- understand the analysis of hazardous and toxic substances, through their sources and effects

3.0. Main Content

3.1. Effects of Hazardous Substances on Soil

Heavy metals are naturally present in the soil and, in the right quantity, are not harmful. Heavy metals are elements that exhibit metallic properties, such as ductility, malleability, conductivity, cation stability, and ligand specificity. They are characterized by relatively high density and high relative atomic weight with an atomic number greater than 20 (Chibuike and Obiora, 2014). Examples include Copper, Iron, Magnesium and Zinc. When their concentration is increased by the introduction of hazardous and toxic substances into the soil, they become harmful. Hazardous substances are, in themselves, composed of chemicals that have high metallic contents. The disposal of hazardous substances is, therefore, considered as one of the major sources of soil pollution because it increases the concentration of heavy metals in the soil.

The negative effects of these pollutants on the soil's biological and biochemical properties are many. Pollution, not only results in adverse effects on various soil parameters necessary for plant growth and yield, but also causes changes in the size, composition and activity of the microbial community in the soil (Singh and Kalamdhad, 2011). Soil properties like organic matter, clay

contents and pH have major influences on the extent of the effects of pollutant on the biological and biochemical properties of soils. Heavy metals indirectly affect soil enzymatic activities by shifting the microbial community which synthesizes enzymes. Heavy metals exhibit toxic effects towards soil biota by affecting key microbial processes and decrease the number and activity of soil microorganisms. According to Chen et al (2010), heavy metals cause a decrease in bacterial species richness and a relative increase in soil actinomycetes. They also cause a decrease in both the biomass and diversity of the bacterial communities in contaminated soils.

Karaca et al (2010) noted that enzyme activities are influenced in different ways by different metals due to the different chemical affinities of the enzymes in the soil system. Cadmium (Cd) for example is more toxic to enzymes than Lead (Pb) because of its greater mobility and lower affinity for soil colloids. Copper (Cu) inhibits b-glucosidase activity more than cellulose activity. Lead (Pb) decreases the activities of urease, catalase, invertase and acid phosphatase significantly. Cadmium (Cd) contamination has a negative effect on the activities of protease, urease, alkaline phosphatase and arylsulfatase but no significant effect on that of invertase.

When these harmful substances are released into the environment from the manufacturing industries, industrial plants and other chemical handling and processing outfits, they interact with different soil properties as described above. The negative results of these interactions trigger soil deterioration and make the soil unsuitable for planting and cultivation. They also lead to depletion of soil cover and vegetal loss. The hazardous substances dry up the vegetation cover on soil and render the soil barren. In some cases, the pollution makes it impossible for the soil to absorb water. That is, pollution also increases water logging in soils and make the soils unsuitable for farming, building and any other major construction activities.

3.2. Hazardous Substances and Plant Growth

The heavy metals that are available for plant uptake are those that are present as soluble components in the soil solution or those that are easily solubilized by root exudates (Chibuike and Obiora, 2014). Although, plants require certain heavy metals for their growth and upkeep, excessive amounts of these metals, through pollution and the introduction of hazardous substances to the environment, can become toxic to plants. As metals cannot be broken down, when concentrations within the plant exceed optimal levels, they adversely affect the plant both directly and indirectly. Some of the direct toxic effects caused by high metal concentration include inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress. An example of indirect toxic effect is the replacement of essential nutrients at cation exchange sites of plants. These toxic effects lead to a decline in plant growth which sometimes results in the death of plant.

The accumulation of heavy metals from pollutants by plants depends upon plant species. Their absorption into the plant tissue also depends on temperature, moisture, organic matter, pH and nutrient availability (Singh and Kalamdhad, 2011). The efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil to plant transfer factors of the metals (Wang et al, 2007). Elevated volume of Lead (Pb) in soils may decrease soil productivity, and a very low concentration may inhibit some vital plant processes such as photosynthesis, mitosis and water absorption resulting in toxic symptoms like dark green leaves, wilting of older leaves, stunted foliage and brown short roots. Heavy metals are potentially toxic and phytotoxicity for plants resulting in chlorosis, weak plant growth, yield depression, and may even be accompanied

by reduced nutrient uptake, disorders in plant metabolism and reduced ability to fixate molecular nitrogen in leguminous plants (Clarkson and Luttge, 1989).

Pollution with heavy metals through hazardous substances also reduces plant growth as a result of changes in physiological and biochemical processes in plants. Continued decline in plant growth reduces yield which eventually leads to food insecurity. In general terms, hazardous substances have various adverse effects on the growth of plants and equally have long lasting impacts on crop yields. Chibuike and Obiora (2014) summarized some notable effects of toxic substances on some common plant varieties as follow:

i. Reduction in seed germination: decrease in seedling height, reduced leaf area and dry matter production;
ii. Reduced fruit yield: decrease in leaf fresh weight;
iii. Stunted growth: chlorosis; wilting;
iv. Reduction in seed germination: decrease in plant nutrient content, reduced shoot and root length;
v. Reduction in plant nutrient content;
vi. Reduction in antioxidant enzyme activities: decrease in plant sugar, starch, amino acids, and protein content;
vii. Inhibition of germination process: reduction of plant biomass;
viii. Plant mortality: reduced biomass and seed production
ix. Decrease in plant height: reduced tiller and panicle formation, yield reduction, bioaccumulation in shoot and root of seedlings;

x. Slower plant growth: decrease in chlorophyll concentration;

xi. Reduction in number of leaves and leaf area: reduced plant height, decrease in plant biomass; and

xii. Accumulation of Zinc in plant leaves: growth reduction, decrease in plant nutrient content, reduced efficiency of photosynthetic energy conversion.

3.3. Effects of Hazardous Substances on Water and Aquatic Life

According to the American Fisheries Society (AFS) Policy Statement, the impacts of chemical substances on the aquatic environment are many and as diverse as the number of beneficial purposes for which these chemicals were initially created. The spread of manufacturing, consumer use, and distribution patterns for this myriad of chemical substances has become so general that there remains essentially no natural surface water communities currently untouched at least to some degree by man-made chemical substances. Measurable residues of persistent organics have been reported from fish and aquatic mammals from all corners of the earth, obviously thousands of miles from any known use or application site of these organics. Frequently, the concentration of a particular toxic substance is sufficiently high so as to leave no doubt about its negative impact on aquatic life. However, it is much more common to encounter lower concentrations of a particular chemical with no obvious or immediate effects but with far-reaching and potentially more significant secondary effects on aquatic communities and consumer species.

The contamination of a river with heavy metals may cause devastating effects on the ecological balance of the aquatic environment, and the diversity of aquatic organisms becomes limited with the extent of contamination. Heavy metals released into aquatic systems are generally bound to particulate matter, which eventually settle down and become incorporated into sediments.

Surface sediment, therefore, is the most important reservoir or sink of metals and other pollutants in aquatic environments (Singh and Kalamdhad, 2011). Because a major fraction of the chemicals introduced into the aquatic environment eventually becomes associated with the bottom sediments, environmental degradation by hazardous substances can occur in areas where water quality criteria are not exceeded, with organisms in or near the sediments being adversely affected.

All manufactured chemical substances possess the potential to enter surface waters sometimes with and sometimes without man's specific intent. The volume introduced into surface water through improper handling of hazardous wastes and toxic substances is what is important for the preservation of water quality and aquatic life. In order to bring about reduction in the distribution or abundance of specific aquatic life, these toxic substances need not be present in acutely toxic concentrations. Species reduction can be caused by significantly lower concentrations of the chemical, which either directly or indirectly affect survival, growth, reproduction or behavior of the species. The well-known example of the bio-concentration of chlorinated organic pesticides, resulting in the deaths of millions of sport and forage fish species in the lower Mississippi River during the early 1960's demonstrated that hazardous wastes and organic chemical could cause significant impacts on aquatic life in areas far removed from their discharge point if all aspects of manufacture, use, and disposal were not carefully considered.

Diatom community structure can be affected by high levels of micro-pollutants and, in particular, by metals, which are often found in rivers (Singh and Kalamdhad, 2011). Results of numerous monitoring and survey programmes show that most surface waters of the world, especially in highly industrialized countries, and many ground water sources contain measurable amounts of potentially harmful chemical substances. Once heavy metals are accumulated by an aquatic

organism, they can be transferred through the upper classes of the food chain. Carnivores at the top of the food chain, including humans, obtain most of their heavy metal burden from the aquatic ecosystem by way of food. Fish is a commodity of potential public health concern as it can be contaminated with a range of environmentally persistent chemicals from hazardous wastes. These exposures have typically resulted in direct and indirect toxic impacts on aquatic biota or in more subtle effects such as rendering these resources inedible for human consumption.

Surface water pollution by heavy metals is widespread and, in some instances, has caused significant human health problems due to bio-concentration of metals by fish and shellfish used as human food resources. A popular example involves the classic Japanese ‘Minamata disease’ associated with human consumption of fish and shellfish laden with high concentrations of methylmercury. Sublethal concentrations of pesticides can alter fish physiology, behaviour, learning and ability to escape natural predation. Similarly, trace concentrations of mercury, zinc, and other metals reduce the swimming rate of crab and fish larvae, thus reducing their ability to escape predation. Another example given by the American Fisheries Society relates to trout mortalities in the late 1950’s, where it was shown that concentrations of DDT could cause fry mortalities via transmittal of DDT from female lake trout to their offspring through the egg. More recently, large sections of the James River estuary in Chesapeake Bay in the United States have been closed for the taking of fish and shellfish due to manufacturing discharges and subsequent bio-concentration of the pesticide ketone.

3.4. Hazardous Substances and Human Health

The toxicity of a substance is its capacity to cause injury once inside the body (Carson and Mumford, 2002). Humans are exposed to hazardous wastes and substances through inhalation, ingestion and absorption through the skin. Gases, vapours, mists, dusts, fumes and aerosols can be inhaled and they can also affect the skin, eyes and mucous membranes. The skin can be affected directly by contact with the chemicals, even when intact, but its permeability to certain substances also offers a route into the body. Direct ingestion is rare although possible as a result of poor personal hygiene, subconscious hand-to-mouth contact, or accidents. Indirect ingestion through the consumption of plants and animals that have been previously exposed to high concentrations of poisonous metals and chemicals is, however, more prevalent. The consumption of food crops and fish contaminated with heavy metals is a major food chain route for human exposure.

Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues (Lalor, 2008). Chronic level ingestion of toxic metals has undesirable impacts on humans and the associated harmful impacts become perceptible only after several years of exposure (Singh and Kalamdhad, 2011).Cadmium (Cd), for example, is a heavy metal toxicant that affects the liver, placenta, kidneys, lungs, brain and bones. Severe exposure may result in pulmonary odema and death. Pulmonary effects (emphysema, bronchiolitis and alveolitis) and renal effects may occur following subchronic inhalation exposure to Cadmium and its compounds (Duruibe et al, 2007). Exposure of humans to Copper (Cu) occurs primarily from the consumption of food and drinking water that have been polluted by toxic substances. Excessive human intake of Copper may lead to severe mucosal irritation and corrosion, widespread capillary damage, hepatic and renal damage and central nervous system irritation followed by

depression. Severe gastrointestinal irritation and possible necrotic changes in the liver and kidney can also occur (Singh and Kalamdhad, 2011).

As illustrated in the booklet of health effects of chemical exposure by the United States Agency for Toxic Substances and Disease Registry (ATSDR), the following body systems are directly affected by exposure to hazardous substances and harmful chemicals: respiratory, renal, cardiovascular, reproductive, nervous, immune and hepatic systems. The skin is also affected. The functions of these systems and the pathways through which exposures to toxic substances can cause diseases are as follow:

The respiratory system - functions to supply oxygen to the body and remove carbon dioxide. It includes the nasal passages, pharynx, trachea, bronchi, and lungs. Possible health effects of the respiratory system include asbestosis, lung cancer, chronic bronchitis, fibrosis, emphysema, and decreased oxygen supply in blood.

The renal system – Its function is to rid the body of waste, to regulate the amount of body fluids, and to regulate the amount of salts in the body. It includes the kidneys, the urethra, the bladder, and the ureter. Possible health effects of the renal system include decreased formation of urine, decreased blood flow to kidney, decreased ability to filter the blood, prevented urine flow, kidney tissue damage, and kidney cancer.

The cardiovascular system – Its function is to move nutrients, gases, and wastes to and from the body, to help stabilize body temperature, and to fight diseases and infections by transporting white blood cells to important areas. It includes the heart, blood, arteries, veins, and capillaries.

Possible health effects include heart failure and the inability of blood to carry the necessary oxygen to the body.

The reproductive system - functions to produce egg and sperm cells, to nurture a developing foetus, and to produce hormones. For males, it includes the testicles, seminal vesicles, prostate glands, and the penis. For females, it includes the uterus, bladder, vagina, fallopian tubes, ovaries, and the cervix. Possible health effects of the reproductive system include decreased ability to have a baby, increased baby deaths, increased birth defects, and infertility (the inability to have children).

The nervous system – Its function is to transmit messages from one part of the body to another. It includes the central nervous system (the brain and spinal cord) and the peripheral nervous system. Possible health effects of the nervous system include inability to move, loss of feeling, confusion, and decreased speech, sight, memory, muscle strength, or coordination.

The immune system's function is to protect the body from tumor cells, environmental substances, and invading viruses or bacteria. It includes the lymph system, bone marrow, white blood cells, and the spleen. Possible health effects of the immune system include over-reaction to environmental substances (allergy), immune system slow down or failure, and autoimmunity (autoimmunity causes the body to attack itself – which makes it more likely to have an over-reaction or infection).

The skin – It serves as a barrier to germs and other substances, prevents dehydration, and regulates body temperature. Possible health effects of the skin include irritation, rash, redness or discoloration, dermatitis, and health effect related to other systems and organs due to contamination through the skin.

The hepatic system – Its function is to break down food and store nutrients, to make proteins which are essential for blood to clot, and to purify the body of drugs, contaminants, or chemicals. It includes the liver and its veins. Possible health effects of the hepatic system include liver damage, tumors, accumulation of fat (steatosis), and death of liver cells.

3.5. Analysis of Some Hazardous and Toxic Substances

When broken down into their component parts, hazardous and toxic substances are composed of heavy metals and other harmful chemicals. Table 4.1 lists some major components of these substances and where they are found in both the human and physical environment. The Table also shows the respective functionality of the human system that is affected by the contaminants.

Table 4.1: Hazardous Substance, Sources and Effects

S/N	Hazardous Substance	Source	Effect
1	Asbestos	Old insulation	Respiratory
2	Radon	The ground	Respiratory
3	Cadmium	Old batteries	Respiratory, renal, nervous
4	Benzene	Degreasers	Respiratory
5	Carbon monoxide	Car exhaust, unvented or faulty furnaces	Respiratory, Reproductive, Cardiovascular, Nervous
6	Soot	Furnaces, wood burning stoves	Respiratory
7	Lead	Old paint, outdated plumbing	Renal, reproductive,

			Immune
8	Mercury	Thermostats, thermometers, Fish	Renal, immune, skin
9	Uranium	Food and water, proximity to nuclear testing sites	Renal
10	Chlorinated hydrocarbon solvent	Degreasers, paint removers, dry cleaning solutions	Renal
11	Carbon disulfide	Industrial production	Cardiovascular
12	Nitrates	Fertilizers	Cardiovascular
13	Methylene chloride	Auto part cleaners, paint removers	Cardiovascular, hepatic
14	Methyl mercury	Fish, coal-burning power	Reproductive
15	Arsenic	Pressure treated wood	Nervous, skin
16	Cyanide	Rat poison	nervous
17	Pesticides	Unwashed fruits and vegetables	Immune
18	Polychlorinated biphenyls (PCBs)	Industrial waste, fish from contaminated water	Immune, skin
19	Polycyclic aromatic hydrocarbons (PAHs)	Cigarette smoke, vehicle exhaust, asphalt roads	Immune
20	Nickel	Cement	Skin
21	Chromium	Paints, industrial production	Skin
22	VOC (volatile organic compounds)	Fumes from gasoline, paint, adhesives, building supplies	Skin
23	Carbon tetrachloride	Adhesives	Hepatic
24	Vinyl chloride	Pipe sealer	Hepatic

Source: Adapted from the Booklet of Health Effects of Chemical Exposure

4.0.Conclusion

The understanding of the interrelationships among hazardous and toxic substances and soil, plant, water and aquatic life and human health is expected to inform a proper waste management method for the betterment of the complex web of life in the environment.

5.0.Summary

In this unit, we have learnt that;

i. Hazardous and toxic substances are composed of heavy metals and harmful chemicals

ii. These substances have adverse effects on soil, plants, water and aquatic life, and human health

iii. Hazardous and toxic substances are found in the environment and have specific negative impacts on the human system

6.0.Tutor-Marked Assignments

i. Discuss the effects of hazardous substances on soil and plants

ii. Examine the negative health consequences of improper disposal of hazardous substances on human health

iii. Mention 10 major components of hazardous substances and discuss where they are found and their implications for the human body system

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UNIT 5:

EMT 304: REGULATIONS AND LAWS GOVERNING HAZARDOUS AND TOXIC SUBSTANCES

Introduction

Management of hazardous wastes has been on the international environmental agenda from the early 1980s, when it was included as one of the three priority areas in the United Nations Environment Programme's (UNEP) first Montevideo Programme on Environmental Law in 1981. Efforts are on globally and locally to control the incidence of unregulated and improper disposal of hazardous wastes. As a global response to the increasing incidence of dumping of hazardous wastes, mostly in developing countries, the *Basel Convention on the Trans-boundary*

Movement of Hazardous Wastes and their Disposal, was negotiated and adopted by 117 countries under the sponsorship of the United Nations, in March 1989 in the Swiss city of Basel.

1. Basel Convention on the Trans-boundary Movement of Hazardous Wastes and their Disposal

This Convention, which came into force in 1992, aimed at regulating the international trade in hazardous wastes. That regulation was to be achieved by requiring exporters of hazardous wastes to obtain consent from receiving countries before shipping waste, and by requiring both the exporter and importer countries to ensure that the waste would be disposed of in an environmentally sound manner. It further places restrictions on the import of hazardous wastes from non-party states to party states, except where compatible bilateral or multilateral agreements are in place between the party and non-party states providing for environmentally sound management of that waste. In addition, the Basel convention provides that, where possible, hazardous wastes should be disposed of as close as possible to their sites of generation (i.e. an international expression of the proximity principle).

A still more restrictive convention was reached in March 1994 when,with the United States dissenting,most western industrialized countries agreed to ban the export of all poisonous or hazardous industrial wastes and residues to the developing world, the countries of Eastern Europe and the former Soviet Union . By 1996, 97 countries had imposed national bans on hazardous waste imports for whatever reasons.

- The Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal was adopted on 22nd March, 1989 and entered into force on 5th May, 1992.

- It was adopted in 1989 in response to a public outcry following the discovery, in the 1980s, in Africa and other parts of the developing world of deposits of toxic wastes imported from abroad.
- The Convention aims to protect human health and the environment against the adverse effects resulting from the generation, management, trans-boundary movements and disposal of hazardous and other wastes.

Important Historical Dates in the Development of the Basel Convention

- Negotiated in the late 1980s
- Adopted on 22nd March, 1989
- Entered into force on 5th May, 1992
- As of 1st Jan. 2011, there are 175 Parties to the Convention.

Significant Developments in Basel Convention Governance

- The Amendment to the Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal ("the Basel Ban") which was adopted by the third meeting of the Conference of the Parties (COP) in 1995.
- The Basel Protocol on Liability and Compensation for Damage resulting from Trans-boundary Movements of Hazardous Wastes and their Disposal was adopted by COP 5 in 1999.
- A Committee for Administering the Mechanism for Promoting Implementation and Compliance was established at COP 6 in Geneva in 2002.

- There has been synergy between the Basel Convention, Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the Stockholm Convention on Persistent Organic Pollutants.

Specific Objectives of the Basel Convention

- The reduction of hazardous waste generation and the promotion of environmentally sound management of hazardous wastes, wherever the place of disposal;
- The restriction of trans-boundary movements of hazardous wastes, except where it is perceived to be in accordance with the principles of environmentally sound management; and
- A regulatory system applying to cases where trans-boundary movements are permissible.

Scope of the Basel Convention Its scope of application covers a wide range of wastes defined as "hazardous wastes" based on:

- Their origin and/or composition and their characteristics (article 1 and annexes I, III, VIII and IX).

Obligations of Parties

- Parties exercising their right to prohibit the import of hazardous wastes or other wastes for disposal shall inform the other Parties of their decision(art.4 (1a)).
- Parties shall prohibit or shall not permit the export of hazardous wastes and other wastes if the State of import does not consent in writing to the specific import, in the case where that State of import has not prohibited the import of such wastes(art.4(1c)

Exemptions to General Obligations

Trans-boundary movement of hazardous wastes and other wastes is only allowed if:

- The State of export does not have the technical capacity and the necessary facilities, capacity or suitable disposal sites in order to dispose of the wastes in question in an environmentally sound and efficient manner;
- The wastes in question are required as a raw material for recycling or recovery industries in the State of import; and
- 47 categories of waste to be controlled under Basel exclude radioactive wastes.

2. Bamako Convention on the Ban of the Import into Africa and the Control of Trans-boundary Movement and Management of Hazardous Wastes within Africa

In 1988, the Organisation of African Unity (OAU) adopted a resolution proclaiming the dumping of nuclear and industrial wastes in Africa to be a crime against Africa and its people. In 1991, the OAU adopted the Bamako Convention on the Ban of the Import into Africa and the Control of Trans-boundary Movement and Management of Hazardous Wastes within Africa (OAU, 1991). Under this treaty, parties are to prohibit the import of all hazardous wastes for any reason into Africa by non-parties and to prohibit the dumping at sea of such wastes.

The 1991 Bamako Convention includes radioactive properties in addition to the under listed properties:

- Explosive
- Flammable liquids
- Flammable solids

- Oxidising
- Organic peroxides
- Poisonous (acute)
- Corrosives
- Toxic (delayed or chronic)
- Ecotoxic

Africa plugged the exclusion of radioactive waste by establishing Bamako Convention in 1991 which included radioactive waste stream

3. Nigeria's National Regulations

*Harmful Waste (Special Criminal Provisions etc.) Decree of 1988*In Nigeria, the Harmful Waste (Special Criminal Provisions etc.) Decree of 1988 was promulgated as a response to the dumping of toxic wastes at Koko. The Decree prohibits all activities relating to the purchase, sale, importation, transit, transportation, deposit and storage of harmful waste. It further makes it a criminal offence liable to life imprisonment to perpetrate any of the above. This Decree yielded immediate results as the consignment of toxic waste was literally repatriated to Italy, from where it came.

Comment [SSO7]: Koko is where? Kindly state the state.

- The discovery of toxic waste dumped in Koko, a remote part of southern Nigeria, in June 1988, and the attendant media and public outcry prompted the government to react swiftly and set up the Federal Environmental Protection Agency.

- Nigeria signed the Basel Convention document on 15th March, 1990 and ratified it on 13th March, 1991

- Nigeria also ratified the amendment to the Basel Convention on 24th May, 2004.

Implementation of Basel Convention in Nigeria: Institutional Framework

- Art.4(4) requires that each Party shall take appropriate legal, administrative and other measures to implement and enforce the provisions of this Convention, including measures to prevent and punish conduct in contravention of the Convention.
- Arising from the Koko toxic waste episode, the Federal Government enacted the Harmful Waste Decree of 1988 – The decree led to the establishment of the Federal Environmental Protection Agency (FEPA) in 1988
- In June 1999, the Federal Ministry of Environment was established to ensure effective coordination of all environmental matters, which hitherto were fragmented. The ministry is the national Competent Authority of Basel Convention
- The Pollution Control and Environmental Health Department of the Federal Ministry of Environment is the focal point for Basel Convention.
- Basel Convention Coordinating Centre for Training & Technology Transfer for the African Region (BCCC-Africa) was established in September 1994.
- BCCC-Africa is located in the University of Ibadan and has the following as core functions: training, technology transfer, information exchange, consulting and awareness-raising.

- The National Environmental Standards and Regulations Enforcement Agency (NESREA) was established by NESREA (Establishment) Act, 2007. NESREA is the enforcement arm of the Federal Ministry of Environment

- In addition, the Federal Environmental Protection Agency (FEPA 1991) developed Hazardous Waste Regulation S.1.15. This regulation makes provision for the proper management and disposal of locally generated toxic and hazardous substances (FEPA, 1991). This Regulation also controls the collection, treatment and disposal of solid and hazardous wastes from industrial and municipal sources, and gives an exclusive list of chemicals and wastes by toxicity categories.

- The National Policy on the Environment (Federal Ministry of Environment 2016) and Nigeria's National Agenda 21 (FEPA, 1999) both emphasise the need for effective control of hazardous substances, among other things.

Priority Hazardous Waste in Nigeria and Africa

- Health care and medical /clinical wastes
- Industrial wastes/petroleum/petrochemical wastes
- Stock of obsolete pesticides and other chemicals already banned internationally (about 120,000 tons?)
- Polychlorinated Biphenyl (PCBs) in electrical transformer oils
- Dioxins and Furans from uncontrolled burning of solid wastes
- Used engine oil: contains PCBs, PAHs, Dioxins and heavy metals e.g. lead, cadmium, nickel etc.
- Used tyres

- Used Lead Acid Batteries and dry cell batteries
- Mining wastes
- Electrical and electronic wastes (e-waste)
- Others: e.g. abandoned/obsolete chemical weapons/munitions – e.g. 2001 January 27, Ikeja cantonment explosions in Lagos, Nigeria.

Regulations for Used Lead Acid Batteries (ULAB)

ULAB: the substances they contain and their components are included in Annexes 1 and VIII to the Basel convention as follows:

Annex 1

Y31: lead, lead compounds

Y34: acidic solutions or acids in solid form

Annex VIII

A1160: waste lead-acid batteries, whole or crushed

A4090: waste acidic or basic solutions, other than those specified in the corresponding entry on list B

Expectations of Stakeholders on ULAB in Nigeria

- Raising awareness of effects of unsound management of ULAB.
- Assessing current status of ULAB management in Nigeria.

- Developing guidelines on environmentally sound collection, storage and transport system.
- Promoting environmentally sound recycling of ULAB in Nigeria.
- Formulating policy for management of ULAB in Nigeria.
- Preparing ULAB educational materials and disseminating information.
- Assessing site contamination and identifying remediating options.
- Developing action plans for remediating contaminated soils in Nigeria.

Conclusion

- Nigeria is a Party to the Basel Convention and has faithfully implemented its provisions.
- Hitherto, Nigeria has exported a high percentage of battery wastes abroad for recycling.
- With the recent permits granted to local recyclers like Union Autoparts Manufacturing Co. Ltd, Nnewi, there is need for increased local recycling to create jobs and wealth and build national capacity.

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