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Unit IV
Hazardous Wastes

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Definition

- It may be defined as any waste or combination of wastes that poses substantial danger to human beings, plants and animals.
- Sources: The sources include the by-products of industrial, domestic,commercial, health care activities.The sources also includes industries, institutions,research labs, mining sites,mineral processing sites, waste disposal sites and agricultural activites too.

- Ref:Hazardous waste-Encyclopedia of life support systemse1-08-00-00.pdf

Characteristics

- EPA established four hazardous waste characteristics: ignitability, corrosivity, reactivity and toxicity.
- Capable of causing fire at standard temperature and pressure through friction, absorption of moisture, or spontaneous chemical changes
- Is an ignitable compressed gas
- Is an oxidizer
- **Corrosive**
- Liquid with pH < 2 or > 12.5
- Solid that has pH < 2 or > 12.5 when mixed with equal weight of water
- **Reactive**
- Normally unstable and readily undergoes violent change
- Reacts violently with water
- Forms potentially explosive mixtures with water
- Forms toxic gases, vapors, or fumes when mixed with water
- Cyanide- or sulfide-bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors or fumes
- Is capable of detonation or explosive decomposition if subjected to a strong initiating source or heated under confinement
- Is readily capable of detonation or reaction at standard temperature and pressure

- **Toxic**
- Has an acute oral LD50 < 2,500 mg/kg
- Has an acute dermal LD50 < 4,300 mg/kg
- Has an acute inhalation LC50 < 10,000 ppm as a gas or vapor
- Has an acute aquatic 96-hour LC50 < 500 mg/l
- Has been shown through testing to pose a hazard to human health or environment because of its carcinogenicity (carcinogen, mutagen, teratogen), acute toxicity, chronic toxicity, bioaccumulative properties or persistence in the environment

List of hazardous wastes

- The federal EPA has designated four "lists" of hazardous wastes, designated by the letters "F", "K", "P", and "U". If a material is found on one or more of these lists, it is considered a "listed hazardous waste". Each of these lists is explained briefly below:
- **F Listed Wastes** - The F listed wastes include a wide variety of commonly found wastes, ranging from solvents to wastewater treatment sludges to dioxin contaminated materials.
- **K Listed Wastes** - These are hazardous wastes from specific processes, many of which are chemical or pesticide manufacturing. Examples are "distillation bottoms from the production of aniline" or "wastewater treatment sludge from the production of toxaphene".
- **P Listed Wastes** - These are known as "acute" hazardous wastes because they are highly toxic. Many are unusual chemicals that are not likely to be found. Some, especially the pesticides, are still in use or were formerly used and may be stored as unusable materials. Examples include endrin, arsenic trioxide (gopher bait), and warfarin (rat poison).
- **U Listed Wastes** - U listed wastes are less toxic commercial chemicals, off-specification products, or manufacturing chemical intermediates. They are normally waste materials only if they can't be used (off-specification) and must be discarded. Examples include benzene, formaldehyde, and vinyl chloride.

Radioactive Pollution

- The radioactive pollution is defined as the physical pollution of atmosphere, hydrosphere and lithosphere by emissions from radioactive materials. Certain materials possess the ability to emit the alpha, beta and gamma rays.
- Those materials are called radioactive elements. The sources of radiations can be natural or man-made. Radioactive wastes are those wastes containing radioactive material, usually by-products of nuclear power plants, nuclear reaction or processes that involve radioactive substance such as research and medicine.

Classification of radioactive wastes

- There are two broad classifications: high-level or low-level waste.
- High-level waste is primarily spent fuel removed from reactors after producing electricity.
- Low-level waste comes from reactor operations and from medical, academic, industrial, and other commercial uses of radioactive materials. Low-level waste includes items that have become contaminated with radioactive material or have become radioactive through exposure to neutron radiation. This waste typically consists of contaminated protective shoe covers and clothing, wiping rags, mops, filters, reactor water treatment residues, equipment and tools, luminous dials, medical tubes, swabs, injection needles, syringes, and laboratory animal carcasses and tissues

Sources of radioactive wastes

- **Natural sources**
- Small amounts of radioactive materials are contained in mineral springs, sand mounds and volcanic eruptions. Essentially all substances contain radioactive elements of natural origin to some extent or the other.
- **Artificial Sources**
- Environmental Encyclopedia (2003) puts the sources of such wastes as:
- Nuclear weapon testing or detonation
- The *nuclear fuel cycle*, including the mining, separation, and production of nuclear materials for use in nuclear **power plants** or nuclear bombs;
- Accidental release of radioactive material from **nuclear power** plants. Sometimes natural sources of **radioactivity**, such as **radon** gas emitted from beneath the ground, are considered pollutants when they become a threat to human health.

- Exposure to any type of ionizing radiation can prove harmful and even lethal. The two types of effects are:
- (i) **Genetic** and (ii) **Non-genetic** or **body damage.**
- In **genetic damage,** genes and chromosomes get altered. Its effect may become visible as deformations in the offsprings (children or grandchildren). Alterations or breaks in the genetic material, that is DNA (deoxyribonucleic acid)- the molecule containing genetic information, is called **mutation**.
- In **non-genetic effects**, the harm is visible immediately in the form of birth defects, burns, some type of leukemia, miscarriages, tumors, cancer of one or more organs and fertility problems.

Effects

- **Short Range (Immediate) Effects** appear within days or a few weeks after exposure. The effects included loss of hair, nails, subcutaneous bleeding, change in number and proportion of blood cells, changed metabolism, and proportion of blood cells, etc.
- **Long Range (Delayed) Effects** appear several months or even years after the exposure. The effects are caused by development of genetic changes, mutations, shortening of life span, formation of tumour, cancers, etc. The effect of mutations can persist in the human race.

Biomedical wastes

- This waste contains material that is infectious including blood-soaked materials, scalpel blades, needles and other waste that is contaminated with body fluids or medications such as chemo drugs. Biomedical waste does not affect only humans but it also affects the environment.

Types of Bio-medical waste

- Human anatomical waste like tissues, organs and body parts.
- Animal wastes generated during research from veterinary hospitals.
- Microbiology and biotechnology wastes.
- Waste sharps like hypodermic needles, syringes, scalpels and broken glass.
- Discarded medicines and cytotoxic drugs.

- Disposal of this waste is an environmental concern, as many medical wastes are classified as *infectious* or *biohazardous* and could potentially lead to the spread of infectious disease. The most common danger for humans is the infection which also affects other living organisms in the region. Daily exposure to the waste (landfill) leads to accumulation of harmful substances or microbes in the person's body.
- **Infection** is the invasion of an organism's body tissues by disease-causing agents, their multiplication, and the reaction of host tissues to the infectious agents and the toxins they produce. **Infectious disease**, also known as transmissible disease or **communicable disease**, is illness resulting from an infection.
- Infections are caused by infectious agents including viruses, viroids,prions, bacteria, nematodes such as parasitic round worms and pin worms, arthropods such as ticks, mites, fleas, and lice, fungi such as ringworm, and other macroparasites such as tapeworms and other helminths.

E-wastes

- E-waste is any refuse created by discarded electronic devices and components as well as substances involved in their manufacture or use. The disposal of electronics is a growing problem because electronic equipment frequently contains hazardous substances.
- Roughly 40 million metric tons of electronic waste (e-waste) are produced globally each year, and about 13 percent of that weight is recycled mostly in developing countries. About 9 million tons of this waste—discarded televisions, computers, cellphones, and other electronics—are produced by the European Union, according to the United Nations Environment Programme (UNEP). And UNEP notes that this estimate of waste is likely too low.

E-wastes affects nearly every system in the human body because they contain a plethora of toxic components including **Mercury, Lead, Cadmium, Polybrominated Flame Retardants, Barium** and **Lithium**. Even the plastic casings of electronics products contain **Polyvinyl Chloride**. The health effects of these toxins on humans include birth defects, brain, heart, liver, kidney and skeletal system damage.

E-Waste Toxic Components and their Damage to Human Health

Toxic Materials	Birth Defects	Brain Damage	Heart, Liver, Lung & Spleen Damage	Kidney Damage	Nervous/ Reproductive System Damage	Skeletal System Damage
Barium		X	X			
Cadmium	X		X	X	X	X
Lead	X	X		X	X	
Lithium	X	X	X	X	X	
Mercury	X	X	X	X		
Nickel	X		X	X	X	
Palladium	X	X	X	X		
Rhodium			X			
Silver	X	X	X	X	X	

Without safe recycling, most of these toxic components will end up in land fill – poisoning the soil and water

- All these toxins are persistent, bioaccumulative toxins (PBTs) that create environmental and health risks when computers are incinerated, put in landfills or melted down.
- When computers monitors and other electronics are burned they create cancer-producing dioxins which are released into the air we breathe.
- If electronics are thrown in landfills, these toxins may leach into groundwater and affect local resources.

Bioassay for hazardous substances

- Bioassay is defined as estimation or determination of concentration or potency of physical, chemical or biological agents by means of measuring and comparing the magnitude of the response of the test with that of standard over a suitable biological system under standard set of conditions.
- A test used to evaluate the relative potency of a chemical by comparing its effect on a living organism with the effect of a standard preparation on the same type of organism. The term "bioassay" is commonly, though not technically correct, used interchangeably with the term "toxicity test".
- Static Acute Fish Toxicity Test and Acute Oral Rat Toxicity Test are the tests available.

Biosensors

- Biosensors can be classified according to their transduction principle such as optical (including optical fibre and surface plasmon resonance biosensors), electrochemical (including amperometric, and impedance biosensors), and piezoelectric (including quartz crystal microbalance biosensors) or based on their recognition element as immunosensors, aptasensors, genosensors, and enzymatic biosensors, when antibodies, aptamers, nucleic acids, and enzymes are, respectively, used.
- Biosensors including immunosensors, aptasensors, genosensors, and enzymatic biosensors have been reported for the detection and monitoring of various environmental pollutants, using antibodies, aptamers, nucleic acids, and enzymes as recognition elements, respectively.

Treatment methods

- Methods used for hazardous waste treatment includes biological treatment, neutralization, oxidation-reduction, stabilization and incineration.
- Depending on the type of waste any single method or combination of methods could be used.
- Biological waste treatment: The mean cell residence time is about 3 to 6 months.Most of the organic hazardous wastes are anthropogenic in nature and are halogenated. Such halogenated compounds are resistant to degradation. They include pesticides, plasticizers, solvents and trihalomethanes.
- These compounds are toxic, but they may be degraded by acclimatization. This can be done both in-situ and ex-situ. The microbes are involved in this process for which many enzymes were developed facilitating the degradation. Addition of nutrients is also done to enhance the degradation.

- Neutralization: The higher or lower pH could be neutralized by the addition of sulfuric ,hydrochloric acid or sodium hydroxide or calcium hydroxide respectively. The final pH of the waste must be around 6.5 to 8.5.
- Oxidation- Reduction: When the constituent of the waste is amenable to redox reaction, then this process is carried out.For example the reduction of Cr(VI) to Cr(III) using SO2 is a redox reaction.
- $3SO_2 + 3H_2O \longrightarrow 3H_2SO_3$
- $2CrO_3 + 3H_2SO_3 \longrightarrow Cr_2(SO_4)_3 + 3H_2O$
- Precipitation: This process helps in removing the insoluble product as a precipitate which could be settled or removed. Normally the precipitation involves the usage of calcium hydroxide or caustic soda to form a precipitate of metal hydroxide. For eg.,
- $M^{2+} + Ca(OH)_2 \longrightarrow M(OH)_2 + Ca^{2+}$

- Solidification and Stabilization: Inorganic wastes cannot be destroyed, but organic wastes could be incinerated. For inorganic wastes the method suggested is solidification and stabilization.
- The waste is concentrated into ash or sludge after mixing with the binding agent namely Portland cement and then it is left to get stabilized so that the constituents would not leach.