E-waste management

E-waste refers to electronic or electrical goods which can no longer be used. They may contain hazardous or toxic material which cannot be disposed with other solid waste.

Sources of e-waste:

It includes mobile phones, batteries, telephones, switch, socket, cable wires, computer hardware's,
Large household appliances like refrigerators/freezers, washing machines, dishwashers, televisions,
Small household appliances which include toasters, coffee makers, irons, hairdryers etc, and other electronic products which are not of use.

Hazards and Toxicity of E-Waste

E-waste contains hazardous substances that can harm human health and the environment if not handled properly.

Hazardous Components:

Heavy Metals:

- Lead: Found in cathode-ray tubes and solder. Causes neurological and developmental issues.
- Mercury: Present in fluorescent lamps and LCD screens. Toxic to the nervous system.
- Cadmium: Found in batteries and semiconductors. Causes kidney damage and is carcinogenic.

Plastics:

- Non-biodegradable plastics release harmful gases like dioxins when burned.

Other Toxins:

- Polychlorinated biphenyls (PCBs) and phthalates in old electronics can disrupt hormones and cause cancer.

Health Impacts:

- E-waste can be toxic, contains various types of toxic metals (lead, mercury, nickel, cadmium, lithium etc.), which can get accumulated in the environment, in the soil, air, water. This can cause a long-term damage to the environment. Humans rely on air to breathe, so when that air fills with toxins, it can affect a person's respiratory system.

- The improper disposal of lead acid batteries and alkaline batteries also causes contamination of toxic chemicals with the soil and water. Lead may get into the blood, kidneys and even the nervous system and can show adverse effects.
- When a pregnant woman is exposed to such harmful substances, it can affect the development and health of her unborn child. Adverse health effects to the child include stillbirth, premature birth and low birth weight.

Environmental Impacts:

- Soil and water contamination from leached heavy metals and chemicals.
- Air pollution from burning plastics and improper disposal.
- Bioaccumulation of toxins in the food chain.

Segregation and Recycling of E-Waste

E-waste (electronic waste) includes discarded electronic devices like computers, mobile phones, and appliances. Effective recycling of e-waste is essential to recover valuable materials, reduce environmental harm, and promote sustainability. The process involves segregation followed by recycling using techniques such as hydrometallurgy, pyrometallurgy, and direct recycling.

1. Segregation of E-Waste

Segregation is the first and most critical step in e-waste recycling. It separates different materials to improve recycling efficiency and ensure hazardous substances are managed safely.

Steps in Segregation:

1. Manual Sorting: Handpicking materials like plastic, glass, and metals.

2. Magnetic Separation: Using magnets to extract ferrous metals.

3. Eddy Current Separation: Removing non-ferrous metals (e.g., aluminium, copper). [Eddy Current Separation (ECS) is a non-ferrous metal separation technique used primarily in recycling to recover materials like aluminium, copper, and other conductive metals from a mixture of waste. It relies on the principles of electromagnetic induction to separate metals from non-metallic materials].

4. Density-Based Separation: Using air or water to separate materials by weight.

5. Chemical Analysis: Identifying precious metals like gold, silver, and palladium in printed circuit boards (PCBs).

2. Recycling Techniques

(a) Hydrometallurgy
Hydrometallurgy is a chemical-based process that uses aqueous solutions to extract metals from e-waste.

Detailed Steps:

Leaching:
Metals such as gold, silver, copper, and palladium are dissolved from e-waste components like PCBs using chemical agents such as:

- Cyanide: Commonly used for gold and silver recovery.

- Aqua Regia: A mixture of nitric acid and hydrochloric acid, effective for dissolving precious metals.

- Thiourea or Thiosulfate: Environmentally friendly alternatives to cyanide.

This process selectively targets metals while leaving other materials relatively intact.

Solution Purification:
Impurities are removed from the leachate using techniques such as:

- Precipitation: Adding chemicals to form insoluble compounds that can be filtered out.

- Solvent Extraction: Separating desired metals into an organic phase for further processing.

- Ion Exchange: Using resin to capture specific metal ions from the solution.

Metal Recovery:
Extracted metals are recovered in pure form through:

- Electrowinning: Applying an electric current to deposit metals onto electrodes.

- Chemical Reduction: Adding reducing agents to precipitate metals from the solution.

Advantages:

1. High recovery efficiency for precious and base metals.
2. Operates at relatively low temperatures, saving energy.
3. Versatile for processing various types of e-waste.

Challenges:

1. Use of toxic chemicals like cyanide and aqua regia requires strict safety measures and proper disposal protocols.
2. The process can be time-consuming and requires precise control of chemical conditions.
3. Management of chemical waste is essential to prevent environmental harm.

Applications:

1. Recovering gold, silver, platinum, and palladium from printed circuit boards and connectors.
2. Extracting base metals like copper and nickel from e-waste components.
3. Recycling lithium-ion batteries to recover cobalt, lithium, and manganese.

(b) Pyrometallurgy
Pyrometallurgy involves using high temperatures to extract metals from e-waste. It is particularly suitable for bulk processing and materials that are difficult to separate using other methods.

Detailed Steps are:

1. Pre-Treatment:

- E-waste is shredded or crushed to reduce its size and increase surface area for processing.

- Hazardous components such as batteries or capacitors may be removed to prevent explosions or toxic releases during heating.

2. Smelting:
- The shredded e-waste is subjected to high temperatures in a furnace (800–1,200°C).

3. Refining:
- Removing impurities from the molten metal.

4. Gas Treatment:
- Emissions generated during smelting (e.g., dioxins, furans, and heavy metal vapors) are captured and further treat these emissions to minimize environmental harm.

Advantages:
- Efficient for processing large volumes of e-waste.
- Recovers metals that are difficult to extract using other methods, such as copper, nickel, and zinc.
- Capable of processing mixed and contaminated materials.

Challenges:
- High energy consumption.
- Releases harmful gases if not properly managed.

Applications:
- Recycling bulk metals like copper, aluminum, and lead from e-waste.
- Recovering precious metals such as gold and silver.

(c) Direct Recycling

Direct recycling involves reusing materials or components with minimal processing. This method is energy-efficient and prioritizes preserving the integrity of the original materials or components.

Detailed Steps:

1. **Disassembly and Inspection:**
   Devices are manually or mechanically disassembled to recover usable parts.
   Components are inspected to determine functionality and potential for reuse.

2. **Cleaning and Refurbishment:**
   Recovered components are cleaned to remove dust, debris, or residues.
   Damaged components are repaired

3. **Reintegration:**
   Refurbished components are reintegrated into new or existing devices.
   Usable raw materials (e.g., plastic casings, wiring) are processed for manufacturing new products.

Advantages:
- Energy-efficient and cost-effective.
- Preserves the original material properties.

Challenges:

- Limited to uncontaminated or minimally damaged components.
- Not suitable for components that have degraded significantly or are highly integrated.

Applications:

- Refurbishing old devices for resale.
- Recycling lithium-ion batteries by reusing electrode materials.

Extraction of gold from E-waste:

E-waste can often comprise of several hazardous components which can include heavy metals like mercury and lead. Despite this reality, gold, as well as other precious metals, also make up a significant amount of e-waste, and its extraction could have advantageous properties for the gold industry.

The extraction of gold is done from e-waste using Hydrometallurgy method.

Prior treatment:

Prior to the Hydrometallurgy method, physical treatments such as sorting, dismantling and size reduction are performed to produce granular form of the waste material.

Hydrometallurgy method:

There are certain metals such as copper (Cu), silver (Ag) and gold (Au) are extracted by dissolving the concentrated e-waste in some suitable reagent and then rescuing the metal from the solution by treatment with some more electropositive metal.

The use of cyanide in gold leaching has been a useful, but dangerous technique of metal extraction.

This extraction process involves the chemical reaction between the pulverized e-waste and sodium cyanide, which produces a soluble gold cyanide solution that allows for easier extraction of the precious metal.

$$4\,Au + 8NaCN + 2H_2O \text{ --------> } 4Na[Au(CN)_2] + 4NaOH$$

Then the solution containing Gold cyanide complex is treated with zinc powder.

As zinc is more electropositive than Au, it results in the precipitation of pure Au.

$$2Na[Au(CN)_2] + Zn \text{ --------> } Na_2[Zn(CN)_4] + 2Au$$