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Environmental Studies — Revision Notes

UNIT III

E-Waste Management and Acts

Topics Covered

E-Waste — Composition and Generation
Global Context of E-Waste
E-Waste Pollutants and Hazardous Properties
Effects of E-Waste Pollutants on Human Health and Environment
Domestic E-Waste Disposal
Basic Principles of E-Waste Management
Technologies for Resource Recovery from E-Waste
Recycling Steps — Mechanical Processing & Recovery Technologies
Occupational and Environmental Health Perspectives (India)

Prepared for S.E. Engineering Students (SPPU 2024 Pattern)

A. E-Waste — Meaning, Composition and Generation

1. Meaning of E-Waste

E-waste (Electronic Waste) refers to discarded, obsolete, broken, or end-of-life electrical and electronic equipment, including their components, that are no longer useful to their original owner. It includes items ranging from large household appliances to small gadgets.

> ***Easy Definition:***
> *E-Waste = Any electrical or electronic device that has been thrown away, is no longer working, or is no longer wanted by the user, including its parts and accessories.*

2. Examples / Categories of E-Waste

- **1. Large Household Appliances:** Refrigerators, washing machines, air conditioners, microwave ovens.
- **2. Small Household Appliances:** Toasters, irons, hair dryers, vacuum cleaners.
- **3. IT & Telecom Equipment:** Computers, laptops, printers, mobile phones, routers.
- **4. Consumer Electronics:** Televisions, radios, music systems, cameras.
- **5. Lighting Equipment:** CFL bulbs, tube lights, LED fixtures.
- **6. Electrical/Electronic Tools:** Drilling machines, sewing machines (electric).
- **7. Toys and Leisure Equipment:** Electronic toys, gaming consoles.
- **8. Medical Equipment:** ECG machines, X-ray equipment (excluding implanted/infected products).
- **9. Automatic Dispensers:** Vending machines, ATMs.

3. Composition of E-Waste

E-waste is a complex mixture of valuable, reusable and hazardous materials. Its rough composition is as follows:

Material Category	Approx. % in E-Waste	Examples
Metals (Ferrous & Non-ferrous)	60%	Iron, copper, aluminium, gold, silver
Plastics	30%	Casings, wires, circuit boards
Hazardous substances	2-3%	Lead, mercury, cadmium, chromium
Glass & Ceramics	5-8%	CRT monitors, screens

Material Category	Approx. % in E-Waste	Examples
Others	Remaining	Wood, rubber, paper components

In simple words: E-waste contains valuable metals (which can be recycled and reused) along with toxic substances (which are dangerous to health and environment if not handled properly).

4. Generation of E-Waste

E-waste is generated mainly due to the following reasons:

- **1. Rapid Technological Advancement:** Frequent launch of new electronic models makes older devices obsolete quickly.
- **2. Short Product Life Span:** Modern electronics are designed with a limited working life, increasing replacement frequency.
- **3. Increasing Consumerism:** Growing demand for the latest gadgets (phones, laptops, TVs) increases the rate of disposal of old ones.
- **4. Population and Income Growth:** More people can now afford electronic devices, increasing overall consumption and waste generation.
- **5. Corporate and Institutional Upgradation:** Offices, schools and industries regularly replace computers and equipment with newer technology.
- **6. Import of Used Electronics:** Import of second-hand or end-of-life electronic goods from developed countries adds to e-waste generation in developing nations.

B. Global Context of E-Waste

1. E-Waste — A Global Problem

E-waste is one of the fastest-growing waste streams in the world, due to increasing use of electronic devices across all countries. It is a global problem because it affects health, environment and economy at an international scale.

2. Global E-Waste Statistics (General Trend)

- The world generates tens of millions of tonnes of e-waste every year, and this amount keeps rising due to growing electronics consumption
- Only a small fraction of global e-waste is formally collected and recycled in an environmentally sound manner; the majority is handled informally
- Developed countries (USA, European nations) generate the highest e-waste per person, while developing countries like India and China generate large e-waste due to high population
- Asia is currently the largest e-waste generating continent in terms of total volume

3. Trans-boundary Movement of E-Waste

A major global issue is the export of e-waste from developed countries to developing countries (like India, China, Nigeria, Ghana) — often illegally — for cheap, informal recycling.

- **Reason:** Developed countries have strict environmental regulations and high labour costs, making it expensive to recycle e-waste locally.
- **Effect:** Developing countries face severe pollution and health hazards due to unscientific, informal recycling methods used to extract metals from imported e-waste.

4. International Efforts to Control E-Waste

- **1. Basel Convention (1989):** An international treaty that controls the trans-boundary movement of hazardous waste, including e-waste, between countries.
- **2. Extended Producer Responsibility (EPR):** A global principle adopted by many countries making manufacturers responsible for the safe disposal/recycling of their products after the consumer discards them.
- **3. WEEE Directive (Europe):** Waste Electrical and Electronic Equipment Directive of the European Union, which sets collection, recycling and recovery targets for e-waste.
- **4. Global E-waste Monitor:** A periodic report published by international organizations (UN agencies) tracking global e-waste generation, recycling rates and policy progress.

Key Point:

E-waste is a global issue because of international trade in used electronics, but its actual impact (pollution and health hazards) is mostly felt locally in developing countries where informal recycling takes place.

C. E-Waste Pollutants and Hazardous Properties

1. Meaning of E-Waste Pollutants

E-waste pollutants are the toxic and hazardous substances present inside electronic equipment, which get released into the environment when e-waste is improperly handled, dismantled, or disposed of.

2. Major E-Waste Pollutants and Their Sources

Pollutant	Found In	Hazardous Property
Lead (Pb)	CRT monitors, solder in circuit boards	Damages nervous system, kidneys, brain
Mercury (Hg)	Switches, flat screen displays, batteries	Damages brain, kidneys; highly toxic
Cadmium (Cd)	Batteries, circuit boards, semiconductors	Causes kidney damage, bone disease
Chromium (Cr)	Metal coatings, corrosion-resistant parts	Causes skin/respiratory issues, carcinogenic
Brominated Flame Retardants (BFRs)	Plastic casings, circuit boards, cables	Disrupts hormones, possible carcinogen
Beryllium (Be)	Motherboards, connectors	Causes lung disease (berylliosis), cancer
Arsenic	Older CRT monitors	Toxic, carcinogenic
PVC Plastics	Wires, cable insulation	Releases dioxins/furans when burnt

3. Hazardous Properties of E-Waste

- **1. Toxicity:** Many components contain heavy metals and chemicals that are poisonous even in small quantities.
- **2. Non-biodegradability:** Most e-waste materials (plastics, metals) do not decompose naturally and persist in the environment for a long time.
- **3. Bioaccumulation:** Toxic substances accumulate in living tissues over time and increase in concentration as they move up the food chain.
- **4. Carcinogenicity:** Several substances found in e-waste (chromium, beryllium, BFRs) are known to cause cancer.

- **5. Flammability/Reactivity:** Certain components like batteries can catch fire or explode if damaged or improperly disposed of.
- **6. Leachability:** Hazardous substances can leach out from e-waste dumped in landfills and contaminate soil and groundwater.

D. Effects of E-Waste Pollutants on Human Health and Environment

1. Effects on Human Health

- **1. Neurological Damage:** Lead and mercury exposure damages the brain and nervous system, especially harmful for children (affects IQ and development).
- **2. Respiratory Problems:** Burning of e-waste (to extract metals) releases toxic fumes causing asthma, bronchitis and lung damage.
- **3. Kidney Damage:** Cadmium and lead exposure can severely damage kidney function over time.
- **4. Cancer:** Long-term exposure to carcinogenic substances (chromium, beryllium, dioxins) increases the risk of various cancers.
- **5. Skin and Eye Irritation:** Direct contact with chemicals during informal dismantling causes skin diseases and eye problems.
- **6. Reproductive Issues:** Certain e-waste chemicals (BFRs) act as hormone disruptors, affecting reproductive health and causing birth defects.
- **7. Effect on Workers:** Informal e-waste workers (including child labourers in many cases) who manually dismantle and burn e-waste without protection suffer the highest health risks.

2. Effects on Environment

- **1. Soil Contamination:** Toxic metals leach into soil from improperly dumped e-waste, reducing soil fertility and contaminating crops.
- **2. Water Pollution:** Heavy metals and chemicals seep into groundwater and surface water, making it unsafe for drinking and irrigation.
- **3. Air Pollution:** Open burning of wires and plastic to recover metals releases toxic gases, dioxins and particulate matter into the air.
- **4. Harm to Wildlife:** Toxic substances entering soil and water affect plants, animals and aquatic organisms, disturbing the ecosystem.
- **5. Bioaccumulation in Food Chain:** Toxins absorbed by plants and small organisms accumulate as they move up the food chain, eventually affecting humans through food.
- **6. Loss of Land Value:** Areas used as informal e-waste dumping/recycling sites become heavily contaminated and unusable for years.

> ***Key Point:***
> *Children and informal e-waste workers are the most vulnerable groups, as they are directly exposed to toxic substances during unsafe handling, burning, and dismantling of e-waste.*

E. Domestic E-Waste Disposal

1. Meaning

Domestic e-waste disposal refers to the methods used by households to get rid of old or broken electronic and electrical items such as mobile phones, chargers, batteries, bulbs, and small appliances.

2. Common (Improper) Disposal Practices

- Throwing e-waste along with regular household garbage
- Storing old gadgets at home for years without proper disposal
- Selling to informal local scrap dealers (kabadiwalas) who use unsafe recycling methods
- Burning e-waste to recover metals at small unorganized scale
- Dumping in open land, drains, or water bodies

3. Correct/Recommended Methods of Domestic E-Waste Disposal

- **1. Authorized Collection Centres:** Hand over e-waste to government-authorized collection centres or recyclers.
- **2. Producer Take-back Schemes:** Many manufacturers/brands offer take-back or exchange schemes for old electronics under Extended Producer Responsibility (EPR).
- **3. E-Waste Collection Drives:** Participate in e-waste collection camps organized by municipal corporations, NGOs, or RWAs (Resident Welfare Associations).
- **4. Selling to Authorized Recyclers:** Sell old gadgets only to government-registered/authorized e-waste recyclers, not informal scrap dealers.
- **5. Donation/Reuse:** Donate working but unused electronics to schools, NGOs or needy people instead of discarding them.
- **6. Battery and Bulb Disposal:** Dispose of batteries and CFL/tube lights separately at designated collection points, as they contain hazardous materials (mercury, cadmium).

> ***Easy Tip to Remember:***
> *Before throwing any electronic item, always think: Can I Reuse it? Can I Donate it? If not, give it to an Authorized Recycler — never throw it with normal household garbage.*

F. Basic Principles of E-Waste Management

Effective e-waste management is built upon a few core principles, which guide how electronic waste should be collected, processed, and disposed of safely:

- **1. Extended Producer Responsibility (EPR):** Manufacturers are made responsible for the entire life cycle of their products, including collection and environmentally sound disposal after use.
- **2. 3R Principle (Reduce, Reuse, Recycle):** Reduce e-waste generation, reuse working devices/parts wherever possible, and recycle materials that cannot be reused.
- **3. Source Segregation:** E-waste should be separated from regular household/municipal waste at the point of disposal itself.
- **4. Safe Collection and Transportation:** E-waste must be collected and transported using proper methods to prevent leakage of hazardous substances.
- **5. Authorized/Formal Recycling:** Processing should be done only by registered and authorized recyclers using scientific methods, not informal/unsafe methods.
- **6. Resource Recovery:** Maximum recovery of valuable materials (metals like gold, copper, silver) from e-waste should be promoted to reduce dependence on virgin resources.
- **7. Safe Disposal of Hazardous Residue:** Non-recoverable hazardous components must be disposed of in scientifically designed hazardous waste landfills.
- **8. Public Awareness and Participation:** Citizens must be educated about correct e-waste disposal methods to ensure cooperation and compliance.
- **9. Polluter Pays Principle:** Those responsible for generating pollution (producers/bulk consumers) should bear the cost of managing and treating the waste.
- **10. Regulatory Compliance:** All stakeholders (producers, dealers, recyclers, consumers) must follow government rules such as the E-Waste (Management) Rules.

G. Technologies for Recovery of Resources from E-Waste

1. Why Resource Recovery is Important

E-waste contains valuable metals like gold, silver, copper, palladium and aluminium. Recovering these resources reduces the need for mining new raw materials, saves energy, and reduces environmental damage.

> ***Did You Know?***
> *E-waste is sometimes called "urban mining" because old electronics contain a higher concentration of precious metals like gold than natural ore mined from the earth.*

2. Resource Recovery Potential of E-Waste

E-waste is a rich secondary source of valuable materials:

- **Precious Metals:** Gold, silver, and palladium found in circuit boards and connectors — used in jewellery and electronics industries.
- **Base Metals:** Copper, aluminium and iron, widely used in wires, casing, and structural parts — recyclable for industrial use.
- **Rare Earth Elements:** Found in small quantities in magnets, batteries, and screens — important for new electronics manufacturing.
- **Plastics:** Can be recovered and reused for manufacturing new plastic products after proper segregation and processing.
- **Glass:** From CRT monitors and screens, can be recycled into new glass products.

3. Technologies Used for Resource Recovery

- **1. Manual Dismantling:** Basic separation of components (screws, casings, circuit boards, batteries) done by hand; usually the first step in both formal and informal recycling.
- **2. Mechanical Processing:** Use of shredders and crushers to break e-waste into smaller pieces, followed by separation technologies (explained in detail in next section).
- **3. Pyrometallurgical Process:** High-temperature smelting process used to extract metals like copper and precious metals from circuit boards; effective but can release harmful emissions if not controlled properly.
- **4. Hydrometallurgical Process:** Uses chemical solutions (acids) to dissolve and extract metals from e-waste components; provides high purity metal recovery with lower energy use than pyrometallurgy.
- **5. Bio-metallurgical Process (Bioleaching):** Uses microorganisms (bacteria/fungi) to extract metals from e-waste in an eco-friendly way; an emerging, low-pollution technology.

- **6. Electrochemical Processing:** Uses electric current to separate and recover metals from e-waste solutions with high precision.

H. Steps in Recycling and Recovery of Materials

1. Mechanical Processing — Step-by-Step

Mechanical processing is usually the first stage of formal e-waste recycling, used to physically break down and separate materials before chemical/thermal recovery methods are applied.

1. Collection and Sorting: E-waste is collected from various sources and sorted by category (mobile, computer, TV, battery, etc.)
2. Manual Dismantling: Hazardous components (batteries, CFC-containing parts, mercury switches) are manually removed first for safe separate handling
1. Shredding: Remaining e-waste is fed into industrial shredders that break it into small fragments
2. Size Reduction/Crushing: Shredded material is further crushed into smaller, uniform-sized particles for easier separation
3. Magnetic Separation: Strong magnets are used to separate ferrous metals (iron, steel) from the crushed mixture
4. Eddy Current Separation: Non-ferrous metals (aluminium, copper) are separated using an eddy current separator, which uses a magnetic field to repel non-ferrous metals
5. Density/Air Separation: Lighter materials like plastics are separated from heavier metals using air classifiers based on density difference
6. Optical/Sensor Sorting: Advanced sensors and optical sorters identify and separate different types of plastics and materials based on colour/composition
7. Final Refining: Separated metal fractions undergo further purification (smelting/chemical refining) to obtain pure recoverable metals

2. Technologies for Recovery of Materials (Summary)

Technology	Purpose	Materials Recovered
Shredding & Crushing	Size reduction of e-waste	Mixed fragments for further sorting
Magnetic Separation	Separates ferrous metals	Iron, steel
Eddy Current Separation	Separates non-ferrous metals	Aluminium, copper
Air/Density Separation	Separates light materials	Plastics, foam
Pyrometallurgy	High-temperature smelting	Copper, gold, silver
Hydrometallurgy	Chemical leaching	Precious & base metals
Bioleaching	Microbial extraction	Copper, gold (eco-friendly)

Key Point:
Mechanical processing alone can recover bulk metals like iron, copper and aluminium, but precious metals (gold, silver, palladium) require advanced chemical or thermal methods like hydrometallurgy or pyrometallurgy for complete extraction.

I. Occupational and Environmental Health Perspectives of Recycling E-Waste in India

1. E-Waste Recycling Scenario in India

India is among the largest e-waste generating countries in the world. A major portion of e-waste recycling in India is still handled by the informal sector, which uses unsafe and unscientific methods, posing serious health and environmental risks.

2. Informal Sector Practices in India

- Open burning of cables and wires to recover copper
- Acid leaching (using strong acids in open containers) to extract precious metals from circuit boards
- Manual dismantling without protective equipment (gloves, masks)
- Dumping of non-recoverable hazardous residues in open land or water bodies
- Employment of unskilled workers, including in some cases children, in hazardous recycling tasks

3. Occupational Health Hazards for Workers

- **1. Respiratory Diseases:** Inhaling toxic fumes from burning plastics and wires causes chronic bronchitis, asthma, and lung damage.
- **2. Skin Diseases:** Direct contact with acids and chemicals during metal extraction causes burns, rashes, and dermatitis.
- **3. Heavy Metal Poisoning:** Continuous exposure to lead, mercury and cadmium causes long-term neurological and kidney damage in workers.
- **4. Musculoskeletal Disorders:** Manual handling and repetitive dismantling work causes back pain and joint problems.
- **5. Cancer Risk:** Long-term exposure to carcinogenic substances increases cancer risk among informal workers.
- **6. Child Labour Concerns:** In some informal recycling clusters, children are employed, exposing them to serious health risks at a vulnerable age.

4. Environmental Health Impact in India

- **1. Contaminated Recycling Hotspots:** Informal e-waste recycling clusters (in cities like Delhi, Moradabad) show heavily contaminated soil and water with heavy metals.
- **2. Groundwater Pollution:** Acid leaching and dumping practices contaminate groundwater used by nearby communities.

- **3. Air Quality Deterioration:** Open burning releases toxic smoke affecting air quality in and around recycling areas.
- **4. Impact on Local Communities:** People living near informal recycling sites (not just workers) also suffer health effects due to environmental contamination.

5. Regulatory Framework — E-Waste (Management) Rules, India

India has notified the E-Waste (Management) Rules to regulate e-waste handling and promote formal, safe recycling practices.

8. Makes Extended Producer Responsibility (EPR) mandatory for manufacturers to collect and recycle a target percentage of e-waste
9. Requires e-waste to be handled only by registered dismantlers and recyclers
10. Prohibits manual dismantling of certain hazardous components without proper safety measures
11. Sets collection targets for producers based on the quantity of products sold
12. Mandates proper labelling and information disclosure on hazardous substances in electronic products
13. Provides for penalties on non-compliance by producers, dealers, and recyclers

6. Way Forward / Improvement Measures

- Formalizing the informal recycling sector by providing training, safety equipment, and registration support
- Strengthening enforcement of E-Waste Management Rules and EPR targets
- Increasing number of authorized collection centres and formal recycling facilities
- Raising public awareness about safe disposal practices and dangers of informal recycling
- Promoting adoption of cleaner technologies (hydrometallurgy, bioleaching) over hazardous open burning/acid leaching methods
- Providing regular health check-ups and protective equipment for workers involved in e-waste recycling

> ***Key Takeaway:***
> *India's e-waste challenge is not just about waste management — it is equally an occupational health and human rights issue, since millions of informal workers (including vulnerable groups) face serious health risks due to unsafe recycling practices.*

— End of Unit III —