



‘E’ Waste: Challenges For Pollution Free Sustainable Development

Renu Rastogi

Professor

Department of Chemistry

Brahmanand P.G. College, Kanpur, India

Abstract : The information technology has revolutionized the way we live, work and communicate bringing countless benefits and wealth to all its users. The creation of innovative and new technologies and the globalization of the economy have made a whole range of products available and affordable to the people changing their lifestyles significantly. The onset of technological advancement of electrical and electronic appliances is so rapid that new products quickly replace existing models or make certain items of electronic equipment redundant, useless or nonfunctioning, thereby generating a constant source of e-waste generation. Unfortunately, electronic discards are one of the fastest growing segments of our nation's waste stream. E Waste contain toxic substances and non-biodegradable and accumulates in the environment, in the soil, air, water and living things. Improper disposal of e-waste is unbelievably dangerous to the global environment, which is why it is so important to spread awareness on this growing problem and the threatening aftermath. To avoid these toxic effects of e-waste, it is crucial to properly re-cycle, so that items can be recycled, refurbished, resold, or reused.

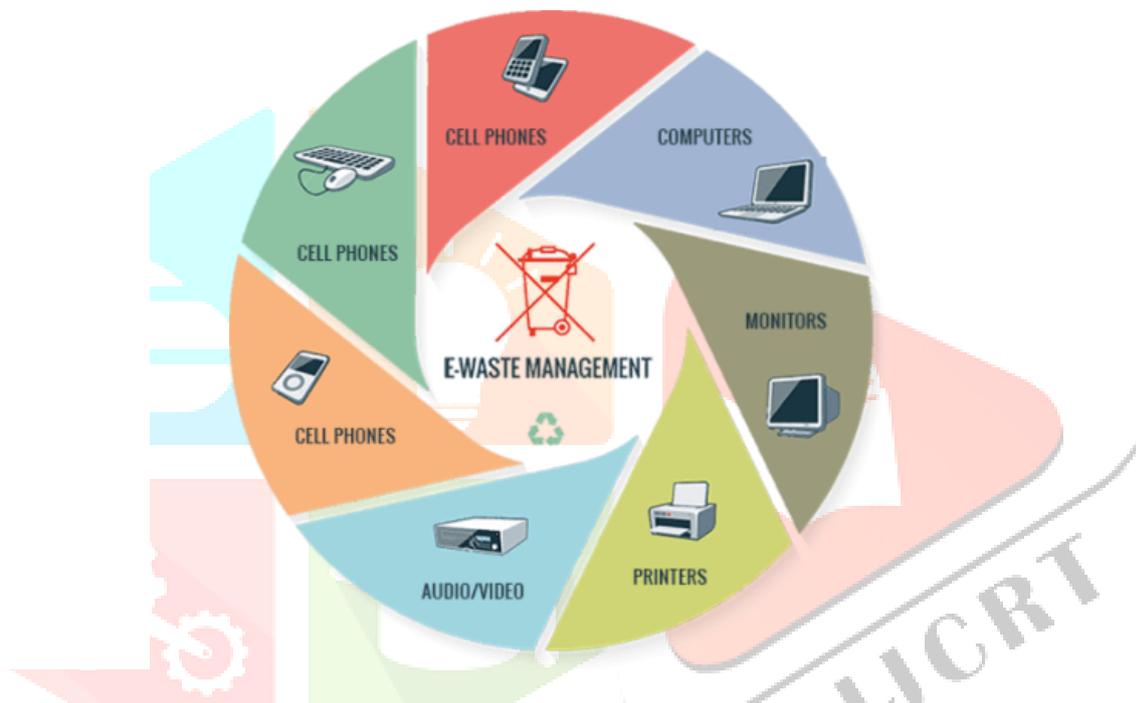
Index Terms: Pollution, E Waste, Sustainable development.

LINTRODUCTION

The ever-growing dependence on electronic products has paved the way for an emerging environment concern ,called electronic waste means electronic gadgets that have broken down in such a way that they cannot be repaired and the only option would be that of throwing them away the way other waste is discarded(1). Increasing disposable income, changing lifestyle, rapid economic growth coupled with urbanization is responsible for the increasing demand of electrical and electronic equipment which in turn increases the manufacturing activities related to electrical and electronic equipment. Undoubtedly, the manufacturing of electrical and electronic equipment is one of the fastest manufacturing activities these days .

New electronic products have become an integral part of our daily lives providing us with more comfort, security, easy and faster acquisition and exchange of information. The rapid growth of technology, upgradation of technical innovations and a high rate of obsolescence in the electronics industry have led to one of the fastest growing waste streams in the world .It comprises a whole range of electrical and electronic items such as refrigerators, washing machines, computers and printers, televisions, mobiles, I-pods, etc., many of which contain toxic materials and obsolescence of these items is termed as ‘technological waste’ or ‘e-waste’ or ‘waste from electrical and electronic equipment (WEEE)’(2). E waste has become a problem of crisis proportions because of two reasons. Firstly ,E waste is hazardous as the vast number of computers, televisions, mobile phones and other electronic products that are disposed of every year all contain a variety

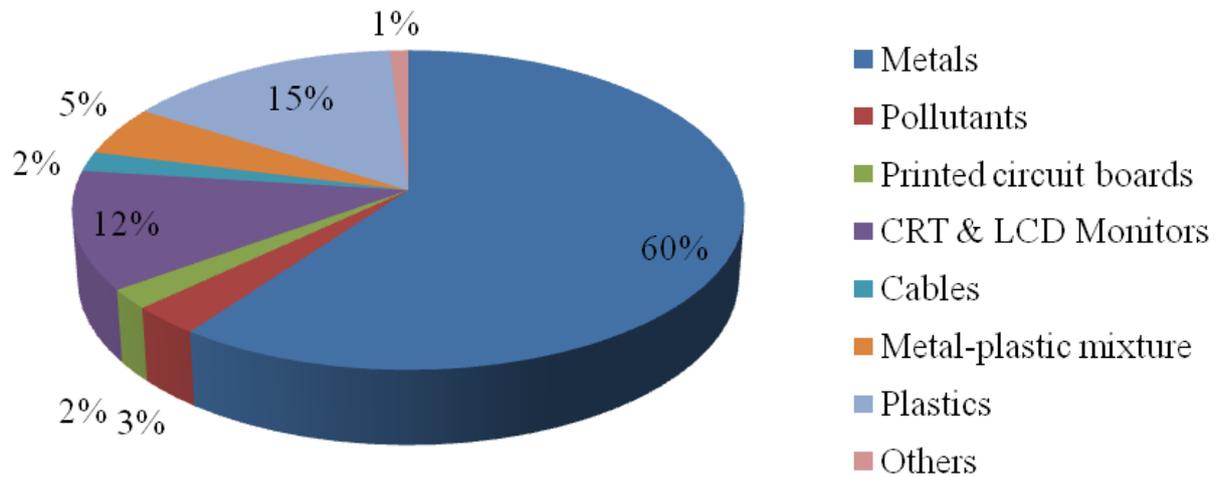
of toxic substances(3). These wastes can be classified into 26 common categories and contain more than 1,000 diverse toxic substances including heavy metals and organics, which pose adverse effects to human health and ecosystems due to improper handling and disposal(4,5). When discarded electronics is dumped in landfills, or when the waste is incinerated, contaminants and toxic chemicals are generated and released into the ground or air risking pollution of the environment and toxins entering the food chain are astronomical. Another reason is E waste being generated at an alarming rate, due to fast obsolescence along with rapidly evolving technology. Developing countries and those in transition are gradually being affected by this imminent toxic threat from e-waste because of their rapid movement towards technological development without the accompanying procedures, policies and infrastructure to deal effectively with the waste(6) . In these circumstances, both recently produced and used electrical and electronic equipment (UEEE) are being consigned from their parent producers from high-income countries to low-income countries(7,8). In this case, some Asian and African developing countries, particularly India, Bangladesh, Pakistan, China, Sri Lanka, the Philippines, Benin, Ghana, the Ivory Coast, Nigeria and Liberia are the most common destinations for dumping(9).



II. CONSTITUENTS OF E WASTE :

E-waste is a unique category of waste. Along with hazardous materials, it also contains precious substances like silver, gold, platinum, palladium, nickel and copper. In general, the electronic gadgets are classified under three major heads:

- White goods: Refrigerators and household appliances such as cables, bulbs, washing machines, dryers, AC units, vacuum cleaners, coffee machines, water heaters, toasters, irons etc.
- Brown goods: TVs, computer monitors, radios, routers, calculators, GPS devices, camcorders, cameras etc.
- Grey goods: Information and communication products such as PCs, mobile phones, printers, fax machines, photocopiers, pen drives, etc.



Concerning global data on e-waste

- 20 to 50 million metric tons of e-waste are disposed of worldwide every year
- Cell phones and other electronic items contain high amounts of precious metals like gold or silver.
- A large number of what is labelled as “e-waste” is not waste at all, but rather whole electronic equipment or parts that are readily marketable for reuse or can be recycled for materials recovery.
- Only 12.5% of e-waste is currently recycled.
- E-waste leads to data theft hence adding to security woes.

III. HARMFUL EFFECTS OF E WASTE

E waste builds up in the environment, in the soil, air, water, and living things. It also contains toxic and non-biodegradable materials. Toxic materials leak into the environment, for instance, when open-air burning and acid baths are used to recover valuable materials from electronic components. The incorrect handling of e-waste is leading to a significant loss of rare and valuable raw materials, including precious metals like neodymium (essential for magnets in motors), indium (used in flat panel TVs), and cobalt (for batteries), according to the joint report "A New Circular Vision for Electronics – Time for a Global Reboot" 2019. Seldom are rare earth minerals recovered from unofficial recycling because their mining is environmentally harmful. However, it can be challenging to extract metals from e-waste; for instance, cobalt recovery rates are only 30%, even with technology that could recycle 95% of it. Nonetheless, there is a high demand for the metal in batteries for electric cars, laptops, and smartphones. Additionally, compared to metals smelted from virgin ore, recycled metals have an energy efficiency of two to ten times. In addition, mining abandoned electronics results in 80% lower carbon dioxide emissions per unit of gold than mining it from the ground. The consequences of incorrectly disposing of e-waste in landfills or other non-dumping locations can seriously jeopardise public health today and contaminate ecosystems for future generations(9). When electronics are improperly disposed of and end up in landfills, toxic chemicals are released, impacting the earth’s air, soil, water, and ultimately, human health. therefore, they must be handled with care when no longer wanted or needed.

Effects on Air quality:

When electronic waste is disposed of and recycled, numerous hazardous gases are released into the atmosphere. The air becomes more contaminated and polluted as a result of the release of these dangerous gases. All living things can get respiratory diseases from breathing in such contaminated air. When e-waste is disposed of improperly—by disassembling, shredding, or melting the components—dust particles or toxins—like dioxins—are released into the atmosphere, causing air pollution and harming respiratory health. People in need rummage through landfills in various parts of the world in an attempt to salvage electronic waste for cash. However, some of these individuals burn undesirable components, such as wires, to extract copper, which can result in both Burning e-waste also releases fine particles that can travel thousands of miles and pose numerous health risks to both humans and animals, increasing the risk of cancer and chronic diseases.

The people who handle this waste are most at risk from the harmful air effects of informal e-waste recycling, but the pollution can spread thousands of miles from recycling locations. When e-waste is dumped at a landfill, it is typically burned in on-site incinerators. This process can release hydrocarbons in the atmosphere, which pollutes the air that many animals and humans rely on. Furthermore, these hydrocarbons can contribute to the greenhouse gas effect, which many scientists think is a leading contributor to global warming(10).

Effects on Soil:

E-waste treatment and processing is typically a costly undertaking, and space becomes a major issue. At approximately 40 million tonnes annually, e-waste is currently the waste stream with the fastest rate of growth in the world. Unresponsible dumping e-waste can have a negative impact on soil fertility. Because heavy metals seep into soil and water, it can also make water unsafe to drink(11). Elevated levels of heavy metals have an adverse effect on the microbial population in the soil, which has a negative impact on soil fertility. When recyclable material is recovered or leftover e-waste is burned in the open, heavy metals are released. This contaminates the water, land, and air. Thus, discharged into the soil, heavy metals are absorbed by plants through their roots and eventually build up in human tissues(12). Research has indicated that the use of both treated and untreated wastewater for irrigation can result in the build-up of Cd and Pb in the edible parts of vegetables, which can pose health risks if ingested over an extended period of time(13)(14). Unrecoverable heavy metals and leftover auxiliary substances, such as cyanide and mercury, can permeate the soil and combine to form inorganic and organic complexes(15) (16). Heavy metal consumption alters the composition of blood and has a negative impact on vital organs like the liver and kidneys. Long-term exposure to these metals may also result in neurological, musculoskeletal, and physical degenerative processes that lead to multiple sclerosis, Alzheimer's disease, Parkinson's disease, and muscular dystrophy. By carefully measuring the number of metals and metalloids that enter the human food chain, the risk of metal-contaminated soils can be estimated(17). Metals connected to acid mine drainage (AMD) have an effect on human health and aquatic ecosystems in mountainous areas where hard rock mines are located. Heavy metals and flame retardants can seep directly from e-waste into the soil when it is improperly disposed of in regular landfills or in locations where it is illegally disposed of.

Effects on Water

Heavy metals from e-waste, including mercury, lithium, lead, and barium, seep further into the earth and end up in groundwater after contaminating the soil. These heavy metals eventually find their way into lakes, rivers, ponds, and streams after they enter groundwater(18). These channels cause the water to become poisonous and acidic, endangering communities, plants, and animals even when they are far from recycling facilities. Finding clean drinking water becomes difficult. Acidification has the potential to destroy ecosystems, disrupt biodiversity, and kill both freshwater and marine life. Ecosystems may be harmed if water supplies exhibit acidification(19).

Effects on Humans

Toxic substances that are harmful to human health can be found in electronic waste, including barium, lithium, polybrominated flame retardants, lead, mercury, and cadmium. These poisons harm the skeletal system, liver, kidney, heart, brain, and other parts of the human body. It can also have a significant impact on the human body's neurological and reproductive systems, which can result in illness and birth abnormalities(20).

E-waste sources	Constituents	Health effects
Solder in printed circuit boards, glass panels, and gaskets in computer monitors	Lead	Damage to central and peripheral nervous systems, blood systems, and kidney damage Adverse effects on brain development of children; causes damage to the circulatory system and kidney
Chip resistors and semi-conductors	Cadmium	Toxic irreversible effects on human health Accumulates in kidney and liver
Relays and switches, and printed circuit boards	Mercury	Respiratory and skin disorders due to bioaccumulation in fishes
Galvanized steel plates and decorator or hardener for steel housing	Chromium	Causes bronchitis
Cabling and computer housing	Plastics and PVC	Burning produces dioxin that causes reproductive and developmental problems
Electronic equipment and circuit boards	Brominated flame-retardants	Disrupt endocrine system functions
Front panels of CRTs	Barium, phosphorus, and heavy metals	Cause muscle weakness and damage to heart, liver, and spleen
Copper wires, Printed circuit board tracks.	Copper	Stomach cramps, nausea, liver damage, or Wilson's disease
Nickel-cadmium rechargeable batteries	Nickel	Allergy of the skin to nickel results in dermatitis while allergy of the lung to nickel results in asthma
Lithium-ion battery	Lithium	Lithium can pass into breast milk and may harm a nursing baby Inhalation of the substance may cause lung edema
Motherboard	Beryllium	Carcinogenic (lung cancer) Inhalation of fumes and dust causes chronic beryllium disease or beryllicosis

Climate Change

It's important to take into account how electronic products affect climate change. Every gadget ever made has a carbon footprint and adds to the warming of the planet caused by humans. A tonne of laptops can produce up to 10 tonnes of CO₂ emissions during manufacturing. When a device's lifetime carbon dioxide emissions are taken into account, the majority of them happen during production, prior to a product being purchased by a customer. Because of this, the manufacturing stage's lower carbon processes and inputs (like using recycled raw materials) and the product lifetime become crucial factors in determining the overall environmental impact(21).

Lack of Recycling

Worldwide recycling rates are low. Merely 35% of e-waste is officially reported as having been properly collected and recycled, even in the EU, which leads the world in this regard. The average worldwide is 20%; the other 80% is unreported, with a large portion ending up as landfill buried for centuries. E-waste cannot break down naturally. The worldwide electronic industry is severely impacted by the lack of recycling, and the problem gets worse as devices get smaller, more complex, and more numerous. At the moment, it costs a lot to recycle some e-waste and recover materials and metals. A more difficult issue is the remaining mass of e-waste, which is primarily made up of plastics mixed with chemicals and metals(22).



Chemistry's contribution to the fight against e-waste

Given the complexity of the e-waste problem, a multidisciplinary strategy and a paradigm shift involving numerous stakeholders are required to successfully address this enormous challenge. Green chemistry advancements in industrial applications and environmental impact reduction across various manufacturing and industry sectors in which chemistry could serve as the foundation for various feasible resolutions, ranging from the creation of more environmentally friendly and sustainable raw materials (like organic electronics) to the application of innovative methods of treatment to lessen hazardous substances and/or salvage precious resources.

Prioritising potentially problematic chemical substances during the production of EEE can be a useful tactic to help the industry develop and employ safer materials.

On the other hand, since developing nations are frequently the ones most impacted by health and environmental problems associated with e-waste, it is necessary to support knowledge transfer to them. Efficient monitoring and screening of environmental pollutants will be beneficial, in addition to building capability for safer recycling and environmental clean-up. This approach may be helpful in developing nations where organic analysis facilities may be scarce.

IV. APPROACHES TO E-WASTE MANAGEMENT

The management of e-waste can be approached in various ways. It is crucial to make sure that any strategy chosen is economical, sustainable, and has the least negative effects on the environment(23,24). Here are a few instances of e-waste management strategies:

- Reducing the amount of electronic waste produced by advising consumers to purchase fewer electronics and to use them for longer periods of time before replacing them.
- reusing and renovating outdated electronics to increase their lifespan and lessen the need to create new ones from raw materials
- Recycling e-waste to disassemble outdated electronics into their component parts for safe disposal or reuse in new products without endangering the environment
- Proper disposal of e-waste through designated drop-off centres or adherence to local regulations for environmental protection.
- Donating used electronics to non-profit organisations that give free or inexpensive technology to underserved communities.
- Enacting extended producer responsibility (EPR) programmes that require manufacturers to take back and recycle their products, encouraging them to design devices that are easier to recycle or repair.
- Proper disposal of e-waste through designated drop-off centres or adherence to local regulations for environmental protection, implementing the circular economy's tenets, which encourage material reuse and recycling to keep it from going to waste.

V. THE CHALLENGE OF MANAGING E-WASTE

The amount of electronic waste, or "e-waste," is rising as the world grows more digitally connected(25,26). There are many difficulties in managing e-waste, some of which are as follows :

Rapid Technological Advancements: Electronic devices soon become outdated due to the speed at which technology is developing. As a result, there is a rise in the quantity of e-waste produced, which makes it challenging to maintain appropriate recycling and disposal.

Hazardous Materials: Hazardous substances like mercury, lead, brominated flame retardants, and cadmium can be found in electronic devices. If these materials are not disposed of and recycled properly, they could be harmful to both the environment and human health.

Lack of Proper Disposal Infrastructure: The infrastructure needed to manage e-waste is lacking in many nations. This indicates that a large portion of the produced e-waste is either illegally exported to developing nations with laxer environmental regulations or ends up in landfills.

Informal Recycling Sector: To handle e-waste, unofficial recycling industries have developed in a few nations. But these industries are frequently unregulated and employ shoddy, dangerous techniques that put the local population's health and the environment at risk.

Data Security and Privacy: Sensitive data, including financial, personal, and intellectual property information, is frequently stored on electronic devices. Therefore, data breaches and identity theft may result from improper disposal of these devices.

High Cost of Recycling: Because of the high cost of separating and processing the materials used in their construction, recycling electronic devices can be costly.

Addressing these challenges requires a coordinated effort from governments, businesses, and individuals to prioritize the proper disposal and recycling of electronic devices while minimizing their environmental and health impacts.

VI. CONCLUSION

It is a difficult task to manage the growing amount of e-waste in an economical and environmentally responsible manner. Therefore, implementing mitigation strategies and adopting best practices are crucial steps in managing e-waste products. Sustainable production and consumption increasingly depend on effective e-waste management. It deals with the appropriate disposal and recycling of electronic devices. It is necessary to identify hazardous materials, create a plan for handling them, and locate approved disposal facilities in order to manage e-waste properly. As a result, both developed and developing nations have created

different legal frameworks, disposal pathways, and other measures to appropriately manage this type of waste in response to the growing amounts of e-waste and its potential effects. It has been determined that the following factors need to be taken into account when creating a successful e-waste management system:

- Special logistic requirements are needed for the collection of e-waste from the point of generation and its transportation to disposal sites and treatment facilities .
- Because e-waste contains many hazardous substances that are extremely dangerous to both human health and the environment, proper handling is needed when disposing of it in order to minimise environmental impacts.
- Precious metals, including gold, silver, and copper, are abundant in e-waste and can be recovered, recycled, and repurposed into the production cycle.

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