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A Review on Recycle of Electronic Waste Materials

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Abstract: *Any electrical and electronic equipment (EEE) and its components that have been thrown away by their owner as garbage without the intention of being reused are referred to as electronic waste, or e-waste. Electronic garbage, often known as WEEE (Waste Electrical and Electronic Equipment) or e-scrap, is found in various places and across the world. Almost any home or commercial item with electrical or electronics components that require a power or battery supply is included in this broad category. One of the world's most complicated and rapidly expanding waste streams, e-waste has an impact on the environment and human health in addition to causing a loss of precious raw resources. An important environmental concern is the exponential rise of electronic garbage or e-waste, which includes electrical and electronic equipment that has reached the end of its useful life. E-waste recycling is a beneficial tool to reduce the growing amount of e-waste, help attend to the shortage of some primary resources and boost the economy. It consists of the systematic collecting of e-waste and its treatment for the recycling of useful materials*

Keywords: E-waste, Management, Recycling, Environment impact, Global perspective

I. INTRODUCTION

Even though e-waste is one of the most important and urgent issues of the present day, it is frequently unnoticed. The increasing amount of e-waste worldwide has an impact on the ecosystem and nearby populations because improperly disposed of e-waste releases hazardous compounds into the environment and reduces precious metals. The amount of e-waste produced annually is growing at an alarming rate, it is noted. Globally, about 50 million tons (Mt) of e-waste were produced yearly. In the Asia Pacific region alone, 24.9 million tons of this total e-waste was produced last year. E-waste production grew three times faster than the world's population. By 2030, the amount of e-waste produced worldwide is predicted to exceed 74 million tons (Mt). But recycling rates aren't keeping up with the rapidity. Actually, in the same year, less than 13 percent of e-waste was recycled. Furthermore, the bulk of e-waste produced is diverted for land filling, which is a widely used method of e-waste disposal globally.

The main problem with the way that e-waste is currently managed is:

(a) Absence of effective methods for collecting and recycling and

(b) Absence of procedures to hold EEE manufacturers responsible for its end-of-life disposal.

As a result, neglecting to implement suitable e-waste recycling procedures could result in serious health and environmental problems. [1]

The definition of e-waste is very wide and covers six waste categories:

- **Temperature Exchange Equipment**: most generally referred to as cooling and freezing equipment. Usual equipment includes refrigerators, freezers, air conditioners and heat pumps.
- **Screens, Monitors**: Usual equipment includes televisions, monitors, laptops, notebooks, and tablets.
- **Lamps**: Usual equipment includes LED lamps, fluorescent lamps and high intensity discharge lamps.
- **Large Equipment**: Usual equipment includes large printing machines, washing machines, clothes dryers, dish-washing machines, electric stoves, copying equipment, and photovoltaic panels.

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- **Small Equipment**: Usual equipment includes radio sets, video cameras, electrical and electronic toys, small electrical and electronic tools, vacuum cleaners, microwaves, ventilation equipment, toasters, electric kettles, electric shavers, scales, calculators, small medical devices, small monitoring and controlling instruments.
- **Small IT and Telecommunication Equipment**: Usual equipment includes telephones, mobile phones, Global Positioning Systems (GPS), pocket calculators, routers, personal computers and printers. [2]

Because each of the six e-waste categories has a unique lifetime profile, each category has a range of waste amounts, economic worth, and possible negative effects on the environment and human health if recycled improperly. As a result, consumer views on the disposal of electrical and electronic equipment vary, so we have to improve the collecting, logistics, and recycling technologies for each category. According to the UN's fourth Global E-waste Monitor (GEM), the amount of electronic waste generated worldwide is increasing five times faster than the amount of e-waste that is recycled. In 2022, 62 million tons of e-waste would fill 1.55 million 40-ton trucks, which are about enough to form a bumper-to-bumper line around the equator, according to the ITU and UNITAR report [3]. E-waste production reached a record 62 million tons (Mt) in 2022, up 82% from 2010, and is expected to increase by another 32% to 82 million tons in 2030.

II. E-WASTE MANAGEMENT

Since India is the world's fifth-largest producer of e-waste, candidates should be aware that the term "e-waste" refers to electronic items that are nearing the end of their useful lives.

E-waste is the term for electrical and electronic equipment that is wasted. Because they include toxic heavy metals like lead, cadmium, and mercury as well as dangerous chemicals like brominates and flame retardants, they are bad for the environment. When the e-waste warms up, the hazardous compounds and its contain are released into the atmosphere. Human health is often harmed by the lead, zinc, barium, and other elements contained in electronic trash. Additionally, Hazardous chemicals leak into the soil and groundwater when e-waste ends up in landfills, endangering the health of people and the ocean.

E-waste can be categorized according to its chemical and physical components. The chemical composition of e-waste may alter as a result of technological advancements. According to a research done between 1991 and 2008 to evaluate the chemical makeup of dynamic random-access memory (DRAM), DRAM's gold and silver content would remain stable, its palladium concentration would drop by 80%, and its copper content would rise by 75% between 2008 and 2020. Even while the number of DRAM modules is declining as a result of modular design and technological advancements that may impact the physical makeup of the world's e-waste, the quantity of precious metals in ICT might stay constant. Therefore technology may alter the physical makeup of the world's e-waste, but the overall chemical makeup is expected to remain constant. [4]

In the majority of nations, e-waste is managed in three ways:

(i) by throwing it in the trash (dust-bin),

(ii) through official collection by entities authorized by the government, and

(iii) collection by private waste dealers and businesses outside of the official system.

According to official recycling, e-waste collected by approved commercial and/or municipal collection sites and pick-up services is often recycled at facilities with cutting-edge machinery, infrastructure, and technology for the safe and effective removal of valuable materials. However, the majority of e-waste collected by private waste companies or dealers outside of the official system is processed and recycled using various methods and typically without any measures to reduce the release of hazardous chemicals into the environment (informal recycling). When e-waste is sold to peddlers or disposed of in landfills, it frequently pollutes the environment by leaking into the groundwater, soil and by releasing pollutants into the air, soil, and surface water. Additionally, a significant quantity of valuable materials is lost when they are disposed of or recycled in given conditions. Therefore, the safest method of managing e-waste is through official recycling. [5]

III. CURRENT STATUS ON GLOBAL E-WASTE GENERATION

In recent years, there has been a significant growth in the global rate of e-waste generation. The worldwide e-waste generation growth rate had risen to almost 6%, compared to earlier projections that indicated an annual growth rate of

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3.4–4%. According to estimates, approximately 17.4 million tons of small equipment, 13.1 million tons of large equipment, 10.8 million tons of temperature exchange equipment, and 6.7 million tons of screens made up the world's e-waste yearly. [5]

An alarming amount of e-waste was generated in India as a result of the average annual growth rate rising from 0.56% in 1991 to 1.62% in 2011. After China and the United States, India is in the top 10 nations in the world for the production of e-waste. Three million tons of e-waste had been produced in 2018 and five million tons had been produced in 2020 and eight million tons of e-waste is generated in 2024.

The Indian electronics market was valued at about USD 65 billion in 2013, and USD 400 billion in 2020, and it would grow to about USD 500 billion in 2025, according to the Association of Indian Industries. In terms of volume and toxicity, e-waste is currently a major waste stream in India. By the end of 2021, almost 152 million laptops in India will be outdated; it causes significant management, health and environmental issues. India generates about 4,00,000 tons of e-waste domestically each year. Therefore, the recycling of e-waste in India is a market-driven sector that is controlled by several unofficial players. In India, the informal sector illegally recycles almost 90% of the country's e-waste, involving women and children among other groups. [1]

The collection, classification, processing, and use of waste materials to create new products are all part of the comprehensive process that is recycling. Steel recycling is one example, which has resulted in significant energy savings, decreased air pollution, water use, water contamination, mining residue reduction, and less reliance on primary resources. Comparing recycling e-waste to landfill disposal, it is clear that recycling contributes to environmental preservation and has positive economic effects. Recycling technology can reduce energy use, protect vital resources, and diminish negative environmental effects. [6]

IV. ECONOMIC AND SOCIAL IMPLICATIONS OF E-WASTE RECYCLING

- **Economic Benefits:** Precious metals, polymers, and other valuable and reusable elements are found in significant amounts in e-waste. An average printed circuit board, for instance, is made up of around 16% copper, 4% solder, 3% iron and ferrite, 2% nickel, and 0.05% silver by weight (Approximate).
- **Social Impacts:** Because it generates more jobs for unskilled locals and migrants, e-waste recycling has been crucial to the industrialization of some rural areas in India. It has grown to be a considerable source of income for both local governments and citizens. [7]

V. ENVIRONMENTAL EFFECTS OF E-WASTE RECYCLING

- **Positive Effects:** E-waste is a rich supply of rare metals and polymers, as was previously mentioned. When treated incorrectly, plastics which are primarily non-biodegradable can become pollutants in and of them. Enormous amounts of waste water, carbon dioxide, and sulfur dioxide are released during the primary manufacture of metals from mining ores, which also uses a lot of energy and land. For instance, the primary production of one ton of gold, palladium, or platinum emits about 100,000 tons of carbon dioxide, while the production of one ton of copper emits 3.4 tons.
- **Negative Effects:** Large-scale toxic releases from outdated recycling facilities can cause danger to the health of nearby employees. Numerous studies have found that higher concentrations of heavy metals and certain chemicals in areas affected by e-waste recycling have an influence on human health. [7]

VI. STRATEGIES OF E-WASTE MANAGEMENT

There are two primary paths: those end-of-life e-waste management solutions for waste materials.

1. Direct disposal to traditional landfills by disposal of municipal waste or
2. Indirect disposal as residue from recycling or recovery efforts.

The long-term effects of waste on landfills are discussed by some authors, and this practice may cause hazardous chemicals and metal ions, like lead, to leak. Recycling and reusing all electrical and electronic devices or their components is a crucially overlooked aspect of waste management strategies.

Reusing electronic gadgets is said to be far more practical than recycling them as long as all of the devices or parts are still in good working order. Therefore, it is essential to fully apply the earlier in order to reduce the amount of trash

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generated. This usually involves the systematic handling and processing of rejected and underused electronic equipment; you may only proceed to the next stage of action, recycling, if the device or component is no longer in use.

On the other hand, you can use the components that are already accessible to make new items. India's booming electronics sector might be able to assist, as the recycling sector might supply manufacturers with functional parts. Electrical and electronic equipment that permits the removal of original parts for possible repair or for future reuse elsewhere presents a difficulty for the remanufacturing business, especially the unorganized sector.

In both industrialized and developing nations, many waste management strategies have been identified in order to recover the entire waste management plan. Developing nations must implement a suitable ERP system that is based on the local economy. Therefore, the conventional way of disposing of garbage in landfills is not advised due to the presence of hazardous components. The amazing growth of e-waste is inspired by the recycling rates of various nations. [8]

VII. INDIAN SCENARIO FOR E-WASTE MANAGEMENT

The India has become a significant hub for IT in recent years, and the market for consumer electronics has expanded at an exponential rate. The Indian PC market is expanding at a compound annual growth rate of 25%, according to the Manufacturers Association of Information Technology (MAIT). According to the study, 14 million mobile phones and 2.2 million laptops were replaced in the past year. An estimated 3,32,979 tons of e-waste were produced, of which 1,44,000 tons were recyclable, and 19,000 tons were actually recycled.

Approximately 12,000 tons of laptops and 7,000 tons of televisions were among the e-waste that was processed. Approximately 50,000 tons of e-waste were projected to be imported in addition to the 3,32,000 tons produced domestically. Economic inequalities make it advantageous for developed countries to ship e-waste to developing countries for recycling or reuse. For example, recycling a computer costs $20 in the US but only $2 in India. Thus, there is a good likelihood that India's e-waste imports will increase significantly. [1]

VIII. CONCLUSION

Electric and electronic equipment are practically necessary in this era of information and communication technology (ICT). Many devices become outdated within a few years after their manufacture due to the rapid advancement of technology. Together with the increased demand for e-devices due to new technology, these factors increase people's purchasing power worldwide and lead to the production of enormous volumes of e-waste. Although recycling of e-waste is practiced worldwide, it is not proportionate with the construction of new e-waste. Therefore, we will need to increase our current e-waste recycling strategies. The ITU (International Telecommunication Union) has acknowledged that there is no one best way to manage e-waste in these nations. So every developing nation has its own unique set for recycling of e-waste in environmental, social, technological, economic, and cultural circumstances.

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