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Extraction and Recovery of Metals from Electronic Waste, Reuse, Recycle and Reduce Waste

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Ph. D (chemistry): Inorganic chemistry (Extraction of Metal from Waste sludges & E-Waste Management – (pursuing)

Abstract: - The issue of electronic waste (e-waste) recycling is the subject of this paper. E-waste refers to electrical and electronic devices that are unwanted, broken, or discarded. This includes old, end-of-life, or discarded electrical and electronic equipment, such as household appliances, office information and communications equipment, entertainment and consumer electronic equipment, lighting equipment, electric and electronic tools, and more. The aim of this research paper is to provide a comprehensive overview of the e-waste problem, the methodology of e-waste management, and various physical, chemical, and metallurgical e-waste recycling processes. Special attention is given to the extraction of both metallic values and non-metallic substances. The hazards generated by heavy metals, brominated flame substances, and other potentially harmful elements in e-waste are also discussed. Due to the presence of hazardous elements, electronic waste is generally considered hazardous waste and, if not managed properly, can have a significant impact on human and environmental health. This paper evaluates the potential hazards and opportunities of e-waste in the future.

It is now widely known through social media that discarded electronic components, or e-waste, represent most of the hazardous solid waste produced worldwide. According to the United Nations University, 53.6 million metric tons of e-waste were generated in 2019, and a 30% increase is expected by 2030. E-waste recycling is an important part of the economy in developing countries and is key to increasing the sustainability of electronic devices that often rely on the exploration of rare earth elements. However, data shows that more than 80% of e-waste is not adequately treated, which negatively impacts the surrounding environment and the health of exposed populations, highlighting the need to reduce e-waste and improve its management.

1. Introduction

This paper provides an overview of e-waste components and discusses present and future perspectives of e-waste recycling. E-waste characterization, dismantling or shredding, magnetic separation to extract ferrous metals like iron and steel, and separation of non-ferrous metals using eddy current and other methods, liberation, and classification processes are also covered. Based on types of electrical waste, manual dismantling after or before desoldering and metal-nonmetal liberation in a micron with the step of crushing are seen as the best techniques.

After large particles to small size reduction, physical separation processes employing gravity, electrostatic, magnetic separators, froth floatation, etc. have been critically reviewed for the separation of metals and nonmetals and other waste like plastic or any solid waste along with useful utilizations of the non-metallic materials. The recovery of metals from e-waste material after physical separation through pyrometallurgical, hydrometallurgical or bio-hydrometallurgical routes is also discussed along with purification and refining. It seems that hydrometallurgical recovery and recycling of metals from electronic waste is a critical process, and various physical separation techniques are used for separating metals and non-metals.

2. Objectives

This paper has discussed the use of gravity, electrostatic, magnetic separators, froth floatation, and other methods for separating metals and non-metals. Moreover, the recovery of metals from e-waste material through pyrometallurgical, hydrometallurgical, or bio-hydrometallurgical routes has also been discussed. It appears that the hydrometallurgical route will play a crucial role in the recovery of base and precious metals from e-waste. E-waste recycling is a vital sector from both economic and environmental perspectives. Recycling technology aims to turn today's waste into sustainable polymetallic secondary resources in the future. Recycling ensures that e-waste is disposed of and re-used in an environmentally friendly way with high efficiency and lowered carbon emissions, at a fraction of the cost involved in setting up billion-dollar smelting facilities. Industrial metabolism, industrial ecology, and circular economy-inspired solutions can offer a lot of benefits, such as increased energy efficiency and lower demand for new raw materials. The recycling process involves three major steps: dismantling, upgrading, and refining, dismantling is labor-intensive and the first crucial step aimed at separating hazardous or valuable constituents.

3. Methods

To research this topic, collected data, and analysed it for this research paper. To quantify the content of the metal elements in the various components of electronic waste, instrumental analysis shows the exact % of the metal elements in different materials. To detect metals like Cu. Zn, Cd, Ni, Ag, Pb, Sn, etc, practices ASTM/BIS/JIS/DIN and a few other published test methods which covered instruments like optical emission spectrometer, Atomic Absorption Spectrometry, Electrolysis & Inductively coupled plasma for micro-level elements are in part per billion or million.

The route is expected to play a crucial role in recovering base and precious metals from e-waste. The recycling of electronic waste is of immense importance today, both from an economic and environmental standpoint. Recycling technology aims to convert waste into sustainable polymetallic secondary resources in the future, which are conflict-free and environment-friendly. By doing so, it helps to dispose of e-waste in an eco-friendly way with high efficiency and reduced carbon emissions, at a fraction of the cost involved in setting up billion-dollar smelting facilities. The cost of managing recycling facilities is high, and natural resources are depleting rapidly, which is why recycling and circular solutions based on principles such as industrial metabolism, industrial ecology, and the circular economy offer several benefits. This leads to increased energy efficiency and reduces the demand for new raw materials by lowering the need for mining.

The recycling process is initiated through three major steps: dismantling, upgrading, and refining. Dismantling is a critical first step that involves human labor, aimed at separating hazardous or valuable constituents from all types of electronic waste.

Below are the recycling e-waste processes:

1. Collecting and Transporting
2. Sorting of e-waste: it is very important and allows the sorting of collected electrical waste as there are precious metals like silver or gold, copper or aluminium as well hazardous elements present which need to be removed it due to dangerous chemicals or glass or hazardous metals or non-metallic elements to reduce pollution which will be harmful to environment and human being as well.
3. Shredding of e-waste is important due to prevent toxic chemicals from leaching into the soil and making it poisonous for plant growth. Also, during the burning, shredding, and dismantling of e-waste large particles of dust are released. These particles also settle on the ground and make it infertile.

4. Unwanted material extraction or Dust extraction: Next, the pieces left over from the electronics are then placed on a conveyor belt to undergo a process called dust extraction. The pieces are spread and shaken on the belt and then dust particles are collected and thrown away. The reason for this procedure is to ensure no environmental degradation takes place during the recycling process.

   Mechanical separation for metal and non-metal material- it is done by magnetic separation and water separation.

   Water separation: Two ways of water separation and making material ready for resale.

i. Once the magnets separate metal from other materials, water separation takes place. In this step, hydraulics are used to separate glass from plastic in a safe and efficient way.

ii. once the magnetic separation is completed, the remaining solid waste consisting of plastic, glass, and water is used to separate different materials & contaminants. It is then sent to smelters to produce glass tubes, X-rays, and many more.

Preparing recycled materials for sale: At this stage, it is ready for resale in different forms or as a raw material for a few products.

Other separation techniques are also used manually, i.e. sorting manually or previewing the waste of the stream. Only large-sized material is sorted, and small and other micro-sized by different techniques.

Recovery process: Landfilling, acid bath, incineration, recycling, and reuse represent a range of e-waste management and disposal methods.

E-waste can be toxic, is not biodegradable, and accumulates in the environment, in the soil, air, water, and living things. For example, open-air burning and acid baths are being used to recover valuable materials from electronic components and release toxic materials leaching into the environment.

Bioleaching is a hydrometallurgical method that is used after solvent extraction and electrowinning to dispose of electronic waste. The bio-hydro-metallurgical technique suggests that a bacterial leaching process is used to extract metals from e-waste. Bacteria and fungi, such as Bacillus sp., Saccharomyces cerevisiae, and Yarrowia lipolytic, have been used to mobilize metals like lead, copper, and silicon from printed circuit boards. Thiobacillus trioxide and Thiobacillus ferroxidase have been able to reach more than 90% of the available Cu, Zn, Ni, and Al at electronic scrap concentrations of 5-10g/l in the medium. Aspergillus Niger and Penicillium simplicissimum have also been shown to mobilize Cu and Sn by 65%, and Al, Ni, Pd, and Zn by more than 95% at a scrap

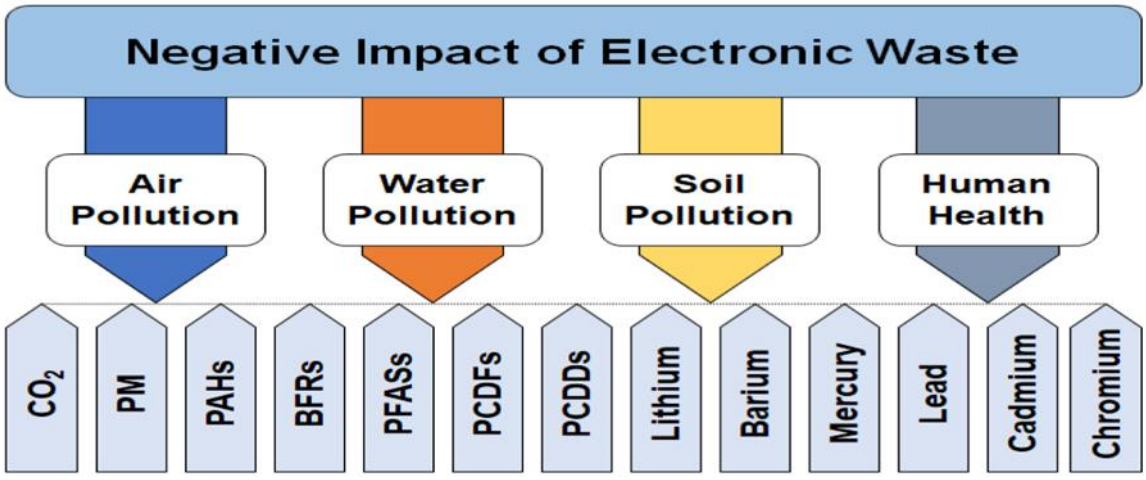
concentration of 100 g/l in the medium. Recovered metals can be reused by metal manufacturing industries as raw materials. This method has the potential to reduce e-waste, raw material costs, and provide income from e-waste. The process involves grinding CPUs, leaching in nitric acid and aqua regia, removing excess nitric acid, extracting precious metals like gold, and washing and purifying the deposits.

Many new electronic recycling companies purchase and recycle all brands of working and broken electronics, whether from individuals or corporations. These companies also offer free recycling for old electronics without market value.

Heavy metal contamination from e-waste can have hazardous impacts on human beings, the environment, soil, animals, air, water, and microbial ecology.

Soil heavy metal contamination can negatively impact microbial respiration and soil organic N mineralization rate at very high concentrations of metals. However, at low concentrations, there is a positive relationship between heavy metals and soil respiration. Heavy metal pollution can enhance soil organic matter accumulation. Various environmental variables like soil pH, soil organic matter, organic pollutants, and the presence of Zn can affect the microbial community. Heavy metal contamination can also affect the number and diversity of soil microorganisms. The toxicity of soil increases with heavy metal contamination, which can cause serious environmental pollution and harmful effects on the ecosystem. Contaminated soils can interfere with the availability and uptake of nutrients by plants, cause nutrient deficiencies or toxicities that can negatively impact plant growth and crop productivity, leach toxic chemicals into nearby ground or surface waters, be taken up plants and animals, contaminate human drinking water supplies, and volatilize and contaminate the indoor air in overlying buildings. Recovering the soil environment after heavy metal contamination is extremely challenging.

E-waste contains multiple known and suspected neurotoxicants, including lead and mercury, that may disrupt the development of the central nervous system during pregnancy, infancy, childhood, and adolescence. Some harmful toxicants from e-waste may also impact the structural development and function of the lungs.



The European Union has published a restricted hazardous list of elements that must not be used in electrical and electronic products. These elements are restricted because they pose a threat to human health and the environment. E-waste, which consists of discarded electronic components, is most of the hazardous solid waste produced worldwide. In 2019 alone, 53.6 million metric tons of e-waste were generated, and this number is expected to increase by 30% by 2030. Unfortunately, more than 80% of e-waste is not adequately treated, which negatively impacts the environment and the health of exposed populations. E-waste recycling is an important part of the economy in developing countries and is key to increasing the sustainability of electronic devices, which often rely on the exploration of rare earth elements.

The substances regulation applies to all electrical and electronic equipment and products containing electronic components that may be sold in Europe. Suppliers are required to remove certain contents from deliverables according to this directive.

Lead (0.1%*), Mercury (0.1%*), Cadmium (0.01%*), Hexavalent chromium (0.1%*), PBBs (0.1%*) and PBDEs (0.1%*) § From 2021 additional: DEHP (0,1%*), BBP (0,1%*), DBP (0,1%*) and DIBP (0,1%*) n *

Substance	REACH	RoHS
Lead	a. Candidate List: 0.1% by weight b. Annex XVII: 0.05% by weight (e.g., for jewelry, articles that might be placed in the mouth by children)	0.1% by weight
Mercury	Annex XVII: Prohibited for general-sale measuring devices (e.g., barometers, thermometers not for fever use)	0.1% by weight
Cadmium	a. Candidate List: 0.1% by weight b. Annex XVII: 0.01% by weight (e.g., for plastic materials, paints)	0.01% by weight
Hexavalent chromium	Annex XVII: 0.0002% by dry weight of cement, 0.0003% by dry weight of skin-contacting leather articles	0.1% by weight
PBB	Annex XVII: Prohibited for use in skin-contact textiles (e.g., undergarments, linen)	0.1% by weight
PBDE	No restrictions found	0.1% by weight
DEHP	a. Candidate List: 0.1% by weight b. Annex XVII: 0.1% by weight of plasticized material (e.g., in toys and childcare articles)	0.1% by weight
BBP	a. Candidate List: 0.1% by weight b. Annex XVII: 0.1% by weight of plasticized material (e.g., in toys and childcare articles)	0.1% by weight
DBP	a. Candidate List: 0.1% by weight b. Annex XVII: 0.1% by weight of plasticized material (e.g., in toys and childcare articles)	0.1% by weight
DIBP	a. Candidate List: 0.1% by weight b. Annex XVII: 0.1% by weight of plasticized material (e.g., in toys and childcare articles)	0.1% by weight

India is the third-largest producer of e-waste after China and the US. Sadly, more than 95% of this waste is handled by the informal sector, leading to improper handling and disposal. This has severe consequences for human health and the environment. New guidelines have been issued by CPCB in 2022 to streamline the management and disposal of e-waste. The latest update came in May 2022, and the new rules have been enforced since April 1st, 2022.

The Waste Electrical and Electronic Equipment Directive was implemented in 2002 to hold manufacturers responsible for e-waste disposal at end-of-life. Similar legislation has been enacted in Asia, with e-waste legislation in the United States limited to the state level due to stalled efforts in the United States Congress regarding multiple e-waste legislation bills.

The new E-waste (Management) Rule discontinues outsourcing recycling to Producer Responsibility Organizations (PRO) by manufacturers, producers, and importers of EEE. The entire responsibility for proper disposal and recycling of e-waste is now on Central Pollution Control Board (CPCB) registered recyclers.

The key points of the new E-waste (Management) Rule:

include restricting the use of hazardous substances in manufacturing EEE, ensuring at least 60% of e-waste is collected and recycled by 2023, with targets increasing to 80% by 2027, and ensuring manufacturers make the product recyclable.

Additionally, the new rule lists 106 product categories that are covered, including cameras, air purifiers, fans, vacuum cleaners, electric cookers, microwaves, ovens, freezers, hairdryers, electric irons, electric kettles, coffee machines, sewing machines, and even toys.

Companies must purchase an Extended Producer Responsibility (EPR) Certificate based on their e-waste liability and in favor of registered recyclers. The EPR certificate has a validity of 2 years and comes in denominations of 100, 200, 500, and 1000 kg. The responsibilities of State Government/UTs include designating industrial space or sheds for e-waste dismantling and recycling facilities in existing and upcoming industrial clusters. The Department of Labor in State Government/UTs must recognize and register workers involved in dismantling and recycling of e-waste, undertake industrial skill development activities for these workers, and ensure their health and safety.

Discussion:

Is it possible to reduce waste rather than generate it, again recycle, and reuse it? It is somewhat possible by following a few control measures i.e., repair and reuse it, donate unwanted gazettes or electronic devices like laptops, hardware, and mobiles to NGOs or charitable trusts, check the packaging for an environmental seal, setting maximum purchase of the necessary products or for the purpose and adopt recycling process to reduce any wastes.

Recovery of precious metals from electronic waste is very difficult as it emits hazardous chemicals and gases which is impacting on the human body, environment, and ecosystem. Cyanidation is the main process that extracts precious metals and creates a huge amount of CO_2 and CO during the processing of discarded e-waste.

Generally, 90% of electronic waste is handled in an improper way i.e., sold to the scrape-drive and then resale or used for other purposes or thrown in a dumping ground like plastic or rubber, or any other component which are not usable further.

Other options are that governments are forcing manufacturing to get back devices and scrap them, recycle them at their own cost, or dispose of them. Once manufacturers have to pay the cost for recycling, they will produce products that are easily recyclable or research for long-term use of the product if it is possible.

Conclusion:

The E-waste (Management) Rules, 2022 are a significant step forward in tackling electronic waste in India. These rules hold the manufacturers and producers responsible for disposing of e-waste sustainably and responsibly, which promotes eco-friendly production and consumption. Additionally, the rules aim to raise public awareness about the issue and encourage individuals to take responsibility for their e-waste and dispose of it in an environmentally friendly way.

The government also notified battery waste disposal in the year 2022 & prohibited battery disposal in landfills & incinerators. The extended producer responsibility mandates that all batteries are collected and sent for recycling

or refurbishment. To get authorization for ERP, one needs to approach the CPCB (Central Pollution Control Board).

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