RECOVERY OF EXPENSIVE METALS FROM E-WASTE: RECYCLING AND PREDICTION MODEL IN INDIAN PERSPECTIVE

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Abstract:

The utilization of electronic gadgets has extremely increased in the current decades and proportionality the amount of electronic gadgets, for example, PCs, cell phones, entertainment gadgets and electrical home apparatuses that are discarded is becoming quickly at that point out of the world. E-waste is one of the worldwide rising problems in developing countries like India. E-waste contains expensive and special metals, including gold, silver, palladium and platinum, as well as potentially toxic substances such as lead, mercury, cadmium and beryllium. Therefore, accountable end-of-life management of e-waste is very important in order to recover valuable components and properly manage hazardous and toxic components. End-of-life management of e-waste includes recycle of functional electronics, restoration and repair of electronics, recovery of electronic components, recycling e-waste, and disposal. Reuse, restoration or repair of electronic products is most desirable since this option increases the life span of the electronic product and higher resource efficiency. Recycling of electronics allows for expensive and special metals to be recovered, reduces the environmental impact coupled with electronic manufacturing from raw materials, and ensures that hazardous and toxic substances are handled properly. Although there are clear benefits to recycling e-waste, the recycling rate of e-waste is relatively low, due to lack of recycling and regulatory infrastructure. The overall rate of e-waste recycling has been estimated at about 13% in 2009 (Jiang et al.)

E-waste contains material that is profitable and in addition toxic and has of inferior quality protection and condition affect. This study presents an overview of global as well as Indian context e-waste stats, health concerns of e-waste components along with the waste management, recycling and recommendations related to e-waste. In this study models for estimation and prediction is given also introduced recent studies about gold recovery form e-waste.

Key Words**:** E-waste, Expensive Metal, Recycling model, Recovery.

INTRODUCTION:

As per an Industry body Assocham, India's 'production' of e-waste is likely to increase by nearly three times, from the existing 18 lakh metric tons (MT) to 52 lakh MT) per annum by 2020 at a compound annual growth rate (CAGR) of about 30%. An Assocham-cKinetics study pointed out that global volume of e-waste generated is expected to reach from 93.5 MT in 2016 to 130 MT in 2018 at a CAGR of 17.6 percent during the period.[12]

A study on 'Electronic Waste Management in India,' conducted to mark World Environment Day, said as Indians become richer and spend more on electronic items and appliances, computer equipment accounts for almost 70% of e-waste material, followed by telecommunication equipment (12%), electrical equipment (8%) and medical equipment (7%). Other equipment, including household e-garbage account for the remaining 4% and only 1.5% of India's total e-waste gets recycled due to poor infrastructure, legislation and framework which leads to a waste of diminishing natural resources, irreparable damage of environment and health of the people working in industry. Over 95% of e-waste generated is managed by the unorganised sector and scrap dealers in this market, dismantle the disposed products instead of recycling it.[9]

E-waste typically includes discarded computer monitors, motherboards, cathode ray tubes (CRTs), printed circuit board (PCB), mobile phones and chargers, compact discs, headphones, white goods such as liquid crystal displays (LCD)/ plasma televisions, air conditioners, refrigerators etc

The Printed Circuit Board (PCB) is a major constituent of outdated and discarded electronic scraps. Printed circuit boards (PCBs) are the boards that are used as the base in most electronics – both as a physical support piece and as the wiring area for the surface-mounted and socket components. PCBs are most commonly made out of non-metal (Plastic, epoxy resins, glass) more than 70%, while other like copper, solder, iron, nickel, silver, gold, palladium including bismuth, antimony, tantalum etc. Comprise of 30%. As a matter of fact the embedded metallic content in PCBs treasure gold content exceeding 400-500 PPM and silver 2500 PPM along with various precious metals**.**

The proper disposal of electrical and electronic waste is currently a concern for researchers and environmental managers not only because of the large volume of such waste generated, but also because of the heavy metals and toxic substances it contains. If this waste is not properly treated and disposed of, it can cause soil and groundwater contamination, resulting in risks to human health.

The electrical and electronic industry is one of the most innovative in terms of products, and this is reflected in the speed with which electronic devices such as cell phones and personal computers become obsolete, generating large amounts of electronic waste that must be treated.[11]

Table1: Pollutants and their sources

Pollutants	Source	Pollutants	Source
Arsenic	Semiconductors, Microwaves, LEDs, Solar cell	Lead	Lead rechargeable batteries, solar transistor, lithium batteries, PVC
Barium	Electron tubes, filter for plastic and rubber, lubricant additive.	Lithium	Mobile phones, photographic equipments, video equipments
Cadmium	Batteries, Pigments, solders, Alloy, circuit boards, Monitor, CRTs	Nickel	Alloy, batteries, relays, semiconductors, pigments
Cobalt	Insulator	Silver	Capacitors, switches, batteries, resistors
Copper	Conducted in cables, Copper ribbon, coils, circuitry pigment	Zinc	Steel, brass, alloys, deposable and rechargeable batteries, luminous substance.

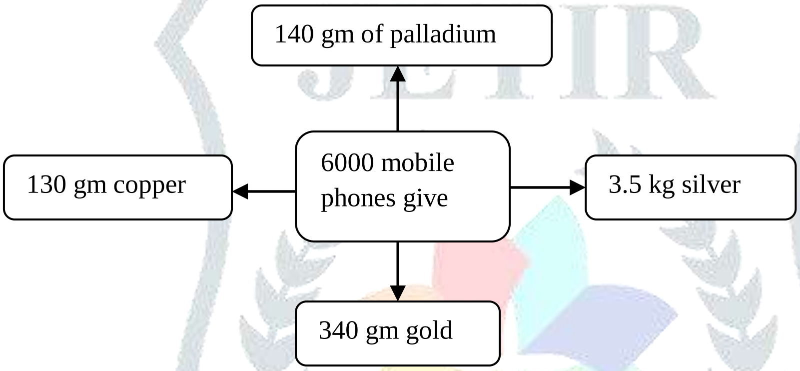

Figure 1: Some facts about metals from e-waste

In view of these total resources recycling with minimum pollution is of prime concern to manage e-waste efficiently. E-waste is thus considered a valuable secondary resources, if treated properly, however if no treated properly it is a major source of toxin and carcinogens. Recycle and reuse of absolute e-waste have now been recognised as a big challenge because of presence of number of metallic elements such as Cu, Pb, Sn, Ni, Fe, Al, Cd, Be etc including the precious metals such as Ag, Au, Pd etc.Many of these materials such as Be, Pb, Cd, Sb, and acrylic and phenolic resin , oxides in such waste are hazardous to the living being. The bulk volume of these waste generated, create a great problem in terms of handling and allocating the storage and disposable space.

Most developed countries are successfully managing the e-waste by formulating effective legislations, developing recycling infrastructures, and strictly adhering to the principle of extended producer responsibility (EPR) to command electronic manufacturers and importers to take back used electronic products (Afroz et al., 2013). However, India, today, is fraught with the emerging volume of E-waste which is either domestically generated or illegally imported due to unsustainable management practices fuelled by increasing perplexity among diverse stakeholders. While developed countries have organized systems for the collection, segregation, recycling, disposal, and monitoring (e.g., Switzerland), other countries (e.g., developing countries such as India and China) are still to find a solution that ensures minimizing the negative environmental and human health impacts of E-waste treatment and recycling. In the past few decades, treatment of E-waste has become a global waste management challenge owing to the fast obsolescence of modern technologies and the potential environmental and human exposures to hazardous materials during their recycling and disposal (Lau, Chung & Zhang, 2013)

E-WASTE RECYCLING PROCESS:

E-waste recycling consists of three main steps: collection, pre-processing and end-processing.

Each step is critical for the recovery of metals and recycling economy. Pre-processing of e-waste is one of the most important steps in the recycling chain. The expired equipments are manually dismantled at collection facilities and individual components are tested and isolated from e-waste. During the early stage, housing, wiring boards and drives, and other components are liberated. Mechanical processing is an integrated part of this stage where e-waste scrap is shredded into pieces using hammer mills. Metals and non-metals are separated during this stage using techniques similar to that used in the mineral dressing, e.g., screening, magnetic, eddy current and density separation techniques. The final stage in the recycling chain of e-waste is the end processing, where the non-metal and metal fractions of e-waste are further processed. There have been a number of studies on the recycling and utilization of the non-metals fractions from e-waste, for example from wasted PCBs that contain >70% of non-metallic fractions.[12]

In general, the non-metallic fractions of PCBs are mainly composed of thermo set resins and glass fibres. Thermo set resins cannot be re-melted due to their chain structure.

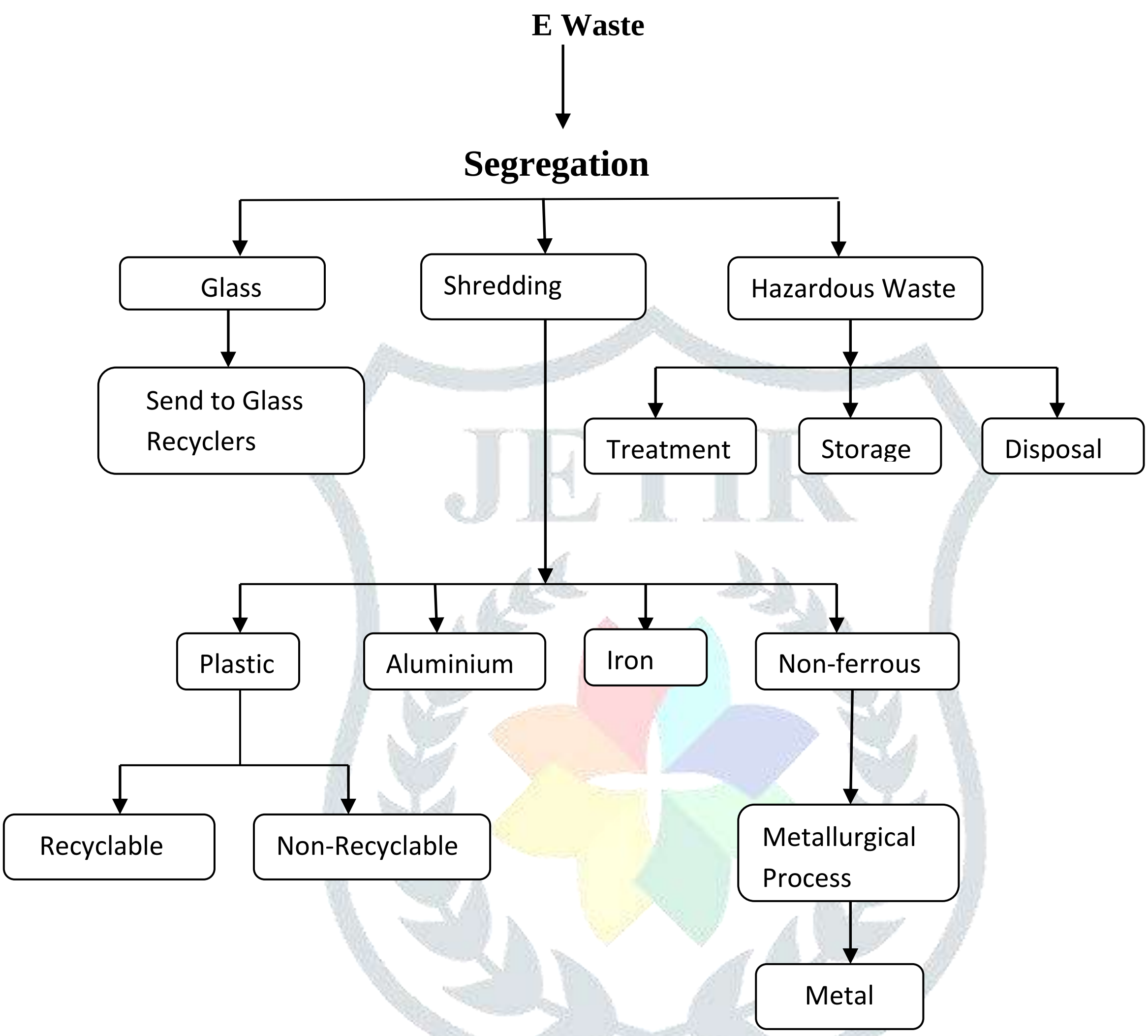

Figure 2: E-Waste Recycling Process at a Glance

E-WASTE ESTIMATION AND PREDICTION MODEL:

In this study, the quantities of e-wastes can be estimated by using the "use and consumption"method. In this method, an average number of electrical and electronic equipment is considered for a typical household, and by considering the end of life of the equipment, the amount of e-waste can be estimated. The end of life of the product is an essential factor for estimating the amount of E-waste generated. The total time that a product remains at the system boundaries from the retail points until the moment it is sent to the solid waste management system is called the end of life time of the product.[13]

Contribution of an item to annual e-waste generation can be calculated by the following equation: $E_w = \frac{M_i N_e}{L_a}$

Where: E_w(Kg/Year) is the quantity of e-waste generated

M_i(Kg) is the weight of the item

N_e - No. of e-products unit in use

L_a- Average life of the product.

In order to calculate predicted quantity of e-waste in future, consider the rate of failure of each item in the e-waste content. On considering the e-waste deposit intensities of various types of e- products such as λ_W for white goods, λ_H for household λ_C for computers, λ_{TV} for television and λ_M for mobile phones.
Now the total e-waste deposit intensity as $\lambda_T = \lambda_W + \lambda_H + \lambda_C + \lambda_{TV} + \lambda_M$
And after the study of many life cycle data we can conclude that logistic distribution fit well for the e-waste data

$$\lambda_T = \frac{N \times \beta \times b e^{-bt}}{[1+\beta e^{-bt}]^2}$$

Where: N- Cumulative quantity of e-waste
β- Inflection Parameter
b- e-waste deposit rate
t- Time Parameter (Year)
From the above total cumulative e-waste deposit is given by

$$W_T = \frac{N}{1+\beta e^{-bt}}$$

In a recent study scientists have discovered a new financially viable and environmentally friendly way to recover and recycle gold from electronic waste, an approach that could revolutionise the industry and be a veritable gold mine. They have found a simple, cheap and environmentally benign solution that extracts gold in seconds, and can be recycled and reused," said Stephen Foley, professor at the University of Saskatchewan in Canada. The biggest issue with gold is it is one of the least reactive chemical elements, making it difficult to dissolve; the common practice of mining for gold creates environmental issues because it requires large amounts of sodium cyanide. Meanwhile, recycling gold from electronic scraps like computer chips and circuits involves processes that are costly and have environmental implications. With lower toxicity, cheaper cost and quicker extraction, the team has discovered an approach that could revolutionise the industry and be a veritable gold mine, researchers said. The environmental effects of current practices can be devastating," said Foley, noting that the world produces more than 50 million tonnes of electronic waste per year and 80 per cent of that winds up in landfills.[4]
Mr. Stephen Foley (Professor, University of Saskatchewan Canada) along with research associate Loghman Moradi and PhD student Hiwa Salimi 2017), have discovered is a process using a solution - acetic acid combined with very small amounts of an oxidant and another acid - that extracts gold efficiently and effectively without the environmental concerns of current industry practices. In this technique, the gold extraction is done under mild conditions, while the solution dissolves gold at the fastest rate ever recorded. According to this team "Gold is stripped out from circuits in about 10 seconds, leaving the other metals intact," He said it requires 5,000 litres of aqua regia (a mixture of nitric acid and hydrochloric acid) to extract one kilogramme of gold from printed circuit boards, none of which can be recycled. With the new solution, one kilogramme of gold can be extracted using only 100 litres of solution, all of which can be recycled over again. The overall cost of this solution is only 50 cents a litre. The next step for the team is to move the process into large-scale applications for gold recycling.[1]

IMPACT OF E-WASTE ON HUMAN HEALTH:

Electronic equipments contain many hazardous metallic contaminants such as lead, cadmium, and beryllium and brominated flame-retardants. The fraction including iron, copper, aluminium, gold, and other metals in e-waste is over 60%, while plastics account for about 30% and the hazardous pollutants comprise only about 2.70%. Of many toxic heavy metals, lead is the most widely used in electronic devices for various purposes, resulting in a variety of health hazards due to environmental contamination. Lead enters biological systems via food, water, air, and soil. Children are particularly vulnerable to lead poisoning – more so than adults because they absorb more lead from their environment and their nervous system and blood get affected. It is found that the e-waste recycling activities had contributed to the elevated blood lead levels in children living in China, which is one of the popular destinations of e-waste. This was due to that fact that the processes and techniques used during the recycling activities were very primitive.[8]

Table 2: E-waste: Hazardous Elements and impact on human health[13]

E-Waste Source	Element	Impact on Human health
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
Nickel–cadmium rechargeable batteries	Nickel	Allergy of the skin to nickel results in dermatitis while allergy of the lung to nickel results in asthma
Power supply boxes, motherboards, relays and finger clips	Beryllium	Exposure to beryllium can lead to beryllicosis, lung cancer and skin disease. Beryllium is a carcinogen
Gallium arsenide is used in light emitting diodes	Arsenic	It has chronic effects that cause skin disease and lung cancer and impaired nerve signaling
Batteries, backlight bulbs or	Mercury	Mercury can damage the brain, kidneys and fetuses

lamps, flat panel displays, switches and thermostats		
Monit ors, keyboards, cabling and plastic computer housing	PVC	The incomplete combustion of PVC release huge amounts of hydrogen chloride gas, which form hydrochloric acid after combination with moisture. Hydrochloric acid can cause respiratory problems
Solder, lead - acid batteries, cathode ray tubes, cabling, printed circuit boards and fluorescent tubes	Led	Can damage the brain, nervous system, kidney and Reproductive system and cause blood disorders. Low Concentrations of lead can damage the brain and nervous system in fetuses and young children. The accumulation of lead in the environment results in both acute and chronic effects on human health

It was found that e-waste recycling operations were causing higher levels of polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/Fs) in the environment as well as in humans. A large number of workers including small children are exposed to different dismantling activities of e-waste. Although findings of these studies cannot be generalized to India but these are enough to alarm and strongly suggest to be replicating in occupational settings in India. There are no data available about the health implications of these workers. They might be ruining their lives in the lack of appropriate knowledge.

INITIATIVES TAKEN TOWARDS E-WASTE MANAGEMENT IN INDIA:

In Environmental (Protection) Act 1986, the "polluter pays principle" is enacted to make the party responsible for producing pollution responsible for paying for the damage done to the natural environment. In international environmental law, it is mentioned in principle 16 of the Rio Declaration on Environment and Development. Polluter pays is also known as extended producer responsibility (EPR). Under the Environment (Protection) Act 1986, central and state governments can enact legislations to safeguard the environment and people from exposure to toxic and hazardous nature of waste. Any violation of the provision of this act or notified rules is liable for punishment. Such penalty can be imposed on the violator if specific rules and regulations on e-waste are violated.[8]

CPCB India is finalizing the set of rules and most recently issued a formal set of guidelines for proper and eco-friendly handling and disposal of the electronic waste. The Ministry of Environment and Forests is now processing the rules framed by electronics equipment manufacturers with the help of NGOs. According to the new guidelines issued by CPCB in 2007, e-waste is included in schedules 1, 2, and 3 of the "Hazardous Waste (Management and Handling) Rules 2003" and Municipal Solid Waste Management Rule, 2000. Each manufacturer of a computer, music system, mobile phone, or any other electronic gadget will be "personally" responsible for the final safe disposal of the product when it becomes a piece of e-waste. Department of Information Technology (DIT), Ministry of Communication and Information Technology, has also published and circulated a comprehensive technical guide on "Environmental Management for Information Technology Industry in India." Demonstration projects have also been set-up by the DIT at the Indian Telephone Industries for the recovery of copper from Printed Circuit Boards.[5]

As an effort to make the users aware of the recycling of e-waste, many electronic companies such as Apple, Dell, and HP have started various recycling schemes. Nokia India announced its "recycling campaign" for the Indian region. The program encouraged mobile phone users to dispose of their used handsets and accessories, irrespective of the brand, at any of the 1,300 green recycling bins put up across the priority dealers and care centers. Nokia is also planning to launch an electronic waste management program.

The Department of Environment, Delhi government, has also decided to involve ragpickers in general waste management in the capital. These rag pickers will be trained, given uniforms, ID cards, and hired to clean waste. The department also intends to involve eco-clubs, now running in over 1,600 government and private schools in the Capital, in this initiative since it is these eco-clubs that will be interacting with rag pickers of that particular area.

CONCLUSION: E- waste tends to be a bigger problem in the coming years and an efficient way is needed to undertake the problem. Another demanding part is selecting the recovery method. This study has presented a model for extraction of metal from e-waste and mathematical approach to evaluation and prediction of metal from e-waste. Also has discussed the bad impact of e-waste on human health. In view of the present business-related processes, the recycled products are not of immense value. The development of more novel recycled products will help the industry by extending the market to new ground. In addition to the efforts by the recycle industry, the printed circuit board industry itself should also promote and practice waste minimization. Facilities can extensively reduce waste production to minimize the secondary environmental risk of waste transportation.

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