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AN EVALUATION OF THE STATE OF ELECTRONIC TRASH RECYCLING METHODS

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ABSTRACT

As the usage of electrical and electronic devices grows, so does the amount of electronic trash produced (e-waste). It is the quickest. The world's increasing garbage stream Printed circuit boards are an integral component of almost all electrical and electronic devices. Improper disposal of these electronic trash may put human health and the environment at risk. On the contrary, the effective management of this trash requires a well-thought-out plan for waste awareness, collection, recycling, and reuse. These days, the effective trash recycling has long been seen as a major problem for any community. Circuit boards (PCBs) (PCBs). Many electronic businesses rely on precious heavy metals and hazardous halogenated organic compounds, which are abundant in these rocks. In this case, the makeup of various PCBs, as well as their hazardous consequences, are addressed in this article. There are a variety of recycling methods in use today. The most significant metals from e-metallic waste's fractions are shown. Metals may be recovered from e-waste once it has been processed. Physical separation through pyrometallurgical, hydrometallurgical, or biohydrometallurgical methods is also addressed, as well as biohydrometallurgical separation.

KEYWORDS: *End-Of-Life (EOL), Electronic Waste (E-Waste), Infrastructure, Materials Recovery, Recycling.*

1. INTRODUCTION

The increasing reliance on electrical and electronic devices in our everyday lives, as well as their end-of-life waste, has created a new environmental and health issue. Reusing and properly recycling this trash, on the other hand, conserves natural resources and prevents water and air pollution[1]. WEEE (waste electrical and electronic equipment) refers to electrical and electronic equipment, including all of its components, that has ceased functioning or has function problems. Cell phones, videocassette recorders, scanners, faxes, printers, tablets, DVD players, microwaves, x-ray machines, and certain scientific equipment are among the electrical and electronic trash. Large amounts of this trash are produced as a result of constant technological innovation and replacement, particularly in the case of computers and mobile phones[2].

Electronic trash (e-waste) produced across the globe in 2016 was approximately 44.7 million tons, and this is expected to rise to 52.2 million tons in 2021, at a pace of 3 to 4% each year. In 2005, the United Nations University estimated that 8.3–9.1 million tons of e-waste were produced throughout European nations. According to a variety of estimates, total electrical and electronic waste would increase at a rate of 2.5 to 2.7 percent per year, reaching approximately 12.3 million tons by 2020. Every year, a growing number of electric and electronic gadgets are withdrawn from the market in most nations[3]. E-waste generated from outdated laptops is expected to rise by 200–400% in South Africa and China by 2020, while e-waste generated from abandoned TVs and refrigerators would be twice or three times as much in China and India. It has been claimed that the quantity of solid e-waste has risen to alarming new heights, posing a significant threat to human health across the globe. Given that a mobile phone has a lifespan of around a year and a computer has a lifespan of 2–5 years, roughly 100 million mobile phones and 17 million computers are projected to be abandoned globally each year owing to faulty or obsolete technology[4].

Egypt is the biggest market in both the Middle East and Africa at the moment. In 2014, about 370,000 tons were produced, and the country's share will continue to increase. South Africa comes in second on the continent with 350,000 tons produced, followed by Nigeria with 220,000 tons produced in the same year. According to the United Nations Environment Program (UNEP), the rise in generation rates in Egypt is due to a 15% increase in home consumption, a 95% increase in computer users, a 74.5 percent increase in television sales, and a 13.5% increase in mobile phone subscribers. In Egypt, the fastest increasing component of the municipal solid waste (MSW) stream is mobile phones (subscribers > 90 million in 2015).

It expands at three times the rate of typical municipal trash (UNDP Egypt 2015, 2016). Electric and electronic equipment, according to reports, contain over 1000 distinct chemicals, including hazardous heavy metals and organics, which may cause severe environmental contamination issues if discarded improperly[5].WEEE (waste electrical and electronic equipment) recycling is a crucial topic for waste management and the recovery of valuable materials. In terms of materials and components, WEEE is heterogeneous and complicated. Developing a cost-effective and environmentally friendly recycling system necessitates identifying and quantifying valuable materials and hazardous substances in order to comprehend the physical characteristics of waste and improve metal recovery in order to conserve natural resources and provide an environmentally sustainable waste management solution[6].

In virtually all electric and electronic equipment, printed circuit boards (PCBs) constitute the most essential component (EEE). Copper, precious metals (PMs), and other valuable metals abound on these boards. Because of the inclusion of chlorinated/brominated flame retardants and inorganic chemicals, waste printed circuit boards (WPCBs) have drawn public attention due to their ecologically hazardous components. WPCBs are improperly disposed of, resulting in hazardous chemicals being released into the environment as well as the loss of numerous precious metals. Copper (20%) and gold (250 g/t) are considerably more abundant in printed circuit boards than in copper or gold ore, i.e. 20–40-fold and 25–250-fold, respectively[7].

For treating electrical and electronic wastes and recovering their metal contents, different treatment methods based on physical, pyro metallurgical, bio metallurgical, and hydrometallurgical processes are available. The potential dangers and economic possibilities of e-waste are outlined in this study. A summary of WPCB components is provided, as well as their harmful impacts on humans and the environment[8]. The physical and chemical metallurgical methods for recovering metals from e-waste are addressed. The information is discussed and contrasted to Egypt's existing e-waste control initiatives. The future prospects and difficulties that Egypt has in terms of effective e-waste recycling are also addressed. Printed circuit boards are made up of a wide range of materials, some of which include a variety of hazardous chemicals that, if not properly handled, may pollute the environment and endanger human health[9].

There are over 1000 hazardous chemicals linked to e-waste, with the following being the most frequently reported: Toxic metals (such as barium (Ba), beryllium (Be), cadmium (Cd), cobalt (Co), chromium (Cr), lead (Pb), lithium (Li), lanthanum (La), mercury (Hg), manganese (Mn), molybdenum (Mo), and hexavalent chromium (Cr(VI)) as well as persistent organic pollutants (POPs) such as bromine The detrimental hazardous consequences of certain metals found in electronic waste on human health[10]. Mechanical processing, which comprises three main steps: dismantling, upgrading, and refining, is typically the first stage in the WPCB recycling process. Dismantling is critical for all types of electronic trash, with the goal of isolating dangerous or valuable components for further treatment. To separate the materials and components into various categories (i.e., plastics, steel, aluminum, copper, printed circuit boards), the dismantling process is done manually using basic equipment like as hammers, tongs, screwdrivers, and conveyors. Following the dismantling process, WPCBs are exposed to a physical process that includes shredding the boards into tiny pieces using a crusher and grinder, followed by magnetic, eddy current, and density separation methods to separate the metallic and non-metallic fractions. Finally, a refining process is used, which includes hydrometallurgical, pyro metallurgical, electrometallurgical, bio metallurgical, and combinations of these processes. In the United States, landfills and incineration are the most common methods of disposal for this trash. The demand for landfills is growing, which is putting a strain on our ecosystem.

Diverted waste treatment techniques are also sought due to a lack of disposal capacity and increasing concern about environmental quality. To keep end-of-life (EOL) electronics out of landfills and incinerators, new waste management solutions are required. However, while developing an effective diversion plan, there are many things to consider. This approach must be founded on the program's long-term economic viability, technological feasibility, and a reasonable degree of societal support. EOL electronic goods should be recycled and reused as part of the plan. The types of processes that can be used and the quantity of trash that can be treated. Transportation, collection, recovery, and resale facilities are all included. The quantity of trash in the waste stream, the recycling technologies available, government restrictions, and the economics of EOL products are all factors that influence the recycling infrastructure.

2. DISCUSSION

We begin at the point when CEDs first become waste (either through obsolescence or through operational failure) and work our way through the collection, treatment, and final disposition of recycled electronic waste to gain a better understanding of the current processes and infrastructure available for electronic recycling in the United States. This overview covers important actors at each stage and gives a complete picture of the infrastructure for electronic trash recycling. Consumers believe that these CEDs are valuable. This logic is incorrect. The residual value of obsolete electrical equipment is constantly decreasing as electronic technologies advance. With the passing of time, both the resale value of components and the resale value of machines decrease quickly. For example, the value of a computer with technology older than two generations approaches zero.

Furthermore, it is more difficult to recycle older equipment than it is to recycle modern technology. In general, older equipment includes a greater range of materials, such as various polymers, as well as a greater quantity of dangerous elements, such as lead. As a result, it is preferable to discard outdated computer equipment as soon as it seems to be obsolete. Consumers must have both access to and awareness about recycling programs in order to effectively recycle electronics. This basically implies that customers must know where to turn when their technological gadgets become outdated or unusable. Several cities have tested collecting systems that are now accessible to the general public. As a consequence, electronic recycling initiatives are becoming increasingly prevalent. Curbside collection is the collection of e-waste on a regular basis, similar to how ordinary municipal trash is collected, or upon request. The operation expenses of e-waste collection may be significantly reduced if it coexists with an existing curbside trash collection service. This is the most practical collecting method for residents.

Operating expenses, on the other hand, may be greater than for other collecting methods. There's also the risk of theft of gadgets left out for recycling, as well as the abandonment of trash that isn't e-waste. A special drop-off event is a one- or two-day event organized over the weekend to encourage residents to participate. The number of devices gathered in this option is determined on the amount of customer engagement and the weather conditions during the special event time. When specialists from the repair sector collaborate with the program, a special drop-off event is regarded to be an excellent recycling program since these experts can pick out the most valuable goods for resale, repair, and reuse. A year-round collection event is what a permanent collection option is. E-waste may be collected at the municipal solid trash collection facility, resulting in little expenses. Although this kind of collection program has been proven to be the most cost-effective, it is not appropriate for every town size. This collecting method requires that the amount of collected devices be verified on a regular basis, and that the devices be delivered to a recycler after specified quantities have been gathered. Consumers may bring old electronic equipment to a shop when they buy new electronic equipment under the point-of-purchase collection model, and merchants act as the collecting agency.

Depending on the retailer's choice, this collection option may be implemented as a permanent or one-time drop-off event. For this technique of collecting to be effective, the retailer's active involvement is required. Geographic location, accessibility and comfort for customers, and population dispersion may all be factors in determining a suitable collecting site. Electronic equipment retail shops or big public parking lots may be utilized as collecting sites for special drop-off events. The transportation element of electronic recycling is also significant. Transportation is supplied by the local government, a private recycler, or a third party with curbside pickup. Residents are responsible for transportation to the collection location in permanent collection, and the recycler is responsible for transporting the collected e-waste to the processing facility. Consumers must bring their e-waste to the collection location in the case of a special drop-off event. The transportation to the recycling processing facility is subsequently handled by the local government or the recycler.

The salvaged and recycled materials market is the third market. Examining and testing for reuse are time-consuming and labor-intensive activities, notwithstanding their simplicity. A plug-and-play test is performed to determine whether or not equipment is functioning. Dismantling equipment that fails the plug-and-play test for component resale and reuse is an option. Individual component recovery from e-waste is more difficult than a simple plug-and-play test that can be used to evaluate an entire system. Employees in charge of component recovery must understand (1) how to dismantle the system, (2) which components are valuable, and (3) which components, such as a hard drive, need extra caution in their handling. To optimize economic value, the disassembly process begins with the more valuable high-end components and ends with the less valuable low-end ones. Hazardous contaminants are also removed throughout the demanufacturing process. Because ink is a hazardous chemical, printer ink cartridges must be removed before the printer may be recycled. Due to the difficulties of removing the laminated layer from the metal, laminated metals are also removed and discarded. The sequence in which the manufacturing processes are performed is critical to output efficiency.

Even though they are destroyed, data from special drop-off event collecting systems has shown that more than half of the computers are in excellent operating order. These used computers may readily be sold on secondary markets since there is still a need for them. In 1997, the TV repair business in the United States had a market value of approximately US$ 17 billion and employed 588,000 people. The computer repair business, on the other hand, is expanding. Because a computer is a combination of current electronic technology, this sector depends on high-tech, qualified personnel. As a result, this sector is divided into two segments: companies that repair computer displays and companies that repair computers themselves.

Those in the computer repair business have the opportunity to collaborate with recyclers. If the collected equipment has any market value, some electronic equipment that has been collected for recycling may be repaired and resold by the repair business. However, even if the unit is still functional, there is no market for it if it is old and outdated, such as 286 CPUs. Overseas is the biggest market for gadgets gathered in the United States.

More than half of the e-waste collected for recycling in the western United States is projected to be shipped to other nations such as China, India, and Pakistan, where recycling prices are far lower than in the United States. However, due to ongoing registration in many of these nations, the situation is still in flux. Because the glass recovered is utilized as a raw material for new

CRTs, glass-to-glass recycling is considered a closed loop recycling process. CRTs are collected and transported to a recycler, where the whole glass is crushed into cullet without the panel and funnel glass being separated. The cullet is sent to CRT producers to be used in the production of new CRTs. The composition of CRT glass varies based on the manufacturer and the time it was manufactured, particularly for panel glass.

One of the reasons why glass producers are hesitant to accept recycled CRT glass is because of this. Glass manufacturers are adamant about avoiding mixing various kinds of glass. Due to the difficulties in establishing the precise composition of recycled glass, using used CRT glass poses considerable risk to the glass production business. The danger of employing glass with an unknown composition is that a little amount of the incorrect composition may contaminate a whole glass furnace's contents, causing changes in glass characteristics. The glass furnace may need to be shut down for 3–4 days to rectify an erroneous glass composition. The glass-to-glass technique has many advantages. First, recycled cullet may be used to substitute virgin materials at a similar or lower cost, and it can enhance the furnace's efficiency, reducing the amount of energy used to make CRT glass. In addition, since recycled glass already has a high purity, this method may enhance the quality of the output glass and decrease emissions from the glass-making process.

Cullet has a greater value to a main CRT glass producer than it does to a lead smelter, which is another glass recycling technique. In addition, as compared to glass-to-lead, the glass-to-glass method lowers regulatory burden by treating CRTs as universal waste rather than hazardous waste, as defined by the Resource Conservation and Recovery Act. Another factor is high-definition television (HDTV). The market for new televisions in the United States is virtually saturated (more than 99 percent), but the arrival of HDTV in the near future, as well as customer preference for flat panel displays, may hasten the obsolescence and replacement of traditional CRT television sets. To deal with these developments, regulation and research will be required to improve glass-to-glass recycling and the development of new uses for old CRT glass. One unique aspect of CRT recycling is that there is a low-cost option: foreign recycling, which costs around a tenth of what domestic alternatives do. Labor costs, variations in work methods, appropriate waste disposal techniques, and environmental effect are all variables that influence cost. Another incentive for exporting CRTs is the low transportation cost: empty containers must return to their home nations after unloading the products in the United States.

Adding value to these containers by filling them with CRTs and other old devices is a good idea. Although this option is applicable to other electronic trash, CRTs are the most important item since CRT recycling facilities are situated on the east coast and exporting is often from the west coast of the United States. Plastics are widely apparent in electrical and electronic devices, such as telephones, TVs, and personal computers. Many plastic components, however, are concealed from view and form the infrastructure that connects and supports contemporary life. Plastics are essential materials for use in electronics because of their unique electrical insulating characteristics, as well as their strength, stress resistance, flexibility, and durability. Because thermo sets cannot be remelted and molded into new items, they are usually shredded when recycled. Circuit wire boards, electrical switch housings, electrical motor components, electrical breakers, and other electronic components utilize thermosets. Plastics, behind metals, offer the most potential for electrical product salvage. Electronic goods are typically made of ‘engineering thermoplastics,' which have a high intrinsic value. Engineering thermoplastics sell for dollars per pound when pelletized, compared to pennies per pound for bottle and container-grade plastics.

3. CONCLUSION

When e-waste is collected, it contains a wealth of useful materials. As a result, appropriate disposal procedures should be implemented to ensure that it does not harm the environment or provide a health risk to humans. WPCB recycling has traditionally relied on physical and chemical techniques. Physical recycling techniques such as magnetic separation or density separations are easy, convenient, ecologically friendly, and energy efficient. They are thought to be more cost-effective in terms of recycling and separating metallic components than non-metallic ones. Brominated fire retardants are converted to monomers via chemical recycling techniques, which remove the metals that remain in the residue. Many studies are being conducted on chemical recycling methods, with an emphasis on the metallic portions.

Despite lacking most of the necessary components to carry out an e-waste system, Egypt remains a viable market for e-waste recycling. Egypt has many organizational and technological challenges. Examples include a lack of recycling methods, a lack of cost recovery for e-waste services, a lack of strong laws, a lack of civic awareness, and a scarcity of suitable disposal locations. Existing recycling efforts in Egypt are still in their infancy and do not meet international environmental requirements. A poll regarding e-waste management activities is included in this assessment. It must be considered that, if the present pace of e-waste production in Egypt continues, there will be a massive hoard and the amount of discarded trash will significantly grow, as well as the noxious impact on people and the environment. To deal with this threat, the community and the government must work together. Everyone must accept responsibility, and the e-waste recycling system must be modernized with the participation and assistance of all sectors. Rigid regulations influencing e-waste management behavior should be examined.

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