A REVIEW OF METAL EXTRACTION METHODS FROM E-WASTE

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Abstract: Globally, E-waste is the fastest growing waste stream due to rapid growth in technology, planned obsolesces in the electronics industry and increased desire for new electronic products. E-waste has the ugly and good sides because it contains substances that can be classified as hazardous and non-hazardous. Management of metal pollution associated with E-waste is widespread across the globe. Currently used techniques for the extraction of metals from E-waste by using either chemical or biological leaching have their own limitations. Chemical leaching is much rapid and efficient but has its own environmental consequences, even the future prospects of associated nanoremediation are also uncertain. Biological leaching, on the other hand, is comparatively a cost-effective technique but at the same moment it is time consuming and the complete recovery of the metal, alone by biological leaching is not possible in most of the cases. The current review addresses the individual issues related to chemical and biological extraction techniques and proposes a hybrid-methodology which incorporates both, along with safer chemicals and compatible microbes for better and efficient extraction of metals from the E-waste.

Keywords :- **Electronic waste, recycling, Pyrometallurgy, Hydrometallurgy, Biometallurgy**

I. INTRODUCTION

E-waste is classified as hazardous material, therefore, should be managed properly. However, the presence of precious metals in e-waste such as Gold (Au), Silver (Ag), Platinum (Pt), Gallium (Ga), Palladium (Pd), Tantalum (Ta) makes it attractive for recycling. Advancement of technology and production of electronic and electrical devices leads to the fastest growing industries in the world. The waste generated after the useful life of a product is termed as E-waste which can be extracted by mining operation, metallurgical

operation, electronic operation, electroplating, and metal finishing operation. E-waste contains both valuable materials as well as hazardous materials which require special handling, dumping and recycling methods. E-waste is hazardous in nature due to the presence of toxic substances like Pb, Cr6, Hg, Cd and flame retardants. One of the most important components in the e-waste are the PCBs (printed circuit boards) where the precious metals concentrations are ten times higher than in rich precious metals bearing ore.

Recovery of metals from WEEE is a necessity, in order to meet the demand for raw materials. Currently, there are several alternatives, such as pyrometallurgical, hydrometallurgical routes and recently emerging bio-based route, a technique that employs metals from waste. Pyrometallurgy is an advanced refining microbial cells to extract and recover technology, currently employed at full scale in commercial plants. In this research, the most effective method is investigated and benchmarked to best available technologies.

II. Types of methods available for recovery of E-waste

There are three main processes of extraction of precious metals.

- Pyrometallurgy
- Hydrometallurgy
- Biohydrometallurgy

I. 1) Pyrometallurgy

Pyrometallurgy is a traditional method to recover precious and non-ferrous metals from e-waste. It includes different treatments on high temperatures: incineration, melting etc. Pyrometallurgical processes could not be considered as best available recycling techniques anymore because some of the PCB components, especially plastics and flame retardants, produce toxic and carcinogenic compounds. Most of the research activities on the recovery of base and precious metals from waste PCBs are focused on hydrometallurgical techniques for they are more exact, predictable and easily controlled techniques.

Limitations of Pyrometallurgical Processes

Pyrometallurgical routes are generally more economical, eco-efficient and maximize the recovery of PMs, however, they have certain limitations that are summarized here;-Recovery of plastics is not possible because plastics replace coke as a source of energy. -Iron and aluminum recovery is not easy as they end up in the slag phase as oxides; -Special installations are required to hazardous emissions such as dioxins to minimize environmental pollution;-Instant burning of fine dust of organic materials can occur before reaching the metal bath.

II. 2) HYDROMETALLURGY

Hydrometallurgy is concerned with processes that use aqueous solutions to extract metals from ores. The most common hydrometallurgical process is leaching, which involves the dissolution of the valuable metals into the aqueous solution. After the solution is separated from the ore solids, the solution is often subjected to various processes of purification and concentration before the valuable metal is recovered, either in its metallic state or as a chemical compound. The solution purification and concentration processes may include precipitation, distillation, adsorption, and solvent extraction. Extraction of precious metals from PCBs, including leaching, purification, and recovery, is the second stage after the recovery of base metals. The most common leaching reagents for precious metal leaching include cyanide, thiourea, and thiosulfate because of the stable metal complex formed.

III. A) CYANIDE LEACHING

For over a century, cyanide has been extensively used as the leaching lixiviant to treat both gold mines and secondary gold source due to its high efficiency and low cost[19].which results in cyanide loss and harmfulness of operators‟ health. Recently, the slow cyanidation rate and severe environmental impact of cyanide gold leaching accelerate the development of a substitute that is more effective and environmental-friendly.

Cyanide as lixiviant for gold has been utilized in the mining industries for more than one century[20]. The mechanism of gold dissolution in cyanide solution is essentially an electrochemical process. The overall reactions are shown in Reactions (1) and (2).

The effect of pH on dissolution rate for the noble metals (gold, silver, palladium, and platinum) investigated by Dorin and Woods[21] The results showed that a maximum dissolution of gold, silver, palladium, and platinum in cyanide solution can be obtained at pH 10–10.5.

IV. B) THIOUREA LEACHING

Thiourea, NH_2CSNH_2, is considered a most promising alternative to cyanide regarding leaching of precious metals due to its fast leaching rate and non-toxicity. The demerits of thiourea leaching are high cost and consumption because of its poor stability. Several studies highlighted thiosulfate leaching of gold. Thiosulfate leaching is operated in an alkaline condition to prevent thiosulfate decomposition. Ha reported that 98% of gold could be recovered using a solution containing 20 mM copper, 0.12M thiosulfate and 0.2M ammonia.

Limitations of Hydrometallurgy Route

Hydrometallurgical routes have been successfully used to recover PMs from e-waste but it has some limitations to:-

-Hydrometallurgical routes are slow and time-consuming and impact recycling economy but it has still concerns.

-Cyanide is a dangerous leachant and should, therefore, be used with the high safety standard.

-Halide leaching is difficult to implement due to strong corrosive acids and oxidizing conditions.

-The use of thiourea leachants is limited in gold extraction due to its high cost and consumption.

-The consumption of thiosulfate is comparatively higher and the overall process is slower, which limits its application for gold extraction from ores as well as from e-waste.

- There are risks of PM loss during dissolution and subsequent steps, therefore the overall recovery of metals will be affected.

3) BIOLOGICAL LEACHING

Microbiological leaching uses a natural ability of microorganisms to transform metals present in the waste in a solid form (in the solid matrix) to a dissolved form. Apart from the possibility of bioleaching of metals in an alkaline environment (involving cyanogenic bacteria), acidophilus microorganisms and conducting the biological process of leaching in an acidic environment play a crucial role in the biohydrometallurgical techniques. Among major groups of bacteria, the most commonly used are: acidophilus and chemolithotrophic microbial consortia of: Acidithiobacillus ferrooxidans, Acidithiobacillus thiooxidans, Leptospirillum ferrooxidans and heterotrophs, for example, Sulfolobus sp. In addition, fungi such as Penicillium sp. and Aspergillus nigerare examples of some eucaryotic microorganisms used in bioleaching during metal recovery from industrial wastes [24]. The bioleaching process is cheaper and easier to conduct in comparison to conventional techniques. Its advantage is flexibility – microorganisms easily adapt to changing and extreme living conditions.

At present, research and development are in progress for a number of metals such as copper, nickel, cobalt, zinc, gold, and silver. However, for recovery of gold and silver, the activity of leaching bacteria is applied only to remove interfering metal sulfides from ores bearing the precious metals prior to cyanidation treatment. Acidithiobacillus ferrooxidans oxidizes elemental copper contained in the waste to the copper in form of an ion, according to reactions:

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$$Cu + Fe_2(SO_4)_3 \longrightarrow Cu^{2+} + 2Fe^{2+} + 3SO^{3-}$$

$$2FeSO_4 + H_2SO_4 + 0.5O + bacteria \longrightarrow Fe_2(SO_4)_3 + H_2O$$

Limitations of Bioleaching Processes

-Economical: The bacterial leaching process is very slow compared to smelting. This brings in less profit as well as introducing a significant delay in case flow for new plants.

-Environmental: Toxic chemicals are sometimes produced in the process. Sulfuric acid and H^+ ions that have been formed can leak into the ground and surface water turning it acidic, causing environmental damage. Heavy ions such as iron, zinc, and arsenic leak during acid mine drainage. When the pH of this solution rises, as a result of dilution by fresh water, these ions precipitate, forming "Yellow Boy" pollution. For these reasons, a setup of bioleaching must be carefully planned, since the process can lead to a biosafety failure. Unlike other methods, once started, bio heap leaching cannot be quickly stopped, because leaching would still continue with rainwater and natural bacteria.

III. Benefits of recycling of E-waste:

Conserves natural resources: Recycling recovers valuable materials from old electronics that can be used to make new products. As a result, we save energy, reduce pollution, reduce greenhouse gas emissions and save natural resources by extracting fewer raw materials from the earth.

Protects Environment: E-waste recycling provides proper handling and management of toxic chemical substances like mercury, lead and cadmium contained in the e-waste stream.

Creates Jobs: E-waste recycling creates new jobs for professional recyclers and creates a secondary market for recycled materials.

Saves landfills: E-waste recycling saves unnecessary dumps and landfills.

This practice is highly lucrative: The Journal of Waste management says that the revenues generated by the waste management would top by $60 million by 2018. But, there are only a few people who sincerely consider this as an industry into various facets of waste management like recycling and reusing, and reap the benefits. Now many companies are looking forward to associating themselves with this industry and are ready for a long term investment.

Keeps the environment clean and fresh:

Perhaps, the greatest advantage of waste management is keeping the environment fresh and neat. These waste disposal units also make the people go disease free as all the resultant wastes are properly disposed and taken care of. The number of waste disposal units can be placed in all the tier-1 and tier-2 cities so that the waste disposal process can be prepped up. Also a point worthy of our consideration here is that this advantage can be taken into account only if extensive and proper safety measures are implemented along with proper waste disposal techniques. There is no use in simply implementing a half-baked technique which, if no use to both the people and the environment. This is the best effects of proper waste disposal.

A. IV. Disadvantages of Waste Management:

We have now seen the merits of waste management in detail. Let us now have a look at the disadvantages also.

1. The process is not always cost-effective: Yes, though it may pay cash to the contributors, the truth is this process needs a lot of money, time and land to set up a plant and run. As the amount of waste that is being contributed to the waste product unit increases, so are the number of plants that process these resources. Setting up a huge factory obviously needs a lot of money, and this management will start fetching yields only in the long run. Hence, this is not seen as a short-term lucrative investment. While dumping more and more garbages in the landfills cause only $50 per ton, recycling them in the proper manner will cause $150 per ton, which is exactly triple the cost and thus many of the companies tend to switch over to the landfill method itself.

2. The resultant product has a short life:

This is also true since the resulting recycled product cannot be expected to have a durable quality. As the product itself has its origin from the remains of the other trashed waste products and heaps of partially used ones. The recycled product, though, is eco-friendly is expected to have a shorter life span than the intended original one.

1) 3. The sites are often dangerous:

As the waste management sites include the landfills to recycling units under its aegis, these sites are highly susceptible to fungal and bacterial growth thereby leading to various diseases. Even the debris formation will be accelerated by such bacterial growth, which makes it totally unsafe for the workers who work there. It also causes widespread pollution and releases harmful chemicals. These chemicals, when mixed with drinking water or any other consumable item pose a high amount of danger to human health.

2) 4. The practices are not done uniformly:

Still, a large scale of these waste management practices are done only as a small scale process and is mostly confined to residential homes, schools, and colleges and is not practiced in a uniform manner in large industries and conglomerates. It is not even practiced globally, as the global level consists of curbing oil spills, ocean disposals and decreasing the tree felling.

V. CONCLUSION

A systematic approach is required to treat and pollution load from this sector. Much emphasis should be given to collection point that should be located in the society. The transportation and processing of waste need
optimization. All the methods should be evaluated from techno-economical point and their feasibility should be accessed. A single method will not be capable of treating the pollution load but the combination of the methods in step is required to recycle, recover and reduction of pollution load.

provide a reward for those who practice these measures in an effective manner.

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