RESEARCH ARTICLE

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Electronic Waste Management by Biological Leaching

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Abstract: The electronic industry is the largest and fastest growing manufacturing industry in the world. Electronic waste or E-waste is one of the emerging problems in developed and developing countries. Most of these e-wastes are ending up in dumping yards and recycling centers, posing a new challenge to the environment and policy makers as well. Toxic metals in the E-waste are usually non -biodegradable and they will create harmful long lasting negative consequences on the environment in general and our health particular. Currently E-waste is treated by chemical leaching, it gives more environmental issues due to usage of inorganic chemicals in treatment process. So that, the E-waste can be used for extraction of metals by the process of biological leaching. It is the process of extraction of metal from source by using biological organism. In this process involve numerous ferrous iron and sulfur oxidizing bacteria, acidophilic bacteria which is grown in acid medium. The acid mine drainage (AMD) is the outflow of acidic water from metal mines or coal mines. AMD is recognized as one of the most serious environmental problem in the mining industry. It is also toxic and difficult to managing this water. Due to the presence of sulphide metal in the ore, which is released after the mining process, will react with atmosphere and water forms sulphuric acid which poses potential harm to the environment and eco system. This acid medium is most suitable for the development of acidophilic bacteria's. In this project, the Acidophilic bacteria in AMD can be suggested for process of recycling in biological leaching of electronic waste. This process can be used for both bioleaching of E-waste and management of mining waste water. The process will suppress the harmfulness in both E-waste and waste mining water.

Keywords: Electronic waste management, Recycle of E-Waste, Bioleaching, Acid mine drainage management, acidophilic bacteria.

1. Introduction

Electronic industry is the world's largest and innovative industry for its kind. Electronic gadgets are meant to make our lives happier and simpler, but they contain toxic substances, their disposal and recycling becomes a health nightmare. It has penetrated every aspect of our lives and most of us do not think about what happens to these gadgets when we discard or upgrade. The use of electronic devices has proliferated in recent decades and proportionality, the quantity of electronic devices that are disposed of, is growing rapidly throughout the world. E-waste is an emerging problem given the volumes of e-waste being generated and the content of both toxic and valuable materials in them. In this paper, the main objective is to provide the alternate way for management of electronic waste and also reduce the effect of acid mine drainage by using the bioleaching process.

2. Current Disposal Method

Currently following methods are used to get rid of e-wastes they are Incineration, Acid baths, Landfills

2.1 Landfills

E-wastes ending up as landfills are described as toxic time bomb. They may release to the environment after several years by natural means, and there is a possibility of leaching of wastes such as batteries releases acids and heavy metals mercury, nickel and cadmium, electronic circuits have lead, zinc, Nickel, Copper, Mercury and cadmium. These may reach the land water and reaches animals and humans, and mixes with other fresh water sources such as rivers and streams. Almost half the e-wastes of US and Australia are dumped as landfills while the rest are exported to Asia and Africa.

2.2 Acid baths

Acid bath method is used to extract Copper, here the circuit board is submerged in to Sulfuric acid for about 12 hours to dissolve Copper then solution is boiled, precipitated Copper Sulfate is taken and remaining solution is added with scraped particles, subsequently Copper smudges are removed. Acid baths also used to dissolve the lead and in the extraction of Gold and Silver.

2.3 Incineration

Incineration also includes pyrolysis; substances generated during incineration are likely to be more toxic than its ordinary form, pyrolysis heating the substance in the absence of oxygen, here the burning does not occur but the substances are converted to fumes, oils and charcoal. However, in gasification limited air is given to convert the substances into fume, ash and tar. Incineration is commonly used method of the dispersal of e- waste in China, Africa, India and Pakistan. When heating the plastic or PVC circuit board it releases erotic fume consists of Polycyclic aromatics (PCA), polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) which are known carcinogens and gases such as carbon monoxide, sulfur dioxide, nitrogen oxides. Smoke also consists of minor quantities of oxides of following heavy metal residues antimony, lead, thallium, arsenic, copper, manganese, mercury and nickel, reminder ended up in the ashes.

3. Bioleaching

It is the mechanism of transformation of solid components present in the waste materials into soluble element by the microorganism. Sometimes, bleaching is a cost effective method in comparison to chemical leaching. Mainly acidophilic group of bacteria plays an important role in bioleaching of heavy metals from the wastes for instance Acidithiobacillusferrooxidans, Acidithiobacillus thiooxidans, Leptospirillumferrooxidans, and Sulfolobus sp. Microorganisms are active in the formation and decomposition of various inorganic as well as organic matters on the earth's crust. Bioleaching is based on the natural ability of microbes to transform solid metallic compounds toits solubility and extractable form. Autotrophic bacteria (e.g. Thiobacilli sp.), heterotrophic bacteria (e.g. Pseudomonas.

Bacillus sp.) And heterotrophic fungi (e.g. Aspergillussp., Penicillium sp.) are the three major groups of microbes involved in bioleaching of metals. Chemolithotrophs of iron- and sulfur-oxidizing nature (which grow autotrophicallyby fixing CO2 from the atmosphere) are the most important mineral-decomposing microbes. Acidolysis, complexolysis, radiolysis and bioaccumulation are the common mechanism involved in bioleaching. At 40°C or less, mineral biooxidation processes involving the use of microorganisms are believed to be comprised of a consortium of gram-negative bacteria which includes iron- and sulfur- oxidizing A. ferrooxidans. Some workers reviewed rapidly growing microbial-based metal extraction industry, which are utilizing a diversity of microbes that can grow at variable temperatures, involving either rapid stirred-tank or slower irrigation technology to recover metals from their ores. Microorganisms have a tendency to extract metals from its sulfide and or iron-containing ores and mineral concentrates. Iron and supplied are microbial oxidized to produce ferric ion along with sulphuric acid, consequently these chemicals convert insoluble sulfides of metals such as copper, nickel and zinc to soluble metal sulfates that can be readily recovered from the solution. The acidophilic group of bacteria is growing well in low pH medium which range between 1 to 2 pH.

4. Acid Mine Drainage

Acid mine drainage (AMD), also is a natural occurrence resulting from the exposure of sulfur and iron bearing materials to erosion and weather. Percolation of water through these materials results in a discharge with low pH and high metals concentration. Although AMD is naturally occurring, mining activities may greatly accelerate its production. AMD production is accelerated since mining exposes new iron and sulfide surfaces (e.g, underground mine walls, open pit walls, and overburden and mine waste piles) to oxygen. As such, AMD is one of the primary environmental threats at mining sites. To efficiently remediate mining sites, project managers must understand the formation of AMD and those factors that influence its quality and quantity, such as the interaction of sulfide minerals, air, water, and micro-organisms. This section has been added to introduce the project manager to these issues. AMD results from the oxidation of sulfide minerals inherent in some ore bodies and the surrounding rocks. Iron sulfide minerals, especially pyrite (FeS2) and also pyrrhotine (FeS) contribute the most to formation of AMD. Oxygen (from air or dissolved oxygen) and water (as vapor or liquid) which contact the sulfide minerals directly cause chemical oxidation reactions which result in the production of sulfuric acid.

5. Amd Treatment

AMD is treated mainly by two types, they are

- Passive treatment
- Active treatment

5.1 Passive Treatment

Passive treatment of these water is naturally occurring chemical and biological reactions occur in a controlled microbiological chemical reactor without powered mechanical assistance. A passive treatment system is a method for removing metals from acid mine drainage. There are several types of passive treatment systems, each of which may be used on their own or in combination to treat effluents. The type of system selected is dependent upon the chemistry of the acid mine drainage and the flow of the discharge, as well as State and Federal regulations. Passive treatment systems do not require power and are less expensive than active treatment systems. They also require less maintenance, which is an advantage in remote locations.

There are many types of water treatment systems available for removing metals from acid mine drainage. Passive treatment systems are a relatively recent technology that involves using sulfate-reducing bacteria or limestone or both to neutralize acidity and precipitate metals. Passive treatment systems provide a controlled environment in which natural chemical and biological reactions that help in the treatment of acid mine drainage can occur. There are several types of passive treatment systems. The various types of passive methods are,

- Aerobic Wetland
- Anaerobic /Compost Wetland
- Open Limestone Channel
- Diversion wells
- Anoxic Limestone Drain
- Successive alkalinity producing system

5.2 Active Treatment

Mechanical addition of alkaline chemicals to the effuent is used raises pH and precipitate metals. Active treatment technologies involve treating mine drainage with alkaline chemical to raise water pH, neutralize acidity and precipitate metals. Although effective active treatment is expensive when the cost of equipment, chemicals and manpower are considered.

The various active treatment process of AMD water is

- Chemical precipitation
- Oxidation
- Dosing of alkali
- Sedimentation
- Reverse osmosis
- Iron exchange

6. Problem in Amd Water

This happens because these metals are bound to the soil under normal conditions, but the added dissolving action of hydrogen ions causes rocks and small-bound soil particles to break down. These effects occur because acid rain leaches many of the existing soil nutrients from the soil.

One of the activities of the exploitation leads to the formation of acid mine drainage that can have a negative impact on the environment. The negative impact in the form of low water pH and the presence of heavy metals dissolved in the water

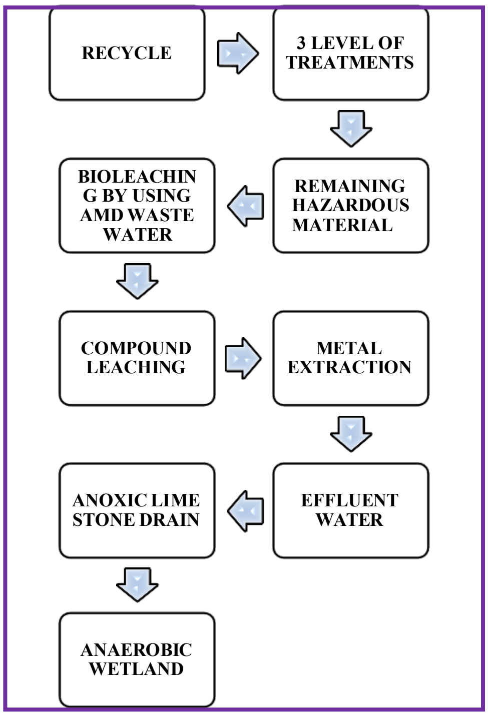
Because of concentration levels, AMD can be 20 to 300 times more acidic than acid rain and can burn human skin and kill fish and other aquatic life. AMD also leaches toxic metals, including arsenic, cadmium, chromium, and lead from waste rock which can cause further pollution.

At metal mines, the target ore (like gold, silver, copper, etc) is often rich in sulphide minerals. When the mining process exposes the sulphides to water and air, together they react to form sulfuric acid. This acid can dissolve other harmful metals and metalloids (like arsenic) from the surrounding rock.

7. Modification of E-Waste Recycle Method

After the recycling process, the most part of the electric and electronic waste are not fully recovered. The remaining semiconducting materials along with the printed circuit board and the various ferrous and nonferrous metals are not recovered or reused due to the high cost for separation of individual components or it may be modernized the old electronic system. The remaining e-waste materials most of the waste are directly dumped into the soil. Dumping of e-waste will cause soil pollution and it will affect the health of the human. so that we need to covert the e-waste into less hazardous material. Leaching is the process which dissolves the materials; this leaching process is also used in the electronic waste management. There are two types one is chemical leaching and another one is biological leaching. In cost wise bioleaching is the cost effective. So that we took bioleaching process for recycle of electronic waste.

Bioleaching is the one of the best method to convert the e-waste into less hazardous by dissolving the metals in the e-waste, in that bioleaching process the bacteria called acidithiobacillus, which is used for the leaching process. This acidithiobacillus bacteria is abundantly present in the acid mine drainage, coal mine drainage or it may acid rock drainage. The acid drainage water is more hazardous to our environment and our ecosystem. So that, we can use these acid mine drainage water of the bioleaching of the electronic waste. These acid mine drainage water also more hazardous by high acidic content present in that water. The acidithiobacillus is more suitable for growing in AMD water because due to the acidic content of this water.



Process Flow Chart

When we use the acid drainage water instead of other chemical leaching process, we will achieve two things one is dissolve and convert the less hazardous of solid electronic waste, and another one is the pH or acidity level of the acid mine drainage water will reduce considerably. After the bioleaching process, the most of the metals in electronic waste are dissolved into the acid mine drainage water, the ferric and nonferric metallic content are get increased in the water. Further we can extract the metal from the water by the separate metal extraction process.

7.1 Collection of Recycle E-Waste

Collection generally takes place at a regional or national level and is achieved through take-back programs sponsored by retails and manufacturers of electronics, municipal drop-off collection centers, and non-profit and for-profit collection programs. There are many different entities which collect e-scrap for recycling, ranging from local municipal governments, to large waste management companies.

7.2 Treatments

Environmentally sound E-waste treatment technologies are used at three levels as described as

- 1st level treatment
- 2nd level treatment
- 3rd level treatment

1st Level Treatment

E-waste items like TV, refrigerator and Personal Computers (PC) Unit Operations: There are three units operations at first level of e-waste treatment

1. Decontamination: Removal of all liquids and Gases

2. Dismantling -manual/mechanized breaking

3. Segregation

All the three unit operations are dry processes, which do not require usage of water.

2nd Level Treatment

There are three unit operations at second level of E-waste treatment

1. Hammering
2. Shredding
3. Special treatment Processes comprising of
   - CRT treatment consisting of separation of funnels and screen glass.
   - Electromagnetic separation
   - Eddy current separation
   - Density separation using water.

3rd Level Treatment

The 3rd level E-waste treatment is carried out mainly to recover ferrous, nonferrous metals, plastics and other items of economic value. The major recovery operations are focused on ferrous and non ferrous metal recovery, which is either geographically carried out at different places or at one place in an integrated facility. The following sections describe the unit operations, processes, available technology and environmental implications.

7.3 Remaining Hazardous Material

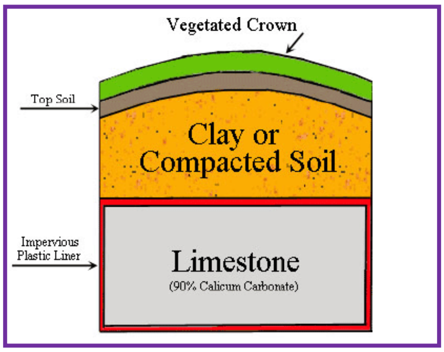
After removing of the ferrous and non ferrous material, the remaining hazardous composite material present in the electronic waste like printed circuit board and this material are in the form of cursed type.

7.4 Bioleaching by Using Amd Waste Water

The remaining hazardous material are dissolve by using bioleaching process, in this process use the acid drainage water ,with the help of acidthiobacillus bacteria that present in the acid mine drainage waste water, the electronic waste will leached

7.5 Compound Leaching

Cost wise the biological leach is better a but the chemical leaching is more efficient and effective, the main Hazard is sulfuric acid used for chemical leaching. For effective leaching process, the compound leaching process is used to dissolve the further remaining metals present in the e waste



Anoxic lime stone drain.

7.6 Metal Extraction

After the compound leaching of the electronic waste, the dissolved metals are present in the leached water are extracted by the metal extraction process. The each and every metal is extracted individual method like copper, silver, gold and other conducting and non conducting materials.

7.7 Effluent Water

After the extraction of metals from the e waste leached water, the remaining water is toxic water and it is flowed out. This water is less toxic compared to the acid mine drainage water. This water is further treatment by the passive treatment of AMD management.

7.8 Anoxic Lime Stone Drain

Compost wetlands, or anaerobic wetlands as they are sometimes called, consist of a large pond with a lower layer of organic substrate. The flow is horizontal within the substrate layer of the basin. Piling the compost a little higher than the free water surface can encourage the flow within the substrate. Typically, the compost layer is made from spent mushroom compost that contains about 10 percent calcium carbonate. Other compost materials include peat moss, wood chips, sawdust or hay. A typical compost wetland will have 12 to 24 inches of organic substrate and be planted with cattails or other emergent vegetation. The vegetation helps stabilize the substrate and provides additional organic materials to perpetuate the sulphate reduction reactions.

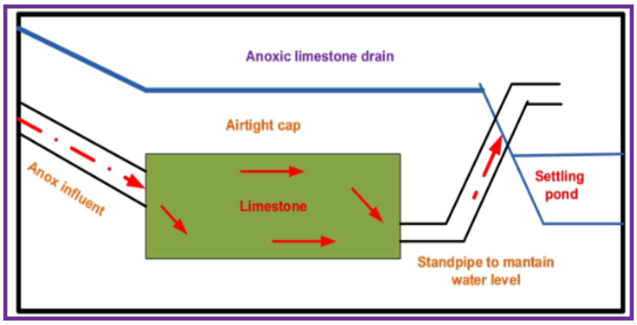
Anoxic limestone drains consist of a buried limestone gravel system that requires the exclusion of oxygen and aluminum in the water. If oxygen or aluminum are present, iron and aluminum hydroxides clog the system, causing failure.

7.9 Anaerobic wetland

Compost wetlands, or anaerobic wetlands as they are sometimes called, consist of a large pond with a lower layer of organic substrate. The flow is horizontal within the substrate layer of the basin. Piling the compost a little higher than the free water surface can encourage the flow within the substrate. Typically, the compost layer is made from spent mushroom compost that contains about 10 percent calcium carbonate. Other compost materials include peat moss, wood chips, sawdust or hay. A typical compost wetland will have 12 to 24 inches of organic substrate and be planted with cattails or other emergent vegetation. The vegetation helps stabilize the substrate and provides additional organic materials to perpetuate the sulphate reduction reactions.

Aerobic wetlands are shallow (1–3 foot deep) ponds, they may be lined or unlined and some are nearly filled with soil or limestone gravel. Such wetlands facilitate natural oxidation of the metals and precipitate iron, manganese, and other metals. Anaerobic wetlands are used to neutralize acidity and reduce metals to the sulfide form.

Anaerobic wetlands may be lined or unlined shallow ponds filled with organic matter, such as compost, and underlain by limestone gravel. Water percolates through the compost, becomes anaerobic and metals precipitate as sulfides. Microorganisms facilitate this reaction by first consuming oxygen. If the system is improperly sized, if flow dries up, or if extended low temperatures are encountered, the microorganisms will die and the performance will be



Anaerobic wetlands

8. Conclusion

The combination of E-waste management by bioleaching and AMD management, the harmful effect of the acid mine drainage will decrease and reduce the level of pH. The acid mine water are not properly treated and the cost of the treatment is high in conventional method. By the combination of this process the cost is more effective.

Comparing to traditional recycle process of e waste, the bioleaching is more effective and less harmful. In this traditional method, we need separate system for both recycling of e-waste and treatment of acid drainage water. When combination of this process, we simplified these two processes in single and we only need to invest for initial cost.

The effluent water that release from the acid mine drainage is more hazardous and harmful to the surrounding environment by normal conventional method. But the combination of anoxic lime stone drainage and anaerobic wetland are used to treated the remaining water in effective manner, and reduce the pH gradually in this process.

References

1. G. Gaidajis, K. Angelakoglou, & D. Aktsoglou, E-waste Environmental Problem and Current Management. *Journal of Engineering Science and Technology*, 3(1) (2010) 193-199.
2. R. Gawikwad, & D. Gupta, Acid Mine Drainage (AMD)Management. *Journal of Industrial Pollution Control*. 23(2) (2007) 285-297.
3. U. M. Jalal, Journal and conference paper on environment E-waste management. *ISOR Journal of Mechanical and civil Engineering*, 2(1) (2012) 25-45.
4. N. Kuyucak, Role of microorganism in Mining Generation of acid Rock Drainage and its mitigation and Treatment. *The European Journal of Mineral processing and Environment Protection*, 3(1) (2002) 179-196.
5. D.M. Musa, A. Ujih, A. Muazu, & H. Rabiatu, Bioleaching an Important Approach for Metal Refinement . *Asian Journal of Applied Sciences*, 3(1) (2015) 82-87.
6. G. Rajiv, E-waste Management in India. *International Journal of Earth Science and Engineering*, 9(2) (2016) 574-588.
7. Santhanam Needhishidasan, Melvin Samuel, & Ramalingam Chidambaram. Electronic waste an emerging threat to the environment of urban India. *Journal of Environment Health Science & Engineering* 12 (2014).
8. C. Shamsul, E-waste Management to Eliminate Environment Pollution for the Greater Good. *Research in Business and Economics Journal*. 11 (2015) 1-9.
9. P. venkaktesa, R. Arulvel, S. Arunkumar, & V. Yoga, Fungal and Bacterial Bioleaching Studies on Bauxite. *International Journal of Bioprocess Technology*, 1(1) (2014) 42-46.
10. J. Yenming, & T. Chen, Effective E-waste management the role of international cooperation and fragmentation. *Munich Personal Repec Achieve Journal*. (2010).

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