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Eliminating the Hazardous Elements from E-Waste by Electrolysis

K. Maheswaran[1], T. Prabaharan[2]

[1]Mepco Schlenk Engineering college, Sivakasi-626 005, Tamilnadu, India.

2 Mepco Schlenk Engineering college, Sivakasi-626 005, Tamilnadu, India.

[1, 2] Department of Mechanical Engineering, Mepco Schlenk Engineering College, Sivakasi, India.

Abstract

Due to the advent of modern technology and sophistication leads to the development of thousands of electronic gadgets and the span of the life is of short duration. These leads to the piling and upheaval of mountainous materials. The managing the e-waste[1] becomes cumbersome due to non availability of suitable methods identified as of now. These being one of the emerging field, different techniques are being employed to initiate the disposal. The developed countries are exporting the e-wastes to the underdeveloped countries. Hence one form of hazards is transferred to the other form. The underdeveloped country people are suffered by Occupational diseases of various kinds and intensity[3]. The disposal and handling of e-waste by means of incinerators, landfill [2] or exporting overseas have become unviable due to the environmental pollution and global legislations. Earlier e-wastes are processed to extract the precious elements which are worthwhile. This paper focuses on effective recovery of hazardous elements from e-waste and makes them to be recyclable. The extraction of the elements includes heavy metals like Lead (Pb), Cadmium (Cd), Copper (Cu) from selected e-wastes of Cathode Ray Tube, Printed Circuit Board. On analysis it is found that the non hazardous process for extracting this metal is electro chemical process[3] which abide the norms laid down by Pollution Control Board (PCB). In this paper various activities being carried out for extracting the heavy metals are spelt out in subsequent topics. This paper not only addresses the e-waste disposal but also the recycling [4] of other materials which includes plastic, ferrous and non ferrous materials. Some mechanical, manual and electrical processes also included in various stages of segregation

Keywords: e-waste, Electrolysis Electro Chemical process, Cathode Ray Tubes (CRT), Heavy metals, Printed Circuit Boards (PCB), hazardous and Pollution Control Board(PCB)

INTRODUCTION:

Advancements in the field of science and technology leads to the sophisitification and comfort for the human society. In the mean while, it is a curse which spoils the environment. The advent of electronic era has brought about the revolutionary changes in the quality of human life and increased the comfort. The other side there was a massive problem of disposal of hazardous wastes generated from these electronic gadgets. The Different variety of electronic scraps/wastes are generated both in electrical and electronic industries which comprises of computers, televisions, mobiles, telephones, etc. and in domestic. These equipments are manufactured utilizing printed circuit boards [5], capacitors, resistance, soldering materials, etc. The scraps are increasing enormously worldwide during production as well as at the end-of-life and with the demand of electronic equipments. The global volume of e-waste generated is expected to reach 110 million tons in 2016 from 41.5 million tons in 2011 at an annual growth rate of 17.6% from 2011 to 2016 [6]. The quantity of the generation of such e-scraps is also increasing drastically in India, China[13] and Korea. In addition, a large quantity of e-waste is also exported to India from the several developed countries. Hence the one form of hazard from their land is transferred to the other area but the ultimate severity remains the same. These e-wastes handling affect the overall population in different forms [7].

These e-wastes contain various metallic and non-metallic values. Some of the substances present in e-wastes are precious and hazardous in nature and their disposal causes not only the loss of resources but also pollutes the environment to drastic extent and affect the health of people involved in segregation and processing. These causes chronic diseases. Most common hazardous chemical elements present in the electrical and electronic equipments are Lead (Pb), Cadmium (Cd), Chromium (Cr), Mercury(Hg), Copper(Cu), Manganese (Mn), Nickel (Ni) and Arsenic (Ar) [8]. These materials are of highly hazardous in nature and affect the health of society overall. In order to make effective utilization of e-waste, different economical methods are being analyzed. The recycling of e-wastes become essential due to the presence of precious metals in it and makes the process economically viable. However, their recycling is very complicated due to the heterogeneity of the materials present in the product. Usually, the physical segregation is followed by hydro / pyro metallurgical processes are being employed for recovering the valuable metallic components from e-scraps. The enriched metallic fraction is leached in acidic/alkaline solution to dissolve the desired components leaving gangue as the residue. In this paper main focus is on the removal of toxic heavy metals from the e-waste and provides the safe disposal method for the other wastages being generated. The metal can be recovered by the application of different processes which includes precipitation, ion exchange, solvent extraction and electrolysis methods. Out of these methods the electro deposition is simple and cost effective one.

SELECTION OF E-WASTE

E-wastes are selected based on the toxicity, severity ranges, criticality and the volume generated which affect the environment to greater extent. The steps taken to process the e-waste has to satisfy the environmental norms [9]. In this paper for the analysis, only two types of e-wastes are being selected. They are CRT's and PCB's wastes were being taken. The major elements that are present in the e- wastes[10], especially in Cathode Ray Tubes (CRT) the materials presented are Lead, Cadmium, Nickel and Glass Materials and in Printed Circuit Board (PCB) the materials are Copper, Lead and Plastics. The processes carried out for separating the e-waste and subsequently explained.

PROCESS DESCRIPTION

1st LEVEL TREATMENT

A)DISMANTLING

The e-wastes are first decontaminated before carrying out the various processes of treatement. The decontaminated e-waste is segregated from the used equipment. The dismantling process could be of manual or mechanized which requires adequate safety measures to be followed in the various operations so that it should not affect the health of the people involved as well as to the nearby area.[11].

In this step the CRT's and PCB's are dismantled from the waste equipments like TV, Computer monitor, Oscilloscopes and PCB contained wastes. The dismantled parts are sent to the next stage of operation for carrying out for further processing.

B) SEGREGATION

After dismantling, the components are segregated as hazardous and non-hazardous components [11]. Then the segregated e-waste fractions are sent for 3rd level treatment. Here the CRT's and PCB's are segregated and sent to the further treatments. In this step the outer plastic covers, internal major iron, copper coils and other reusable materials are removed from the CRT's and PCB's contained wasteags.

Usually this segregation process is done by manually and hence, during this process the employees may exposed to the hazardous environment and can have direct contact to the toxic material is possible. So the employees who are involved in this segregation process should follow all the safety measures and safety norms to avoid health hazard.

2nd LEVEL TREATMENT

A) HAMMERING AND SHREDDING

In 2nd level treatment the two major unit operations are hammering and shredding. The major objective of these two unit operations is size reduction [12]. In hammering process the larger size CRT and PCB wastes are hammered by manually. Due to this operation, the size of the waste will be reduced. After hammering process the shredding process was carried out. In this process the hammered wastes are shredded by using smaller and larger size crushers. After this process, the both CRT and PCB wastes are reduced to micron levels by crushing (100-500microns).

3rd LEVEL TREATMENT

A) SEPARATION OF FUNNELS AND SCREEN GLASS OF CRT

The separation of funnel section and screen glass of CRT monitor has a important role in CRT waste handling. Here the separation was done by laser cutting. A laser beam is focused inside and this heats up the glass. It is immediately followed by a cold water spray that cools the surface of the glass and causes it to crack along the cutting edge [12].

B) ELECTROMAGNETIC SEPARATION

This electromagnetic separation comes under the special treatment processes. In which the shredded wastes are passed through the electro magnet, due to the action of magnetic field , the ferrous materials and non-ferrous materials are being separated. This method is not suitable for CRT wastes because the shredded CRT wastes are contained only glass and non- ferrous materials. But this is efficient for PCB wastes to separate the ferrous and non-ferrous materials, by which we can easily separate the Iron like ferrous materials from shredded PCB waste.

C) DENSITY SEPARATION.

In Density separation a mixture of minerals with different density can be placed in a liquid with an intermediate density, the grains with densities less than that of the liquid will float and grains with densities greater than the liquid will sink [8]. By this method we can separate the plastic materials from the shredded e-waste, because the plastic materials have low density than the metals. Here the shredded PCB waste was placed in the water, the water has intermediate density compare to plastics and metals so in this stage the separation of Plastic matters from the PCB waste was done. This method was not suitable for CRT wastes.

D) METAL EXTRACTION PROCESS

The metals present in the shredded waste are extracted by acid bath method[13]. Acid bath method means soaking of the wastes into powerful acids (H_2SO_4, HCl, and HNO_3, aquaregia) for dissoluting metals in acids for the purpose of separating the metals present in the shredded waste. The metals are dissolved in acids but the glass materials are not dissolved in acid, By this method , we can easily separate the glass materials and metal particles in shredded CRT waste. Here the 2% Sulphuric acid was used, metals in the CRT will react with acid and produce its metallic salts like Lead Sulphate, Cadmium sulphate and hydrogen gas. The separated glass materials are sent for the recycling process. For PCB waste, the shredded PCB waste was soaked in strong Sulphuric acid. Metals in the PCB will react with acid and produce its metal salts and hydrogen gas after the separation of metal from shredded waste. Now we have the solution with dissolved metals.

Metals + Strong acids ---> Salt +Hydrogen gas

E) CALCULATION FOR METAL CONTENT

The total metal content present in the solution was calculated by using ICP (Inductively Coupled Plasma Spectrometry)[15]. Inductively Coupled Plasma has been commercially available for over 40 years and it is used to measure the trace metals present in a variety of solutions [9] especially in effluent analysis. Sample solutions are introduced into the ICP as an aerosol is carried into the center of the plasma (superheated inert gas)[15]. The plasma desolvates the aerosol into a solid, vaporizes the solid into a gas, and then dissociates the individual molecules into atoms. This high temperature source (plasma) excites the atoms and ions to emit light at particular wavelengths, which correspond to different elements in the sample solution[15]. The intensity of the emission corresponds to the concentration of the element detected. Formula for calculating the metal content (mg/kg) is given by

$$metal\ content\ (\frac{mg}{kg}) = \frac{sample\ taken\ \left(\frac{mg}{l}\right) * volume\ of\ sample\ (ml)}{sample\ weight\ (kg) * 1000}$$

RECOVERY OF METALS FROM E-WASTE SOLUTION

There are several methods are available for separation and recovery of metals from solutions, some of them are using a combination of various techniques, such as membrane processes, electrolysis or precipitation, to recover metal ions in the metallic state or as oxides or hydroxides,with the possibility of being reused later, thereby recovering the precious and hazardous materials by electrochemical process. So many health effects are caused during the metal revovery process which includes the metals may affect target organs[11].

The application of electrochemical techniques in the environmental remediation is increasing because, besides being very versatile, they can be applied in the removal of polluting solids, liquids and gases. The recovery of heavy metals from aqueous solutions is one of the examples of the use of electrochemical methods with environmental purposes. In fact, several metal ions in solution can be recovered in the metallic form by reduction at a cathode under specific conditions.

In the case of lead, besides the reduction at the cathode, its oxidation can also take place at the anode, obtaining lead metallic and lead oxide respectively, being both useful products. During the metal ion recovery from solution, cathodic side reactions can take place, like hydrogen evolution or reduction of the dissolved oxygen to form water, thus decreasing the current efficiency of the process. Besides the recovery of isolated metal ions, several papers were also published in what concerns the recovery of metals from mixed solution[13]. In this paper, the deposition of several metals from aqueous solutions containing either a single metal ion or a mixture of metal ions is reported. Metal recoveries were performed under potentiostatic conditions.

A) ELECTRO DEPOSITION

For the convenient of the metal recovery operation the waste solution was maintained at pH range 3.5. The range was adjusted by adding H_2SO_4 and Na_2SO_4. The electrochemical method is mainly based on the electro negativity of the individual metal ions. Generally the metal ions have positive charge so by this electro deposition method we can deposit the metals on the cathodic side and we can recover the metals easily.

The cell had four electrodes connected to the potentiostat /galvanostat: an Ag/AgCl, KClsat electrode as reference electrode; Because of the heavy metals present in the solution so that the Ag/AgCl, KClsat electrodes are selected as reference electrode [13]. The steel plate with 10 cm^2 (both sides) as working electrode; two square platinum plates, 12.5 cm^2 each, as auxiliary electrodes, placed on each side of the steel plate [13].

The platinum plate is used as anode side, because the metal may deposited over the anode also possible due to the chemical reactions in the solution. But the metal cannot deposit over the platinum plate so that the platinum electrode is used as anode.

This electro deposition process was carried out for 180minutes (3hrs) under the acidic condition. Due to the applied potential the metal salts present in the solution gets break and form metal ions. The metal ions normally have +ve charges so we will easily deposit over the cathode electrode (-ve charge). For various applied potential the various metal ions will deposit over the steel plate. The solution was maintained at pH range 3.5 for effective deposition. Applied potentials for deposition of metals on cathode were E=-900 for Cadmium (Fig.1), E=-100 for Copper(Fig.2) and E=-800mV for Lead (Fig.3),. The deposited materials are tested by X-Ray Diffractometer and their XRD patterns were shown below to confirm the corresponding metals.

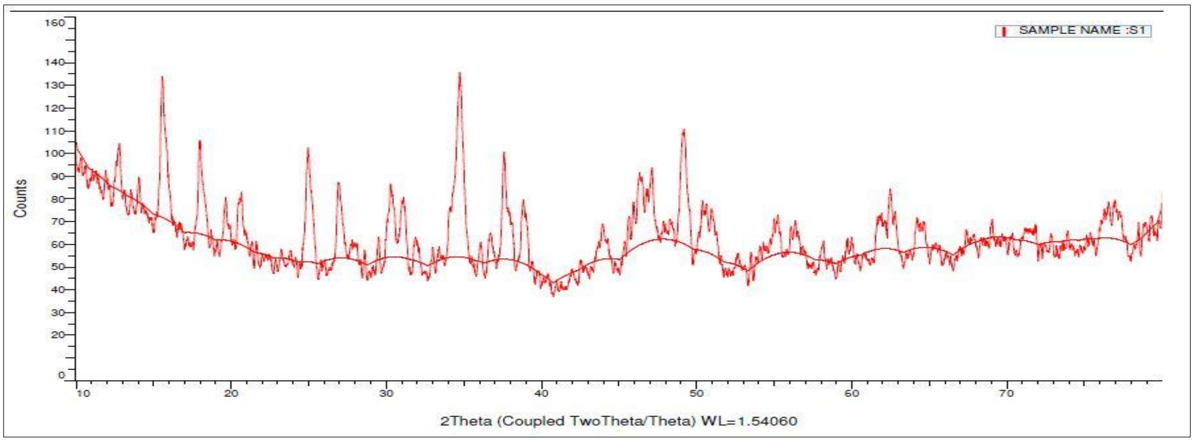

Figure 1: XRD results for Cadmium deposits

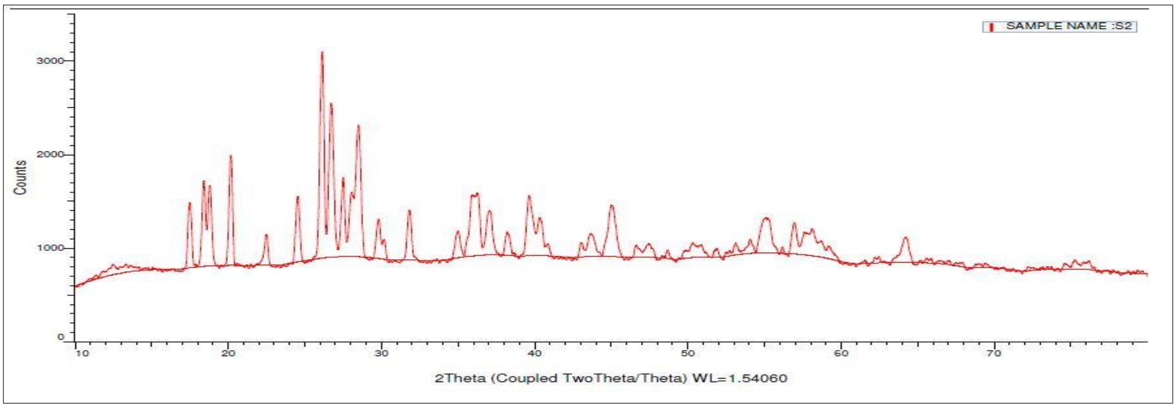

Figure 2: XRD results for Copper deposits

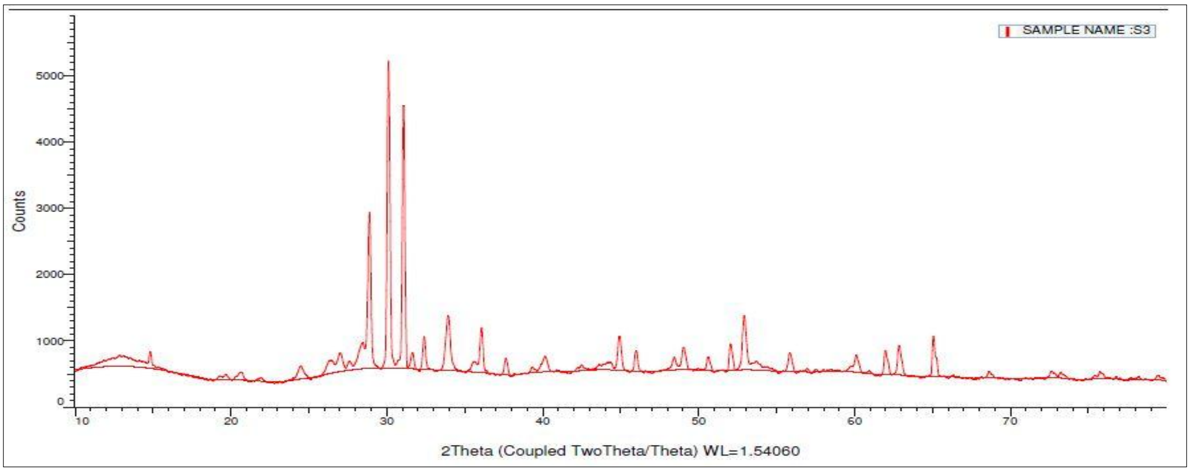

Figure 3: XRD results for Lead deposits

XRD results are also presented in above figures. The experimental diffractograms was analysed and comparing them with XRD datafiles, JCPDS, references (39-1221 for Cd), (80-1916 for Cu) and (85-1289 for PbO).

The metal content deposited is also found out. The following tables will demonstrate the percentage of metal extracted fromn the effluent. Table:1 , gives the metal content before and after the electro deposition processes of the treated effulent. Table.2 gives the treated effluent with the standard.

Table 1: Metal content before and after electro deposition

Heavy Metals	**Metal content in solution before Deposition**	**Metal content in solution after deposition**	**% of Metal removed**
Lead in CRT Waste	0.8805	0.0965	89
Cadmium in CRT waste	0.245	0.002	80
Copper in PCB waste	3.546	0.2773	92
Lead in PCB waste	1.595	0.0556	96

Table 2: Comparison of treated effluent with standards

Paremeters	Central Effluent Standard	Effluent standard for electroplating industries	Treated CRT waste effluent	Treated PCB waste effluent
Suspended solids	100-200 mg/l	120 mg/l	42.3 mg/l	63 mg/l
pH value	5.5 – 9	6 – 9	6.7	6.4
COD	250	-	142.92	163.56
Copper	3	3	-	0.2773
Lead	0.1	0.1	0.0965	0.0556
Cadmium	2	2	0.085	-

C) FINAL DISPOSAL

The effluent from the electro deposition process will be discharged as a water effluent. Other than the reusable materials, the unwanted plastic like things are incinerated and the emission during the incineration process will be monitored. Now days the plastic wastes are used as a fuel in power generation plant so we can use the residue and other waste plastics as a fuel [14]. During the processing of plastics it emits dioxin which is very toxic to atmosphere and human health[14]. By which we can recover the metals effectively from the e-waste and dispose the wastes in safe manner.

CONCLUSION

From the results of material recovered from e-waste. It was founded that the hazardous heavy metals can be removed by this electro chemical process. This causes recovery of precious and hazardous elements from the selected e-waste, it also reducing the pollution of air, water and soil overall. Also it is concluded that final plastic residue may be used as fuel. Further studies may be carried out to reduce the hazardous emissions into atmosphere by proper means of research in the field of incineration.

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REFERENCES

[1] Muhammad Akbar Rhamdhani,A.K. Brooks.G and Masood .S "Metal Extraction Processes for Electronic Waste and Existing Industrial Routes: A Review and Australian Perspective" in journal of Resources 2014, *3*, p.p 152-179.

[2] Jaiswal,A , Samuel,C Bharat S. Patel and Manish Kumar "Go Green with WEEE: Eco-friendly approach for handling e- waste" in journal of Procedia Computer Science 46 (2015) 1317 – 1324

[3] Ascensão, C. Ciríaco L., Pacheco M.J. and Lopes A. "Metal Recovery from Aqueous Solutions" in journal of Portugaliae Electrochimica Acta 2011, 29(5), 349-359.

[4] Anneli Julander, et al.,"Formal recycling of e-waste leads to increased exposure to toxic metals: An occupational exposure study from Sweden" in journal of Environment International 73 (2014) 243–251.

[5] Devin N. Perkins, et al., "E-Waste: A Global Hazard" in Annals of Global Health, Volume 80, Issue 4, July-August 2014, Pages 286-295.

[6] E-waste (management and handling) Rules 2011.

[7] Marie Noel-Brune, et al.," Health effects of exposure to e-waste" inThe Lancet Global Health, August 2013, Volume 1, Issue 2, Page e70.

[8] Gaidajis, G. Angelakoglou K. and Aktsoglou D. "E-waste: Environmental Problems and Current Management" in journal of Engineering Science and Technology Review 3 (1) (2010), pp. 193-199.

[9] Guidelines for environmentally sound management of e- waste (2008)

[10] Kenta Torihara, Tomoaki Kitajima and Nozomu Mishima "Design of a Proper Recycling Process for Small-Sized E-waste" in journal of Procedia CIRP 26 (2015), pp. 746 – 751.

[11] Kristen Grant, et al., "Health consequences of exposure to e-waste: a systematic review" in The Lancet Global Health, December 2013, Volume 1, Issue 6, pp. e350- e361.

[12] Lin Wei and Yangsheng Liu "Present status of e-waste disposal and recycling in China" in journal of Procedia Environmental Sciences 16 (2012) , pp. 506 – 514.

[13] Manis Kumar Jha, et al., "Solvent extraction of copper, zinc, cadmium and nickel from sulphate solution in mixer settler unit (MSU)" in journal of Separation and Purification Technology 122 (2014). pp. 119–127.Pérez-Belis, V. Bovea MD and Ibáñez-Forés V. "An in- depth literature review of the waste electrical and electronic equipment context: Trends and evolution" in journal of *Waste Management & Research* 2015, Vol. 33(1), pp. 3–29.

[14] ICP Optical Emission spectroscopy manual.