ISSN 2349-7203
IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
HUMAN

# EXTRACTION OF GOLD AND OTHER PRECIOUS METALS FROM E-WASTE

**Jaising Gadekar**

*Dnyaneshwar Gramonnati Mandal Ale's Hon.Balasaheb Jadhav Arts, Commerce and Science College, Ale. Tal-Junnar, Dist-Pune, Pin-412411*

**ABSTRACT**

E-Waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use. E-waste is a popular, informal name for electronic products nearing the end of their "useful life." Computers, televisions, VCRs, stereos, copiers, mobile phones and fax machines are common electronic products. Most electronics that are improperly thrown away contain some form of harmful materials such as beryllium, cadmium, mercury and lead. These materials might be trace elements, but when added up in volume, the threat to the environment is significant. However electronic waste also contains fair percentage of precious metals like Cu, Ag, Au, Pd, Rh etc. These metals can be recovered from E-waste at cheaper cost than from the usual ores. Techniques like pyrometallurgy, hydrometallurgy, and biohydrometallurgy are used to recover precious metals like copper, silver and gold.

**Keywords: -** E-waste, PCBs, gold, precious metals, pyrometallurgy, hydrometallurgy, biohydrometallurgy

ISSN 2349-7203
IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
HUMAN

## INTRODUCTION

E-Waste or Waste Electrical and Electronic Equipment (WEEE) is the term used to describe old, end-of-life or discarded appliances using electricity. It includes computers, consumer electronics, fridges etc which have been disposed of by their original users. Precious metals are used in electronics for their superior conductivity and resistance to oxidation. Gold is used as solder and connection pads where good electrical connections are paramount; this is easily seen on cell phone battery connections and on some audio cables [1]. Silver is used in batteries, solder and switches[2]. Palladium is used in capacitors and solder pad [3]. Cell phones and other electronic items contain high amounts of precious metals like gold or silver. For every 1 million cell phones that are recycled, 35,274 lbs of copper, 772 lbs of silver, 75 lbs of gold, and 33 lbs of palladium can be recovered. PCBs contain high amounts of precious metals; about 20 wt% copper, 0.04 wt% gold, 0.15 wt% silver, and 0.01 wt% palladium. The extraction of these metals from PCBs is both profitable and environmentally worthwhile.

### 1.1 Global E-Waste Generation

In 2014, 41 metric tons of e- waste was generated comprising more than 5% of all municipal solid waste. When the millions of computers purchased around the world every year (183 million in 2004) become obsolete they leave behind lead, cadmium, mercury and other hazardous wastes [4]. The global quantity of e-waste in 2014 is comprised of: 1.0 Mt lamps, 3.0 Mt of Small IT, 6.3 Mt of screens and monitors, 7.0 Mt of temperature exchange equipment (cooling and freezing equipment), 11.8 Mt large equipment, and 12.8 Mt of small equipment. 41.9 Total The amount of e-waste is expected to grow to 49.8 Mt in 2018, with an annual growth rate of 4 to 5 percent[5].

### 1.2 Need of E- waste management

More than 70% of the E waste is directly dumped into landfills. Toxic heavy metals are leaching into landfills. Incineration of E-Waste releases heavy metals vapors and toxic gases in the environment. E waste constitutes nearly 2% of the total solid waste but it contains 70% toxic materials of all.

E-Waste contains many valuable metallic and nonmetallic materials. It requires 1 ton of rock to obtain 3 grams of gold from mines. E- Waste is scrap is an ‘urban mine’ that is significantly richer in gold than the sources of the primary ores. We got 200-250 g/t for computer circuit boards. The metal content of waste PCBs can be as high as 40% [6] and such metals typically include Cu, Sn, Pb, Cd, Cr, Zn, Ni, and Mn[7]. Therefore, one special target for waste EEE recycling is PCBs. These waste PCBs can be a rich secondary source of valuable metals. Recycling waste PCBs is useful for not only resource recovery but also protecting the environment[8]

**MATERIALS**

There are a wide variety of materials that can be classified as electronic waste. Each component adds to the complexity of any recycling effort. Below is an exploration of a number of the most common components, by weight.

**2.1 Printed circuit boards**

A printed circuit board (PCB) is the piece of hardware acts as a base and provides electrical connections to the mounted components. They are present in almost all types of electronic waste, including cellphones, computers, TVs, and printers. A PCB is made of a number of components. FR 4 is the most common base material [6] for printed circuit boards[9]. FR 4 is an abbreviation of Flame Retardant 4, referring to its flame resistance and self-extinguishing properties. It is a brittle material formed by hardening a woven fiberglass sheet with an epoxy resin, usually created from ethylene chlorohydrin and bisphenol-A[10]. To give it self extinguishing properties, a brominated flame retardant is incorporated in the epoxy resin. The type glass used to create the fibre glass sheets is S-glass. Content ranges of this glass are by weight are, 52-56% silicon dioxide, 16-25% calcium oxide, 12-16% aluminium oxide, 5-10% boron oxide, 0-2% sodium oxide or potassium oxide, 0-5% magnesium oxide, 0.05-0.4% iron oxide, 0-0.8% titanium oxide, and 0-1% fluorides[10] .

IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
ISSN 2349-7203
HUMAN

### 2.2 Surface mounted components

A wide variety of components are soldered onto printed circuit boards. A resistor is comprised of copper leads attached to a painted ceramic or carbon core[11]. Microchips are composed of small amounts of silicon, aluminium, and copper[12], with plastic coatings. CPUs today have integral aluminium heat sinks and are built on their own printed circuit board. Capacitors contain a variety of metals and plastics, depending on size and type.

### 2.3 Casings

Most consumer electronic devices have plastic casings, such as a TV or a cell phone. Household appliances also have aluminium or steel cases. Other products, such as computer cases have both metallic and plastic components.

### 2.4 CRT monitors

CRT, or cathode ray tube, monitors are currently being phased out in favour of LCD monitors. A CRT monitor consists of the electron gun and focusing equipment, a plastic casing and leaded glass. Lead is present to shield people from the x-rays produced as a by-product of the electron acceleration. An analysis of the glass resulted in the following results, by weight, are 49.61% silicon dioxide, 24.17% lead oxide, 7.79% potassium oxide, 5.32% sodium oxide, 3.63% aluminium oxide, 2.99% strontium oxide, 2.30% calcium oxide, 1.96% barium oxide, 1.49% magnesium oxide, 0.58% zirconium oxide, 0.07% iron oxide and 0.07% phosphorous oxide[13].

### 2.5 Wire

Wire is a common element in electronic waste, as it has a method of connecting to a household wall socket, either through a power cord or charger. Internal wiring is common especially in desktop computers and older audio and video equipment. It is mostly made of copper with plastic insulation, though the connection may be made of a number of metals.

IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
ISSN 2349-7203
HUMAN

**2.6 Precious metals**

Metals are removed by the melting down of all the materials. The metal is the very last material to melt and is easily separated. Precious metals are used in electronics for their superior conductivity and resistance to oxidation. Gold is used as solder and connection pads where good electrical connections are paramount; this is easily seen on cell phone battery connections and on some audio cables. Silver is used in batteries, solder and switches. Palladium is used in capacitors and solder pads.

**3. Process Methodology**

Recycling of e-waste can be broadly divided into three major steps:

a) Disassembly-mechanical pretreatment: selectively removing hazardous and valuable components for special treatment. The remaining waste is shredded, with care that the dust is collected. The dust then undergoes a bioleaching process to remove metals.

b) Concentrating: increasing the concentration of desirable materials using mechanical and/or metallurgical processing and

c) Refining: metallurgical treatment and purification of desirable materials[14]. The flow sheet for E- waste processing is as shown below Fig.1.

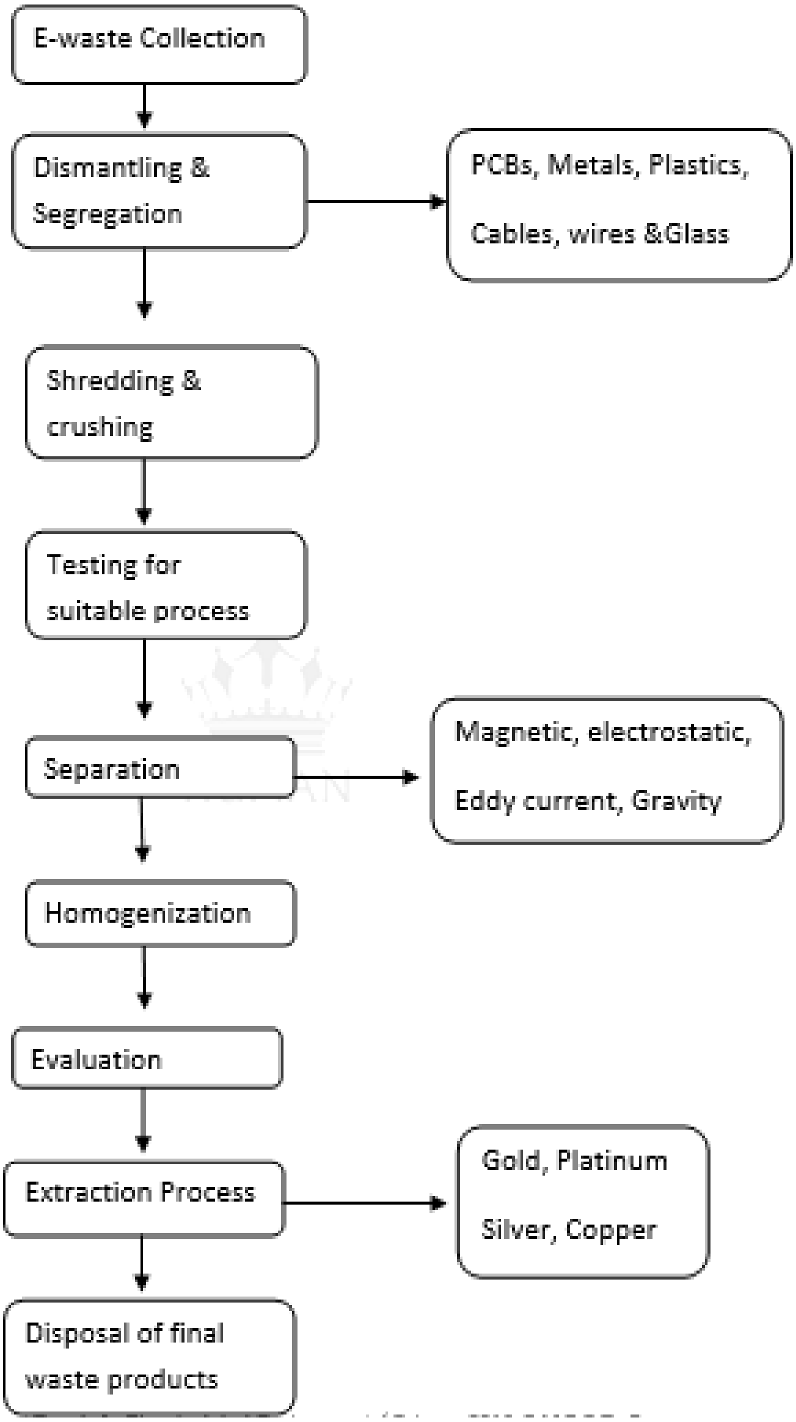


**Figure 1: E-waste treatment for recovery of precious metals.**

IJPPR INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH An official Publication of Human Journals ISSN 2349-7203 HUMAN

**4. Extraction of precious metals**

There are three main process of extraction of precious metals

1. Pyrometallurgy
2. Hydrometallurgy
3. Biohydrometallurgy

**4.1 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 componenets, especially plastics and flame retardants, produce toxic and carcinogenic compounds. The most of the research activities on recovery of base and precious metals from waste PCBs are focused on hydrometallurgical techniques for they are more exact, predictable and easily controlled techniques.[14, 15]

**Dunn's process**

In this process the gold scrap is reacted with chlorine at a temperature with the range of about 300–700 ◦C to form a mixture containing metallic gold, silver chloride, and other metal chlorides. The mixture is washed with air-sparged hydrochloric acid to dissolve the impurity metal chlorides other than silver chloride forming a metallic gold/silver chloride mixture. Then ammonium hydroxide and nitric acid are used respectively for washing the metallic gold/silver chloride mixture to dissolve the silver chloride and the traces of metallic silver from the metallic gold. Gold with 99.9% purity is recovered from gold scraps. Dunn's processing is developed for refining high grade gold materials that contain more than 80% of gold[16].

**4.2 Hydrometallurgy**

Hydrometallurgy is concerned with processes that use aqueous solutions to extract metals from ores. The most common hydrometallurgical process is leaching, which involves

IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
ISSN 2349-7203
HUMAN

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[17]. 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 [18].

**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) [21].

$$4Au + 8CN^- \longrightarrow 4Au\,(CN)_2^- + 4e \quad (1)$$

$$O_2 + 2H_2O + 4e \rightarrow 4OH^- \quad (2)$$

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.

**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

IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
ISSN 2349-7203
HUMAN

thiourea leaching are high cost and consumption because of its poor stability. Several studies highlighted thiosulfate leaching of gold. Thiosulfate leaching is operated in alkaline condition to prevent thiosulfate decomposition [22]. Ha [23] reported that 98% gold could be recovered using a solution containing 20 mM copper, 0.12M thiosulfate and 0.2M ammonia. The reaction happening in the thiosulfate leaching is shown in the following equation.

$$Au + Cu\,(NH_3)_4^{2+} + 5S_2O_3^{2-} \longrightarrow Au\,(S_2O_3)_3^{5-} + Cu\,(S_2O_3)_3^{5-} + 4NH_3$$

**4.3 Biohydrometallurgy or 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 alkaline environment (involving cyanegenic bacteria), acidophilus microorganisms and conducting 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 niger*are 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 is 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 [25]. *Acidithiobacillus ferrooxidans* oxidizes elemental copper contained in the waste to the copper in form of ion, according to reactions:

$$Cu + Fe_2\,(SO_4)_3 \longrightarrow Cu^{2+} + 2Fe^{2+} + 3SO_4^{3-} \quad (1)$$

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

IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
ISSN 2349-7203
HUMAN

The concentration of $Fe^{3+}$ ions, pH and the number of used microorganisms playa crucial role in the leaching process of metals from solid state to solution [26].

**CONCLUSION**

E- Waste is a one of the biggest problem we are facing worldwide. To overcome this we need to process the e-waste. E-waste contains hundreds of hazardous materials which cause threats to environment as well as human beings. Thus this waste should be properly treated instead of dumping into landfills. The collected E-waste is pretreated and subjected to recovery of precious metals. The E-waste also contains valuable metals in it. The cost of metal recovery from E-scrap is much less as compared to extraction of these metals from mining ores. This processing is not only a new business to get money but helps directly environment too. We have to re-evaluate our needs of electronic gadgets. We need to try finding one device with multiple functions. We must extend the life of your electronics. Buy environmentally friendly electronics**.** Donate used electronics to social programs and help victims of domestic violence, children safety initiatives, environmental causes, and more. Reuse large electronics**.**



**REFERENCES**

1. http://www.azom.com/Details.asp?ArticleID=1899 Accessed November 24, 2008.
2. http://www.edrsilver.com/i/pdf/2008-03-07_HR.pdf Accessed November 25, 2008.
3. http://www.stillwaterpalladium.com/electronics.html Accessed November 25, 2008.
4. Press Release, “Basel Conference Addresses Electronic Wastes Challenge.” November 27, (2006) United Nations Environment Programme (UNEP). Available at http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=485&ArticleID5431.
5. Baldé, C.P., Wang, F., Kuehr, R., Huisman, J. (2015), “The global e-waste monitor – 2014,” United Nations University, IAS – SCYCLE, Bonn, Germany; http://i.unu.edu/media/unu.edu/news/52624/UNU-1stGlobal-E-Waste-Monitor-2014-small.pdf Page 22-24
6. Sheng P. Etsell T. (2007). Recovery of gold from computer circuit board scrap using aqua regia. Waste Manage. Res. 25, 380–383.
7. Tuncuk A. Stazi V. Akcil A. Yazici E. Deveci H. (2012) Aqueous metal recovery techniques from e-scrap: Hydrometallurgy in recycling. Minerals Eng. 25, 28–37.
8. Behnamfard A.,Salarirad, M. Veglio,F. (2013) Process development for recovery of copper and precious metals from waste printed circuit boards with emphasize on palladium and gold leaching and precipitation. Waste Manage. 33, 2354–2363.
9. Coombs C. (2001) Printed Circuits Handbook Fifth Edition, McGraw-Hill, New York, section 6.
10. http://www.p-m-services.co.uk/how% 27s_fr4_made_.htm Accessed Nov. 7, 2008.
11. http://www.ecawa.asn.au/home/jfuller/electronics/resistors.htm Accessed Nov. 11, 2008.

12. http://www.intel.com/education/makingchips/index.htm Accessed Nov. 11, 2008.
13. Chen M.( 2008), Lead recovery and the feasibility of foam glass production from funnel glass of dismantled cathode ray tube through pyrovacuum process, Journal of Hazardous Materials, currently unprinted, 2.
14. Cui L J.Zhang (2008) Metallurgical recovery of metals from electronic waste: A review, Journal of Hazardous Materials, 158 (2-3), 228–256.
15. Lee J. C. Song H. T. Yoo J. M. (2007) Present status of the recycling of waste electrical and electronic equipment in Korea, Resources, Conservation and Recycling 50 (4), 380–397
16. Dunn J. Wendell E. Carda D.D (1991) chlorination process for recovering gold values from gold alloys, US Patent, US5004500.
17. Source: Boundless. (2016) Extractive Metallurgy." *Boundless Chemistry* Boundless, 26 -27.
18. https://www.boundless.com/chemistry/textbooks/boundless-chemistry-textbook/metals-20/metallurgic-processes-142/extractive-metallurgy-559-3578.
19. Tuncuk A, Stazi V, Akcil A, Yazici EY, Deveci H (2012) Aqueous metal recovery techniques from e-scrap: Hydrometallurgy in recycling. Miner Eng 25: 28-37.
20. Syed S (2012) Recovery of gold from secondary sources-A review. Hydrometallurgy 115-116, 30-51.
21. Hilson G. Monhemius A.J.(2006) Alternatives to cyanide in the gold mining industry: what prospects for the future? J. Cleaner Prod. 14 (12–13), 1158–1167.
22. Dorin R. Woods R.(1991) Determination of leaching rates of precious metals by electrochemical techniques, J. Appl. Electrochem. 21 (5), 419.
23. Hilson G, Monhemius A.J (2006) Alternatives to cyanide in the gold mining industry: What prospects for the future? J Clean Prod 14: 1158-1167.
24. Ha V.H. Lee J.C. Jeong J. Hai H.T. Jha M.K (2010) Thiosulfate leaching of gold from waste mobile phones. J Hazard Mater 178, 1115-1119.
25. Silesian University of Technology, Department of Metallurgy, ul. Krasińskiego 8, 40-019
26. Rohwerder T. Gehrke T. K. Kinzler. K. (2003) progress in bioleaching: fundamentals and mechanisms of bacterial metal sulfide oxidation, Appl.Microbiol. Biotechnol. 63 (3), 239–248.
27. Tao yang, Zheng X.U. Jiankang N.(2009) Factors influencing bioleaching copper from waste printed circuit boards by Acidithiobacillus ferrooxidans, Hydrometallurgy, 97(1, 2), 29.