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E-Waste Indian Perspective And Recovery of Valuable Metals From E-Waste-A Review

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Abstract:- Innovation in information technology leads to obsolesce of electronic component. Due to high rate of obsolesce and damages in electronics components alarming waste generation in developed and developing countries. According to Indian scenario only ten states contributes 70% of the total E-waste. Developed countries minimize their E-waste using export strategies to developing countries. E-waste contains hazardous element and cause serious problem on human health and environment due to their improper disposal and handling. Apart from hazardous component electronics and electrical component contains precious and heavy metals that should be recover as they have its economic value. Recovery of precious metal is worthy than extracting from ore. For Inbound recycling process Manufacturers, government, council etc are the main body of E-waste supplier. In this article, we described E-waste generation by different countries, Indian scenario of E-waste, compositions of different metals in electronics components, recycling strategies, percentage recovery of precious, and heavy metals using different leaching agent including biological bacteria. Different authors described that more than 90% recovery of heavy and precious metals can obtained from E-waste like CRT, PCB and batteries.
Keywords:- E-waste, Forecast, Compositions, Recycling, Recovery, Precious metal

I. INTRODUCTION

In this information technology era, electrical and electronic component is integral part of our daily life. Demand of electronic gadgets increase day by day may be due to short lifespan and use of innovative technology. For Example earlier days life span of computer approximately 4.5 years in 1995, recently which get decrease to only 2 to 2.5 years in 2005 (Widmer *et al*., 2005). Many advances taking place in electronic gadgets like CRT to LED or LCD for Television and computer, keypads of mobile phone to smart phones etc. Due to obsolesce of these old gadgets and technology they contribute 90% of E-waste generation. Every year 20-50 million tonnes of E-waste generate globally (Davis and heart. 2008, UNEP Press). E-waste quantities increase 3-5% at every year which is three time faster than urban solid waste (Hischier *et al*., 2005).

In 2013, globally E-waste production was 39.8 million tonnes, which increased 2 million tonnes and reaches to 41.8 million tonnes in 2014 (UN report-2014). One third of world's total E-waste discarded in U.S and China in 2014 (Balde *et al*., 2015). In developing countries generation of E-waste, dramatically increase in last seven decades. Major electronic gadgets that contribute to E-waste generation are CRT, CD's, Computer, Mobile, etc.

E-waste from developing countries exported to some developed countries that are also contributing of total E-waste generation in developing countries like India, Bangladesh, Pakistan, etc. Developing countries export about 80% of total E-waste (Hicks *et al.,* 2005). At the end of the year 2007 USA was the largest E-waste generator in the world followed by China, Japan, India and South Africa. USA generated total 2.25Mt of E-waste in the year of 2007, which tremendously increase in 2012 up to 9.04Mt (Table-1).

E-waste contains toxic and hazardous component, which affect to human and environment due to improper handling and disposal (Jain 2009). More than 1000 hazardous elements are use in manufacturing of electronic components. Electronic components also contain some heavy metals like Cu, Al, Zn, Fe, etc. Some time it is very profitable to recover metals from E-waste than extracting ore from mine (Pradhan and Kumar, 2012). For example, recovery of precious and heavy metal content 10 times richer in PCB than rich-in ore from mine (Syed, 2013). Therefore, it realizes that recycling of E-waste is prime important to avoid health hazard and from economic point of view (Robinson 2009; Widmer *et al*., 2005). Different countries have their own recycling strategies according to their legislation. In 2009, E-waste generated by U.S.A was 3.19 million tonnes; only 17.7% of e-waste was recycled (Electronics Take Back Coalition, 2012). After U.S.A, percentage of E-waste recycled was China followed by EU, India and Japan (Zoeteman *et al*., 2010).

Table-1 E-waste generated by different countries

No	Countries	E-waste generation Mt-2007	E-waste generation Mt-2012	E-waste generation Mt-2014	Collection and treatment routes
1	U.S.A	2.25	9.40	7.10	Municipal waste service: A number of voluntary scheme, export to different countries
2	China	2.12	7.30	6.00	Mostly informal collection and recycling
3	Japan	0.86	2.70	2.20	Collection via retailers
4	India	0.44	3.03	1.70	Informal and formal
5	South Africa	0.59	0.30	0.35	Informal and formal
6	Reference	Ongondo et al (2011)	Vats et al (2014)	Balde et.al (2015)	Ongondo et al (2011)

II. CATEGORIES OF E-WASTE

Especially in India due to very lack information about recycling process, also people do not know how to dispose their unused electronic equipments, only 40% obsolete electronic product unused at home (Saphores et al., 2009, Kumar and shah 2014). Major source of E-waste comes from following sectors, Large household appliance (42.1%), Small household appliance (4.7%), Consumer Equipment (33.9%), Lighting equipment (13.7%), Electrical and electronic tools (1.4%), Toys, and Leisure and sports equipment (1.4%), Medical devices (0.2%) (Nageswara rao 2014).

Life span and weight of electronic component play vital role in generation of E-waste. Due to innovation in science and technology, some features and capabilities changed and life span of electronic gadgets and weight get decrease. For example, in 1997 life span of central processing unit was 4 to 6 years and it getting decrease to 2 years in the year of 2005 (Babu *et al*., 2007). Life span and weight of electronic gadgets with their label can see in Table 2.

Table-2 Categories of E-waste

Item	Mass(Kg)	Life span (Yr) 2005	Category of E-Waste[4]	Label for identification[5]
Personal computer[1]	25	3.0	IT and Telecommunication Equipment	ICT
Fax machine[2]	3.0	5.0	IT and Telecommunication Equipment	ICT
Hi-fidelity system[3]	10	10	Consumer equipment	CE
Cell phones[3]	0.1	2.0	IT and Telecommunication Equipment	ICT
Photocopier[2]	60	8.0	IT and Telecommunication Equipment	ICT
Radio[3]	2.0	10	Consumer equipment	CE
Television[4]	30	5.0	Consumer equipment	CE
Refrigerator[3]	35	10	Large household appliances	Large HH
Telephone[3]	1.0	5.0	IT and Telecommunication Equipment	ICT
Tumble dryer[3]	35	10	Small household appliances	SHH
Washing machine[3]	65	8.0	Large household appliances	Large HH

[1] Betts 2008, [2] Robinson 2009, [3] Cobbing 2008, [4] Li et al., (2009), [5] Sayed et al., (2013)

2.1 Hazardous Elements In Electronic Components

Different types of elements exists in E-waste such as ferrous, Non-ferrous, plastic, etc, some of them exist in hazardous and toxic limit that can harmful to human health and environment if not properly handle. E-waste contains more than 1000 toxic substance, various toxic components reported are barium (Ba), beryllium (Be), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), lithium (Li), lanthanum (La), mercury (Hg), manganese (Mn), molybdenum (Mo), nickel (Ni), silver (Ag), hexavalent chromium (Cr(VI)) and persistent organic pollutants (POPs) such as dioxin, brominated flame retardants (BFRs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), Polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/Fs), Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and polyvinyl chloride (PVC), (Table 3).

Table-3 E-waste: Hazardous Elements (Guo *et al*., 2010, Puckett and Smith 2002)

Element	Source	Health effects
Sb	Melting agent in CRT glass, plastic computer housings and a solder alloy in cabling	Stomach pain, vomiting, diarrhea and stomach ulcers through inhalation of high antimony levels over a long time period
As	Gallium arsenide is used in light emitting diodes	It has chronic effects that cause skin disease and lung cancer and impaired nerve signaling

Ba	Sparkplugs, fluorescent lamps and CRT gutters in vacuum tubes	Causes brain swelling, muscle weakness, damage to the heart, liver and spleen though short-term exposure
Be	Power supply boxes, motherboards, relays and finger clips	Exposure to beryllium can lead to beryllicosis, lung cancer and skin disease. Beryllium is a carcinogen
Cd	Rechargeable Ni-Cd batteries, semiconductor chips, infrared detectors, printer inks and toners	Cadmium compounds pose a risk of irreversible impacts on human health, particularly the kidneys
Pb	Solder, lead-acid batteries, cathode ray tubes, cabling, printed circuit boards and fluorescent tubes	Can damage the brain, nervous system, kidney and Reproductive system and cause blood disorders. Low Concentrations of lead can damage the brain and nervous system in fetuses and young children. The accumulation of lead in the environment results in both acute and chronic effects on human health
Hg	Batteries, backlight bulbs or lamps, flat panel displays, switches and thermostats	Mercury can damage the brain, kidneys and fetuses
Ni	Batteries, computer housing, cathode ray tube and printed circuit boards	Can cause allergic reaction, bronchitis and reduced lung function and lung cancers
PVC	Monitors, keyboards, cabling and plastic computer housing	The incomplete combustion of PVC release huge amounts of hydrogen chloride gas, which form hydrochloric acid after combination with moisture. Hydrochloric acid can cause respiratory problems

There are mainly two methods of E-waste disposal (1) Landfill (2) Incineration. Landfill cause ground water pollution due to transfer of toxic substance in to the land. Incinerations cause Air pollution due to combustion of E-waste that emits toxic gases into environment. During recycling process, toxic element directly affect to workers. Near recycling areas, peoples are suffering from disease due to recycling process. For example, in china high level of PBDE observed near recycling areas (Qu *et al*. 2007).

2.2 Composition Of E-Waste

E-waste contains computers and its accessories, mobile phones, laptops, printers, Compact disk, etc. E-waste classified as hazardous and non-hazardous. It contains ferrous and non-ferrous metals, wood, glass, ceramics. Ferrous metal contributes 50%, non-ferrous metal 13% and plastic 21% in electronic components. In No-ferrous metal, it consist mainly heavy and precious metals like Pb, Hg, Cd, Zn, Cu, Al, Ag, Au, Se and so on. Different metal compositions in electronic gadgets can see from Table 4. Metallic compositions and its position in electronic components may vary from type and age of electronics.

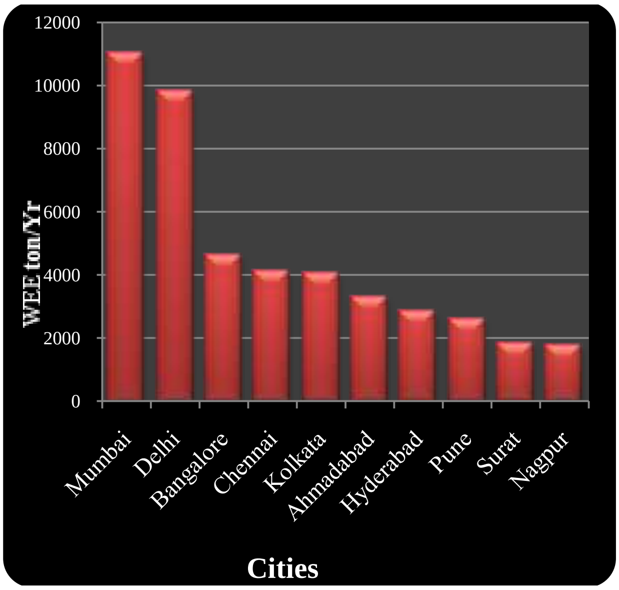
Table-4 Metal composition of different electronic component

Metal (wt %)	TV board	PC board	PCB(mobile)	PCB(Comp.)	DVD player	LI-Ion batteries	CRT
Al	20	5	NA	11.7	2	4.3	1.44
Ba	NA	NA	NA	NA	NA	NA	0.68
Ca	NA	NA	NA	NA	NA	NA	3.10
Fe	28	7	0.28	15.21	62	0.05	0.59
Na	NA	NA	NA	NA	NA	NA	5.90
Pb	NA	NA	1.36	6.70	NA	NA	25.1
Zn	NA	NA	0.41	1.86	NA	NA	0.16
Mg	NA	NA	NA	NA	NA	NA	1.09
Cu	10	20	40.8	30.57	5	22.13	NA
Sn	NA	NA	1.60	7.36	NA	NA	NA
Ni	NA	NA	0.39	1.58	NA	0.26	NA
Au	20(ppm)	250(ppm)	0.0065	238mg/kg	15	NA	NA
Ag	280(ppm)	1000(ppm)	0.106	688mg/kg	115	NA	NA
Pd	10	110	0.005	NA	4	NA	NA
Li	NA	NA	NA	NA	NA	2.87	NA
Co	NA	NA	NA	NA	NA	23.67	NA
Reference	Khaliq et al. 2014	Khaliq et al. 2014	Xiu et al. 2015	Birloaga et al. 2013	Khaliq et al. 2014	Jha 2013	Zhang et al. 2013

III. E-WASTE: INDIAN PERSPECTIVE

In India particularly after 2004 number of studies carried out on E-waste generation and its recycling. Estimation of E-waste generation is independent studies, which estimates by government agencies. Major E-waste generation states are Maharashtra, Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab. These ten states contribute about 70% E-waste of total E-waste generated in India (Financial Express 2008).

Maharashtra is the biggest hub of electrical and electronic manufacturing states in India. Maharashtra generates 20275.29 ton per year, which is highest E-waste generating states in India (Figure 1). Mumbai is the biggest E-waste generating cities among all Indian cities. Indian cities contribute 60% of total E-waste in India. More than 1000 ton of E-waste generates only ten cities per year such as Mumbai, Delhi, Bangalore, Chennai, and Hyderabad, Pune, Surat, Nagpur (Figure 2).



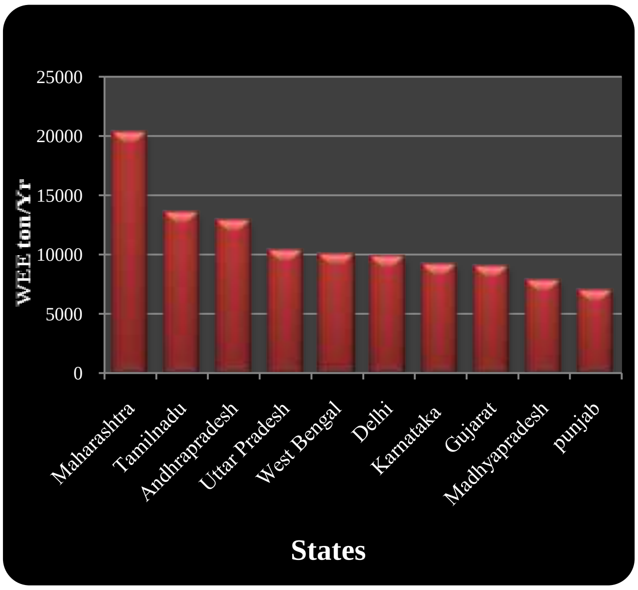


Figure-1 Top 10 states E-waste generation in India newsletter parisana, 2011)

Figure-2 Top 10 cities E-waste generation in India (Envis (Yoheeswaran 2013)

Televisions and desktop is the major E-waste generator in India, which estimated by An Indian market Research Bureau (IMRB) survey of 'E-waste generation at Source in the year of 2009. Television and Desktop contributes 68% and 27% respectively.

In India, labors are available easily at low wages for dumping of E-waste. It is very cheaper to dump electronic waste in India for developing countries (Chatterjee and Kumar 2009). India is one of the highest importing of E-waste in the world. Approximate e-waste importing is 50,000 tonnes at every year in India. U.S.A is the largest E-waste exporting country in India followed by China, European Union, Germany, Denmark, etc (Figure 3).

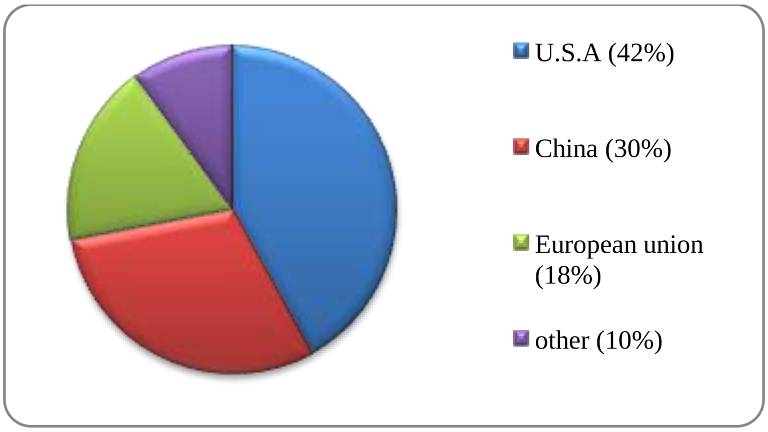


Figure-3 Import of e-waste in India (Atterio)

3.1 Sales Of Electronic Devices

Sales of electronics devices affect the economics of country and alarming the E-waste generation due to high sailing of devices. Sales of electronic devices changes yearly with innovative technology. For example, demand of computer in 2003-2004 was 3.1 million units, which jump to 6.778 million units in 2012 (MAIT report). People buy mobile phone at very large scale within short period, less than decades. Mobile phone market is three times higher than television and PC. So that at every two years people change their mobile phones than other appliances (IDC report 2013). Televisions are available at affordable cost due to very low import duty on LCD panel and other parts of TV (Consumer report-2013). Due to certain advantages of laptops over computer people move towards laptops, so that sailing of laptops in last few years increases compared to desktop (Table 5).

Table-5 Sales E-Component in million units up to 2013 in India (MAIT,'IT industry performance annual report)

Year	2007	2008	2009	2010	2011	2012	2013
Desktop	5.522	5.28	5.22	6.016	6.71	6.778	5.015
Laptops	1.822	1.516	2.508	3.284	4.022	4.421	6.849
Mobile phones	-	94.6	100.9	166.5	213	231	251
Television	13.28	14.53	15.77	17.14	18.45	19.8	21.1

3.2 Forecasting Of Sales

Impressive tool for predicting the sales of different component is regression analysis in excel using pastyear sales. Plotting the data between sales of devices and sales year in excel. From the trend line equation, sales of device in next year can easily predict. In this paper sales of different devices from 2007-2013 is list out in Table 5. From the past year 2013 trend line equation for Desktop, Laptop, Mobile phone and TV generated using regression analysis in excel. For example, trend line equation for Desktop sales given below.

$y = 0.105x - 207.0$ (1) *where, y = million unit sales, x = sales year*

Suppose we have to predict total sales unit in 2014, so from equation (1) predicted value is 4.47 million units. Similarly for laptop, mobile phone and TV trend line is

$y = 0.800x – 1604$ (2)
$y = 34.82x – 69835$ (3)
$y = 1.31x – 2615$ (4)

Based on equation (1), (2), (3) and (4), Sales of Desktop, Laptop, Mobile phone and TV predict for 2014-2020 respectively (Table 6).

Table 6 Forecast of Sales E-Component in million units (2014- 2020) in India

Year	2014	2015	2016	2017	2018	2019	2020
Desktop	4.47	4.57	4.68	4.78	4.89	5.0	5.1
Laptops	7.2	8.0	8.8	9.6	10.4	11.2	12.0
Mobile phones	292.48	327.3	362.12	396.94	431.76	466.58	501.4
Television	23.34	24.65	25.96	27.27	28.58	29.89	31.20

3.3 Forecasting of E-waste generation

A data of forecasting of E-waste is very helpful for implementing recycling technology and for minimizing E-waste generation. These predicted data of E-waste generation also useful for planning, storage and handling of E-waste. From the data of number of sales unit (N) Table 5, Mass (M) and lifespan of device (L) Table 2, E-waste generation can predict using equation (5), (Gaidajis *et al*., 2010).

$$E= MN/L \quad (5)$$

For example, expected sales of computer in 2015 will be 4.57 million units, weight and lifespan of Desktop is 25kg and 2 yrs respectively. According to equation (5), expected E-waste generation due to Desktop will be 38.04 million kg. From Table it is observe that generation of E-waste can reach up to 2.72Mt in 2020.

Table 7 E-waste prediction (million Kg)

Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Desktop	37.25	38.04	39	39.83	40.75	41.66	42.5
Laptops	10.8	12	13.2	14.4	15.6	16.8	18
Mobile phones	14.62	16.35	18.1	19.84	21.58	23.33	25.07
Television	140.04	147.9	155.76	163.62	171.48	179.34	187.2
Total	**2216.71**	**2229.29**	**226.06**	**237.69**	**249.41**	**261.13**	**272.77**

IV. RECYCLING OF E-WASTE

Recycling of E-waste classified as (1) Formal recycling (2) Informal recycling

(1) Formal recycling: - In formal recycling, recycling of E-waste carried out by authorized and government approved recycling company. Only 5% of the total E-waste treated in formal sector while remaining 95% E-waste treated in informal sector (Khattar et al., 2007).

Table-8 Registered Recycling E-waste Companies in India (Kumar and Shah D 2014)

No.	**Recycling Company**	**Location**	**Recycling capacity (MTA)**
1.	M/S Ramky E-Waste Recycling Facility(Ramky Environ Engineers Ltd)	Maheshwaram, Andhra Pradesh	10,000
2.	M/S Earth sense Recycle Pvt. Ltd.	Rangareddy Andhra Pradesh	1800
3.	M/S Ash Recyclers Unit II	Bangalore, Karnataka	120
4.	M/S New Port Computer Services (India) Private Ltd.	Bangalore, Karnataka	500
5.	M/S EWA RDD & Co.	Bangalore, Karnataka	600
6.	M/S E-R3 Solutions Pvt. Ltd.	Bangalore, Karnataka	120,000 Units
7.	M/S Ash Recyclers, Unit I	Bangalore, Karnataka	120
8.	M/S E-Parisana Pvt. Ltd.	Bangalore, Karnataka	1800
9.	M/S Surface Chem. Finishers	Bangalore, Karnataka	600 Kg/Annum
10.	M/S Jhagadia Copper Ltd.	Bharuch, Gujarat	12,000
11.	M/S Eco Recycling	Thane, Maharashtra	7200
12.	M/S Earth Sense Recycle Pvt. Ltd.	Thane, Maharashtra	360
13.	M/S Hi- Tech Recycling India (P) Ltd	Pune, Maharashtra	500
14.	M/S Greens cape eco management Pvt. Ltd	Alwar, Rajasthan	450
15.	M/S Trishyiraya Recycling India Pvt. Ltd	Chennai, Tamil Nadu	740
16.	TES AMM Private Ltd.	Kanchipuram, Tamil Nadu	30,000
17.	M/S Global E-waste Management and Services (GEMS)	Kanchipuram, Tamil Nadu	387
18.	M/S Victory Recovery and Recycle Technologies India Pvt. Ltd.	Thiruvalluvar, Tamil Nadu	6000
19.	M/S Ultrust Solutions (India) Pvt. Ltd.	Thiruvalluvar, Tamil Nadu	1500
20.	M/S INAA Enterprises	Chennai, Tamil Nadu	300
21.	M/S TIC Group India Pvt. Ltd.	Noida, Uttar Pradesh	1000
22.	M/S Attero Recycling Pvt. Ltd.	Roorke, Uttarakhand	12,000
23.	M/S Earth Sense Recycle Pvt. Ltd.	Gurgaon, Haryana	1200

E-waste recycling carried out environment friendly by applying best available technology with enhancing the source of recovery. Formal recycling is stepwise procedure followed to carry out E-waste recycling with rules and regulation of environment. Total 23 companies registered at central pollution control board in 2010 (Table 8). From these recycling companies Kanchipuram (Tamil Nadu) has highest capacity of recycling of E-waste with capacity of 30,000 MTA. In India, total seven recycling companies in Bangalore (Karnataka) out of 23 units (Table 8).

(2) Informal recycling: - Recyclers does not dealt with government agencies or they do not authorized with central pollution control board. India faces a big problem of health hazard and environments due to recycling of E-waste by informal sector. In India, recycling of E-waste mostly carried out by informal sector. Recyclers are separate valuable components and unusable parts are either burn or disposed with expense of hazardous toxic substance expose to environment. E-waste recycling in informal sector carried out at small workshop or at home with polluting surrounding and without health protection measures (Chatterjee and Kumar, 2009). Delhi is the main hub of recycling of E-waste in the world. Total 70% of E-waste generated in developed countries finds its way to reduce it in to usable material at Delhi. Although recycling of E-waste by informal manner is high risk to human and environment, there are total 20 recycling location in Delhi such as Mayapuri, Turkman Gate, Wazirabad, Mandoli, Kirti Nagar, Seelampur, Shastri Park and Mustafabab (Kowsar *et al*., 2013).

V. Recovery of metals from E-waste

Electronics devise such as DVD players, Printed circuit board, Computers, rechargeable batteries, etc contains heavy metals whilst mobile memory cards, Laptops, CRT displays contains large amount of precious metals. For manufacturing of mobile phones, laptops and other electronic devices, 267.3Mt of gold and 7275Mt of silver being consumed annually (Vats and Singh 2015). If feasible technologies applied with environment friendly treating of E-waste, it would be worth recovering heavy and precious metals.

Printed circuit board is integral part of electronics devices such as Cell phones, Laptops, Desktop computers, and mobile phones etc, which contains valuable metals and its contribute 3% of total E-waste generation (Vats and Singh, 2015). United Nations university report (2009) states that recoverable metals composition is Cu (130kg), Au (0.34kg), Ag(3.5kg) and Pd(130g), which exist in one tons of mobile waste (Petter et al., 2014).

Three methods are widely used for recovery of metals from E-waste components namely Hydrometallurgy, Pyrometallurgy, Bio recovery. These three methods have their pros and cons. From these three methods, researchers are widely using hydrometallurgy for recovering valuable metals by environment friendly manner. For recovery of valuable and hazardous metals from CRT panel Pyrometallurgy is the most efficient method.

Different authors recover valuable metals using different leaching agents and recovery methods with more than 90% recovery. Leaching agents such as Thiourea, Ammonium sulfates, Aqua regia, Halides, Cyanides and Thiosulfates used by various author to investigate dissolution of precious and heavy metals like Au, Ag, Pt, Cu, Zn and Fe from PCB of mobile phones and computers.

Extraction and precipitation are the secondary recovery process in hydrometallurgy. From the leached solution, metals can recover using extractant like Cyanex 272, PC-88, D2EHPA, etc which can gives highest purity of metals compared to precipitation. Precipitation process is depending on amount of OH forms. Total percentage recovery of metals from E-waste components investigates different authors are depicted in Table 9, 10, 11 with various reagents and recovery methods used.

Table 9 Recovery of Pb from waste Cathode Ray Tube glass panel

No	Reagent	Recovery Method	% Recovery	Reference
1	Nitric acid	Power ultrasound	90	Saterlay etal.,2001
2	Aluminum	Pyrometallurgy	50	ICER (pdf)
3	Na_2EDTA	Mechanochemical process	99	Sasai et al., 2008
4	Iron	Thermal reduction	58	Lu et al., 2013
5	Sodium Hydroxide	Mechanochemical Process	97	Zhang C et al., 2013

Table 10 Recovery of heavy and precious metals from PCB of mobile phones

No	Reagent	Recovery Method	% Recovery	Reference
1	Aqua regia	Hydrometallurgy+ Electro winning	92.0(Cu)	Angela et al., 2011
2	HCl	Ion Exchange Process	95.0(Au)	Kim et al., 2011
3	Sulfuric Acid +Hydrogen peroxide	Super critical Extraction	83.1(Cu)	Calgaro et al., 2015
4	Acid Thiourea	Adsorption (CPT gel)	80.0(Cu)	Gurung et al., 2013
5	Cyanide generating Bacteria	Bio-Leaching	11.31(Au)	Tran et al., 2011
6	Sodium thio Sulfate+ Ammonium hydroxide+ Copper sulfate	Hydro metallurgy	15.0(Au) 03.0(Ag)	Petter et al., 2014

Table 11 Recovery of heavy and precious metals from PCB of computer

No	Reagents	Recovery Method	%Recovery	Reference
1	Nitric acid LIX-984	Hydrometallurgy Solvent Extraction	99.7 (Cu)	Le et al., (2011)
2	Sodium Cyanide	Leaching Column technique	46.6(Au), 51.3(Ag),47.2(Nb),62.3(Cu)	Montero et al.,
3	Sulfuric acid, Hydrogen peroxide, Thiourea, sodium hypochlorite, Hydrochloric acid,	Hydrometallurgy Precipitation	100(Pd), 100(Au)	Behnamfard et al., (2013)
4	Sulfuric acid, hydrogen peroxide, Thiourea	Bio-recovery	Cu(75), Au(69)	Birloaga et al., 2013
5	Acidithiobacillus ferrooxidans	Bio-recovery	100(Cu),100(Ni)	Arshadi et al., 2014
7	Ammonium thio sulphates, Ammonia	Hydrometallurgy	90(Au)	Ha et al., 2010
8	Ammonium thio sulphates, Copper sulphates	Hydrometallurgy	98(Au),93(Ag)	Ficeriova et al., 2011

5.1 Recovery Of Heavy And Rare Earth Metals From Waste Li-Ion Mobile Battery

In this electronic communication technology world, we cannot predict our life without mobile phones and or batteries. After certain advancement in batteries for mobile phone manufacturers are prefer to use Li-ion battery. Due to certain advantages of Li-ion battery such as smaller, lighter, high energy density, high working voltage, long cycle life, low self-discharge rate and have no memory effect, compared to Ni-Cd, Ni-MH, Lead acid battery Li-ion battery market booms Figure 4.

In 1979, Jhon goodenough who gives first rechargeable cell using lithium cobalt oxide as positive electrode and lithium metal as negative electrode. Sony and Asahi Kasei released the first commercial lithium-ion battery in 1991. Due to sort lifespan of this Li-ion battery (1-3yrs), it gives large contribution in E-waste generation. Li-ion battery does not affect directly but when it disposes in landfill it contact with water form hydrogen fluoride. In addition, it contains heavy and rare earth metals like copper, aluminum, cobalt, nickel and lithium. Throwing of battery it simply means throwing of fresh metals. World's LIBs production reached 2.05 billion units in 2005 and has reached 4.6 billion in 2010 Figure 4.

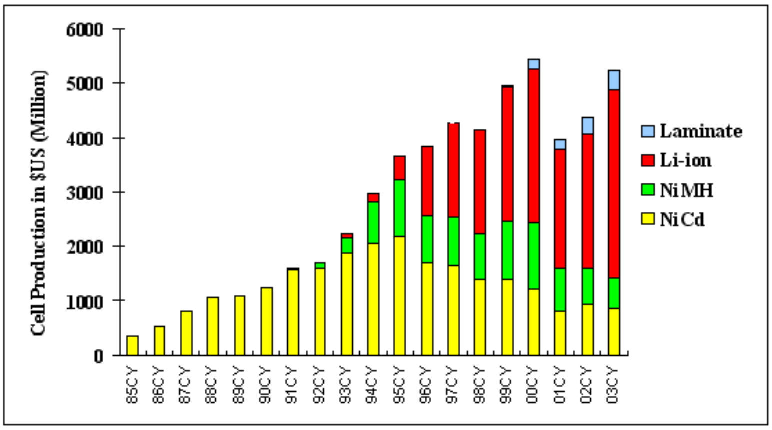


Figure 4: Battery world market

5.1.1 Structure Of Li-Ion Battery

Each battery contains anode and cathode to carryout chemical reactions; in addition, Li-ion battery contains electrolyte/binder, separator, and protective steel casing and control unit.

Figure 5 Internal and external part of Li-ion Battery

Carbon is use as active anode material in battery. This active anode material is fixing on to a copper conductor using polymer binder. In cathode, aluminum is use as conductor plate. Commercially, different cathode materials used, but it always lithium containing material like mainly including lithium cobalt oxide (LiCoO2), lithium manganese oxide ($LiMn_2O_4$), lithium nickel oxide ($LiNiO_2$), lithium vanadium oxide (LiV_2O_3), Li $(NiCoMn)O_2$, and $LiFePO_4$.Among this all lithium containing materials most commonly used material as cathode is $LiCoO_2$ due to its good performance.

Active electrode (anode and cathode) attached on to conductor plate using binder. Inside battery highly reactive environment exist, so the property of binder such that it should withstand heat and electricity. Polyvinyllidene fluoride (PVF) is use as binder due its thermo-resistant and nonreactive property. Ions are transfer between anode and cathode using electrolyte. Electrolyte is use as transport media, which convert chemical energy to electrical energy and vice versa during charging and discharging. Possible electrolyte salts are $LiPF_6$, $LiBF_4$, $LiCF_3SO_3$, or Li $(SO_2CF_3)_2$. However, LiPF6 is by far the mostly used one as electrolyte.

When anode and cathode contacts each other short circuiting take place. In order to avoid this short circuiting separators are use. The separator is a micro-porous film usually made of polymers such as polyethylene (PE) or polypropylene (PP). So that Li-ion mobile battery consist mainly heavy and rare earth metals like Cobalt, Aluminum, Copper, Nickel and Lithium. Recovery of these valuable metals is quite challenging. Precipitation and or solvent extraction process are use to recover these valuable metals from Li-ion mobile battery Table 12. Recently widely used extractant is Cyanex 272 followed by D2EHPA and PC-88 in order to extract Co and Li.

Table 12 Recovery of Heavy and rare earth metals from waste Li-Ion mobile battery

No	Reagents	Recovery Methods	%Recovery	References
1	Sulfuric Acid, Hydrogen Peroxide, sodium carbonate, Ammonium oxalate	Hydrometallurgy Precipitation	96.3(Co) 87.5(Li)	Zhu et al., 2012
2	Sulfuric acid, Cyanex 272	Solvent Extraction	30(Co)	Ferreira et al., 2009
3	Sulfuric acid, Hydrogen peroxide, Ammonium hydroxide, Cyanex 272	Solvent Extraction+ Precipitation	75(Co),100(Li),80(Al)	Ferreira et al., 2009
4	Nitric acid, Hydrogen peroxide, Citric acid	Precipitation	95(Co),95(Li)	Ferreira et al., 2009
5	Hydrochloric acid, Ammonium hydroxide,D2EHPA, PC 88	Solvent Extraction	90(Co), Li(90)	Ferreira et al., 2009
6	Sulfuric acid, Hydrogen peroxide, Ammonium hydroxide, Cyanex 272,	Solvent Extraction+ Precipitation	85(Co)	Dorella et al., 2007
7	Hydrochloric acid, Sulfuric acid, nitric acid, sodium hypochlorite	Precipitation	100(Co),99.99(Ni)	Joulie et al.,2014
8	Oxalic acid	Precipitation	97(Co), 98(Li)	Zheng et al., 2015

VI. Summary

India is the origin of electronic industry growth but also faces a problem of exponential growth of E-waste. India is the second largest population in the world, so that demand of electronic gadgets increases tremendously. E-waste generation directly related to demand. It means that high amount of sales of electronic device lead to large amount of E-waste generation. Rules and regulation does not followed strictly in India and cause informal recycling and dumping of E-waste. Informal recycling treats E-waste by 90% of total E-waste. E-waste contains various costly heavy and precious metals. Printed circuit boards, Batteries, CRT, etc are richer in valuable metals. E-waste tonnage increase worldwide due to short lifespan and developed technology in electronic devices. If suitable technology not applied to E-waste for recycling, it will dangerous for health and environment. Recovery of metals would benefit economics of country, because E-waste contains valuable metal and its price is higher than extracting ores from ores. There are tremendous studies going on for recovery of valuable metals from E-waste. E-waste containing precious metals such as gold and silver, so that recovery of precious metal beneficial to both environment and economics. Various investigators reported that Hydrometallurgy technique for recovery of metal from E-waste is more advantageous for environmental point of view. Maximum no of metals present in Li-ion mobile battery. Therefore, it can give better price even after discarded. After recovering valuable metals, it can be use as secondary element or process like making of catalyst for liquid and gas phase reactions, different complexes based on metals, etc

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