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Status of Electronic Waste Management in India- A Review

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Abstract—*Electronics waste is becoming a major global issue. Huge accumulation of e-waste and their recycling through primitive means for extraction of precious metals are real concern in the developing countries due to presence of hazardous materials in e-waste. The major portion of the e-waste generated domestically as well as illegally imported are recycled in crude manner leading to pollution of the environment. The current practices of e-waste management in India encounters many challenges like the difficulty in inventorization, ineffective regulations, pathetic and unsafe conditions of informal recycling, poor awareness of consumers and reluctance on part of the stakeholders to address the issues. As a result toxic materials enter the waste stream with no special precautions to avoid the known adverse impacts on the environment and human health as well resources are wasted when economically valuable materials are dumped. This paper highlights the hazards caused due to improper handling of e-wastes and also describes about some appropriate measures to be adopted for its management and safe disposal.*

Keywords*: Electronic waste, Extended Producers Responsibility*

1. INTRODUCTION

India is the fifth biggest producer of e-waste in the world; discarding 1.7 million tones (Mt) of electronic and electrical equipment in 2014. In India e-waste collection, transportation, segregation, dismantling, recycling and disposal is done manually by untrained labors in informal sector (Kumar and Karishma, 2016). Globally, WEEE is growing by about 40 million tons a year. In developed countries, e-waste constitutes 1-2% of the total solid waste generation. In US, it accounts for 1-3% of the total municipal waste generation. In European Union (EU), total amount of e-waste generation ranges from 5-7 million tons per annum or about 14-15 kg per capita and is expected to grow at the rate of 3-5% per year. Developing countries are also in the challenging phase as they are already facing the continuum of hazardous e-waste mountains. In South Africa and China for example, the report predicts that by 2020, e-waste from old computers will jumped by 200 to 400 percent from 2007 levels and by 500% in India (Bhat et al.2012). About 80,000 people working for recycling sector, and scrap markets exists where piles of e-wastes are separated for recycling. They separate copper from wires after burning them. Plastic and PVC codes produce noxious smoke which is irritable to eyes and cause respiratory problems. In addition, acid treatment is given to isolate metals also corrosive acids releases from used batteries of cell phones and computers. However, currently they are building an e-waste recycling plant in Bangalore which was estimated as having the capacity to handle 60,000 tons of e-wastes annually. In India about 24% of e-waste was produced from Mumbai, and, Delhi, Bangalore and Chennai are 21.2%, 10.1% and 9.1% respectively (Sivaramanan,2013).

2. E-WASTE GLOBAL SCENARIO

As far as global e-waste management is concerned, Switzerland is the first country to implement the organized e-waste management system in the world. Extended Producer Responsibility (EPR) and Advance Recycling Fee (ARF) are the backbone of e-waste management system in Switzerland and other developed countries. Advanced countries like USA, UK, France & Germany generate 1.5 to 3 million tons of e-waste annually and are among the largest generators of e-waste. But these countries also have standardized e-waste management processes in place. Proper e-waste management, from efficient sourcing and collection right upto extraction and disposal of material, has ensured that this huge pile of junk turns into a lucrative business opportunity. Due to very stringent environmental standards, the cost of collection, pre-processing, recycling and disposal are pretty high. So for every organized recycler in the first world countries, there are quite a few who pose as recyclers and are mere brokers who ship these obsolete items to developing countries like India and China in the pretext of donation or second hand goods. With very ambiguous laws related to environmental protection, India, China and a few African countries have become dumping sites to the first world countries .There are many countries that have already started the “take back” system for electronic products and they also have dedicated laws on e-waste management. In USA, National Electronics Action Plan has been initiated by US Environment Protection Agency to address the various issue related to electronic waste. Two very important frameworks for protecting

environment from e-waste have been put forward by European Union i.e., WEEE Directives and Restriction of use of Certain Hazardous Substances(RoHS),which are also implemented by other countries. According to EU directives (2003), it is mandatory for all 27 countries of European Union to recycle their e-waste (Jadhav,2013).

3. E-WASTE PRODUCTION AND MANAGEMENT IN INDIAN SCENARIO

The story of current Indian e-waste management is different from the worldwide. Practices e-waste is a serious issue because of the informal recycling activities. Therefore, quantification of e-waste in India is very difficult and there is no mechanism and policy to check the flow of e-waste in the system. Business sector is mainly responsible for the waste generation. In addition to this, about 1050 tones per year of computer waste comes from retailers and manufacturers. This is important to note that in spite of global agreements, e-waste from developed nations is imported to developing nations like India. Sixty-five cities in India generate more than 60% of total e-waste generated in India. Ten states generate 70% of the total e-waste generated in India. Maharashtra followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab in the list of e-waste generated states in India (Shagun et al.,2013).

The composition of e-waste is divided into various categories such as ferrous metal, non-ferrous metal, plastics, glass and others. The classification of different constituents of electronic waste as represented in literature is summarized below in table 1.

Table 1: Composition of e-waste
(source: http://ewasteguide.info/e-waste-composition)

Ferrous Metal	Iron and steel
Non- ferrous metal	Aluminium , copper ,lead, cadmium, mercury ,gold ,silver ,palladium, arsenic, indium, selenium
Plastic	Brominated and non-brominated plastic
Glass	Lead glass and normal glass

A number of countries have come out with their own definition, interpretation and usage. But, the most widely accepted definition is as per European Union (EU) directive, followed in member countries of EU and other countries of Europe. Definition as per EU directive is electrical or electronic equipment which is waste including all components, subassemblies and consumables, which are part of the product at the time of discarding presents various definitions provided by the different organizations. The definitions pertaining to e-waste from different organizations is summarized in table 2 (Mohan and Bhamawat,2008).

Table 2: E-waste definitions prescribed by different organizations (Source: Mohan and Bhamawat,2008)

Organization	Definitions
Basel Action Network	E-waste encompasses a broad and growing range of electronic devices, ranging from large household devices such as refrigerators, air conditioners, cell phones, personal stereos, and consumer electronics to computers, which have been discarded by their users.
*OECD (USA)	Any appliance using an electric power supply that has reached its end of- life is known as electronic waste.
StEP	E-waste refers to the reverse supply chain, which collects products no longer desired by a given consumer and refurbishes for other consumers, recycles, or otherwise processes wastes.
Sinha	An electrically powered appliance that no longer satisfies the current owner for its original purpose.
Maharashtra Pollution Control Board	Electronic Waste (E-Waste) comprises of waste electronic goods, which are not fit for their originally intended use. These range from household appliances such as refrigerator, air conditioner, cellular phone, personal stereos and consumer electronics to computers.

* Organization for Economic Cooperation and Development

In Indian contest, as given in the report of Rajya Sabha (2011), ferrous metal contributes (43%) in large household appliances. There are four categories which are large household appliances, small household appliances, ICT & consumer electronics and lamps. It is seen that percentage of ferrous metal is decreasing day by day as the percentage of plastics is increasing to make the products lighter and thinner. The problem while using plastics is this that they use the blended plastic (mixed plastic) which is not separable when we dismantle the laptops or monitors. The data of Indian e-waste scenario is prescribed report 2011 is tabulated in table 3.

Table 3: E -waste producer and characterization in Indian scenario E-waste in India (source: research unit, 2011)

Material	Large house -hold appliance	Small household appliances	ICT and consumer electronics	Lamp
Ferrous Metal	43	29	36	-

Non Ferrous Metal	27.67	26.19	9	14.3
Plastic	19.31	37.75	30	3.7
Glass	0.02	0.16	19.3	77
Others	10	6.9	5.7	55555

Data from table 4 indicates that the refrigerators and freezers have more percentage of ferrous metal (64.4%) then television and computers while televisions have more percentage of plastics (22.9%) than refrigerators and computers. But in today's time, manufacturers and companies tend to move towards plastics than ferrous metal. Similarly if televisions converted to recent TV sets, it is observed that the usage of more plastics has been taken place to make the product lighter and also to reduce the manufacturing cost. The overview composition of appliances enter plastic and metals are used is given below from table 4.

Table 4: Overview of the composition of the appliances in the three categories is given in table (Source: Jalal Uddin, 2012)

Appliances	**Ferrous wt. (%)**	**Non - ferrous wt. (%)**	**Glass wt. (%)**	**Plastic wt. (%)**	**Electronic component wt. (%)**	**Other wt. (%)**
Refrigerator and Freezers	64.4	6	1.4	13	0.2	15
Personal Computers	20	24	15	23	17.3	0.7
TV sets	5.3	5.4	6.2	22.9	0.9	3.5

The recoverable materials in the refrigerators are ferrous metals 46.61%, compressors 23.80%, and plastics 13.84% by weight. All these materials are refrigerators can be reused. The data of recoverable materials in refrigerators are given in table 5. The reuse of these materials will effect the less usage of virgin materials and hence the manufacturing costs can be reduced.

Table 5: Recoverable Quantity of Materials in a Refrigerators (Source: Jalal Uddin,2012)

Material Type	**% (by weight)**
CFCs	0.20
Oil	0.32
Ferrous Metals	46.61
Non- Ferrous Metal	4.97
Plastics	13.84
Compressors	23.80
Cables / Plugs	0.55
Spent Foam	7.60
Glass	0.81
Mixed Waste	1.30
Total	100.00

4. ROLE OF NON-FORMAL SECTOR

Ninety-five percentage of the e-waste in India is being recycled in non-formal sector and five percentage of the e-waste volume are handled in formal unit. In and around of metropolitan cities in India, there are over 3000 units engaged in non-formal sector for e-waste recycling. Non-formal units of e-waste recyclers are distributed all over India. A large cluster of industries exists in Delhi, Tamil Nadu, Uttar Pradesh, Karnataka, Maharashtra, Gujarat, Kerala, Andhra Pradesh, West Bengal, Rajasthan, etc. Non-formal units generally follow the steps such as collection of the e-waste from the rag pickers, disassembly of the products for their useable parts, components, modules, which are having resell value. The rest of the material is chemically treated to recover precious metals. Due to inadequate means, it may cause leaching of hazardous substances to the air, soil, and water. This recycling method has low efficiency and recovery is carried out only for valuable metals like gold, silver, aluminium, copper, etc. Other materials such as tantalum, cadmium, zinc, palladium etc. could not be recovered (Chatterjee,2012).

5. ROLE OF FORMAL SECTOR

Few formal recyclers are operating in India. The processes followed informal sector is mainly limited to the segregation, dismantling of e-waste till the size reduction stage of printed circuit boards. A shredder is employed for PCBs size reduction. The pre-processed PCB is exported to smelting refineries in developed countries for further recovery of precious metals like copper, silver, gold, aluminium, palladium, tantalum, ruthenium, platinum etc. and also treating the slag by-product in an eco-friendly manner. The recycling of valuables substances by units in formal sector is carried out in the protected environment and with due care to minimize any damage to the environment or society. The use of advanced processes and technologies leads to efficient recovery of metals. Recovery technology by units in formal sector will be economically viable as the high cost of capital equipment and needed techniques could be shared by the volume of products. The efficiency of recovery in the formal recycling is high and metals at the trace level can also be recovered. Some technology works with a zero-landfill

approach. Most of the e-waste in India is channelized to a non-formal sector, whereas, the formal sector is facing a problem of not having sufficient input materials (Chatterjee, 2012). Cost is another big issue for e-waste management. Cost of logistics and transportation is a challenge faced by most recyclers, preventing the flow of waste volumes in the country. Places where e-waste ends-up landfill where toxic chemicals in electronics products can leach into the land over time or be released into the atmosphere, impacting nearby communities and the environment.

Incineration process releases heavy metals such as lead, cadmium, and mercury into the atmosphere and which can bio-accumulate in the food chain, particularly in fish, which is the major source of exposure for the general public. Reuse is a good way to increase a product's lifespan. Many old products are exported to developing counties. Although the benefits of reusing electronics in this way is clear, the practice is causing serious problems because the old products are dumped after a short period of use in areas that are unlikely to have hazardous waste facilities. Although recycling can be a good way to reuse the raw materials in a product, the hazardous chemicals in e-waste mean that electronics can harm workers in the recycling yards, as well as their neighboring communities and the environment.

E-Waste is routinely exported by developed countries, often in violation of the international law. Inspections of 18 European seaports in 2005 found that as much as 47 percent of waste destined for export, including e-waste, was illegal. At least 23,000 metric tons of undeclared or "grey" market electronic waste was illegally shipped in 2003 to the Far East, India, Africa, and China. In the USA, it is estimated that 50–80 percent of the waste collected for recycling is being exported in this way. This practice is legal because the USA has not ratified the Basel Convention (Khurrum et al.,2011). Recycling of electronic waste is another important subject not only from the point of waste treatment but also from the recovery of valuable metals. The value distribution for personal computer shows that, the precious metal make up more than 70% of the value. This indicates that the major economic driver for recycling of electronic waste is from the recovery of precious metals and their industrial application (Jatindra and sudhir,2009).

The data summarized in the table 6 is based on the environmental effect due to incineration, land filling and recycling of e-waste. In case of incineration, brominated flame retardants when burn at high temperature generate highly toxic dioxins and furans which are very harmful for human health as well as environment.

Table 6: Hazard due to improper disposal of e-waste end products (source: http://ewasteguide.info/e-waste-composition)

Disposal Type	Hazard
Incineration	Brominated flame retardants at a high temperature of 600-800^{0}C generate extremely toxic polybrominated dioxins (PBDDs) and polybrominated furans (PBDFs);PVCs generate toxic flue gas;
Land-filling	Hazardous metal (e.g. lead, chromium, mercury, cadmium etc.), PCBs, PBDEs leach into soil and groundwater.
Recycling	It often causes hazardous emission, due to recycling of plastics, halogenated substances and heavy metals like lead, cadmium, etc. shredding without proper disassembly causes hazardous substances dispersed into environment.

6. ENVIRONMENTAL AND HEALTH EFFECTS OF E-WASTE

Environmental effects of hazardous waste arise due to primary, secondary and tertiary emissions of hazardous waste. Primary emissions include hazardous waste present in e-waste including heavy metals like lead, arsenic, mercury and PCB whereas secondary emissions are generally due to incomplete treatment of e-waste which leads to generation of dioxins and furans. Tertiary emissions occur due to harmful chemicals used for recycling of hazardous waste. Often electronic goods can be classified into three main categories, white goods that consist of household appliances, brown goods including televisions, and cameras and grey goods include computers, printers and scanners. Literature review suggests that grey goods are more hazardous than white and brown goods. Some of the major associated health impacts include affecting reproductive systems of humans both male and female, damaging lymphocytes and affecting growth retardation. Toxic chemicals present in e-waste can damage central nervous system and vital organs including liver and kidney. Continuous handling of such materials without use of protective gear can cause skin cancer, anaemia and carcinogenic tumors and may cause hormonal problems. Other problems include hypertension and psychological problems. Both scientific and non-scientific literature show growing incidence of several lethal or debilitating health conditions, which includes cancer, neurological, respiratory disorders, and birth defects. This impact is found to be worse in developing countries like India where people engaged in recycling e-waste are mostly in the unorganized sector, living in close proximity to dumps or landfills of untreated e-waste and often working without any protection or safeguards. Many workers engaged in these recycling operations are the urban poor and

unaware of the hazards associated with them. For example, such recycling activities can lead to contamination of local drinking water sources causing severe health impacts (Ganguly, 2016).

7. ENVIRONMENTAL AND HEALTH HAZARDS OF E-WASTE

Arsenic is widely used in the semiconductors, diodes, microwaves, LEDs (light emitting diodes), solar cells which cause chronic exposure to arsenic can lead to various diseases of the skin and decrease nerve conductivity velocity. Chronic exposure to arsenic can also cause lung cancer and can often be fatal. Barium is used in electron tubes, filler for plastic and rubber, lubricant additives causes short-term exposure to barium could lead to brain swelling, muscle weakness, damage to the heart, liver, and spleen. Animal studies reveal increased blood pressure and changes in the heart from ingesting barium over a long period of time. Brominated flame retardants cause casing, circuit boards (plastic), cables, PVC cables can lead to combustion of halogenated case material and printed wiring board at lower temperature releases toxic emissions including dioxins which can lead to severe hormonal disorders.

The management of e-waste in Indian context is quite difficult because the source of income is less and more and more people are engaged in this business. Recycling and reuse is the most adopted method for proper disposal of e-waste. As several private companies are also working in the e-waste recycling business. In fig 1, proper management of e-waste is shown without affecting our environment is shown through figure1.

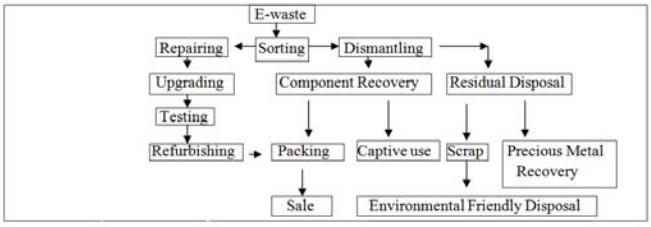
8. MANAGEMENT OF E-WASTE BY INDUSTRIES

E-Parisaraa Pvt. Ltd, India's first government authorised electronic waste recycler started operations from September 2005, is engaged in handling recycling and reusing of waste electrical and electronic equipment in eco-friendly way. The initiative is to aim at reducing the accumulation of used and discarded electronic and electrical equipment's, which most end up in landfills or partly recycled in a hygienic conditions by backyard recyclers and then partly thrown into waste streams damaging the environment (Source:http://ewasteindia.com).

Attero's recycling, is the only unit which does the complete e-waste management process with its end to end e-cycling plant, zero dumping technology. Attero's recycling technology aims to take today's waste and turn it into conflict-free, sustainable resources for tomorrow. Mobile phone recycling: Scanned and updated in the system, separating components which can be used again in different industries, such as electronics, plating, jewellery, automotive and art foundries. Display unit recycling: cathode ray tubes (CRT) contain lead, glass which can be recovered and reused. The process involves glass cutting, heating & air blow. Using magnetic separator, ferrous metals removed. Battery recycling: furnace smelting, treatment with alloys are the technologies involved. Attero recycles all types of batteries classified as e-waste by the EPA. PCB recycling: Printed circuit boards Component Removal Machine which separates components. I.T Goods recycling: Includes desktops, laptops, servers to printers, scanners, copiers etc (Source:http://www.attero.in). Earth e-waste management private limited industries in collection of e-waste material from premises and safe transportation to our factory premises. Sorting, Identify, Usefulness,Identifyhazardousness,Dismantling,Segregation,Treatment/Disposal(http://www.eemplindia.com).

9. CONCLUSION

Due to the presence of the toxic elements, it is all the more dangerous for the society to stock them without carrying out appropriate disposal. There exist many hurdles to e-waste management in India. The major one is the dominance of the informal sector. The major challenges are to reduce e-waste through reuse, recycle, recovery and reduced use of toxic substances, to invent labor intensive intermediate technology to recycle. It is confirmed that the public awareness and cooperation of manufactures are essential for the advancement of e-waste management system. And also it is the responsibility of governments to allocate sufficient grants and protecting the internationally agreed environmental legislation within their borders. Licensing of certification like e-stewardship may ensure the security to prevent illegal smugglers and handlers of e-waste.



(Source: E-waste in India Research Unit, Rajya Sabha Secretariat, New Delhi, June, 2011)

Fig1. Management of e-waste

(Source: E-waste in India Research Unit, Rajya Sabha Secretariat, New Delhi, June, 2011)

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