"e-Waste – Environment and Human Health Hazards and Management"

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1. Introduction

Advances in the field of science and technology brought about industrial revolution in the 18th Century and the information and communication revolution in the 20th Century has brought enormous changes in the way we organize our lives, our society, our economies, industries and institutions. These developments enhanced the quality of our lives but led to manifold problems including the problem of massive amount of hazardous waste and other wastes generated from electric and electronic products.

Basel Convention - According to the Basel Convention, wastes are substances or objects, which are disposed of or are intended to be disposed of, or are required to be disposed of by the provisions of national laws.

2. e- Waste

e-waste or electronic waste are broadly describes loosely discarded, surplus, obsolete, broken, electrical or electronic devices which are at the end of their useful life and need to be disposed or dismantled to recover some valuable components.

The problem of e-waste has become an immediate and long term concern as its unregulated and improper accumulation and recycling can lead to major environmental problems endangering not only human and animal health but also environment health due to toxic and other dangerous materials available in them.

The countries of the European Union (EU) and other developed countries are adopting scientific methods of recycling and disposal of such waste. The EU defines this e-waste stream as 'Waste Electrical and Electronic Equipment' (WEEE). The main features of the WEEE include definition of 'EEE', its classification into 10 categories and its extent as per voltage rating of 1000 volts for alternating current and 1500 volts for direct current.

3. Source

Electrical and electronics devices generating e- waste are from IT & telecommunication equipment and consumer electrical / electronic products such as refrigerators, washing machines, computer and its accessories, monitors, printers, keyboards, central processing units, typewriters, mobile phones and chargers, remotes, compact discs, headphones, batteries, LCD/Plasma TVs, i-pods, air conditioners, dryers, fridge, VCRs, Stereos, Copiers, fax machines, video games, presenters, music system and other household appliances etc. many of which contain toxic materials.

4. Composition

The composition of e-waste is diverse and falls under 'hazardous' and 'non-hazardous' categories. Broadly, it consists of ferrous and non-ferrous metals, plastics, glass, wood and plywood, printed circuit boards, concrete, ceramics, rubber and other items.

The E&E products are homogenous solid components containing heavy metals, polymers, flame retardants, polychlorinated biphenyls, etc. Some examples are given below:-

1. Cathode ray tubes, found in televisions and computers contain lead, mercury, cadmium, beryllium and brominated flame retardants.
2. A mobile phone/ smart phone contains more than 50 different components, including base metals (such as copper, tin), special metals (such as cobalt, indium, antimony) and precious metals (such as silver, gold, palladium). The most common metal is copper (9g), while the precious metal

content is in the order of milligrams only (about 250 mg silver, 24 mg gold and 9 mg palladium).
3. The lithium-ion battery contains about 3.5 grams of cobalt.

Iron and steel constitute about 50% of the waste, followed by plastics (21%), non ferrous metals (13%) and other constituents. Non-ferrous metals consist of metals like copper, aluminium and precious metals like silver, gold, platinum, palladium and so on. The presence of elements like lead, mercury, arsenic, cadmium, selenium, hexavalent chromium, and flame retardants beyond threshold quantities make e-waste hazardous in nature. It contains over 1000 different substances, many of which are toxic, and creates serious pollution upon disposal. Obsolete computers pose the most significant environmental and health hazard among the e-wastes.

5. Generation

It is estimated that about 50 million tonnes e-waste is generated every year all over the world. USA generates about 3 million tonnes, China generates about 2.5 million tonnes, EU generates about 8-9 million tonnes. India generates about 1 million tones of e-waste. It is anticipated that generation of e-waste will be on rise in years to come.

According to the Comptroller and Auditor- General's (CAG) report, over 7.2 MT of industrial hazardous waste, 4 lakh tonnes of electronic waste, 1.5 MT of plastic waste, 1.7 MT of medical waste, 48 MT of municipal waste are generated in the country annually. In 2005, the Central Pollution Control Board (CPCB) estimated India's e-waste at 1.47 lakh tonnes or 0.573 MT per day. A study released by the Electronics Industry Association of India (ELCINA) at the electronics industry expo – "Componex Nepcon 2009" had estimated the total e-waste generation in India at a whopping 4.34 lakh tonnes by end 2009. The CPCB has estimated that it will exceed the 8 lakh tonnes or 0.8 MT mark by 2012.

The main sources of electronic waste in India are the government, public and private (industrial) sectors, which account for almost 70 per cent of total waste generation. The contribution of individual households is relatively small at about 15 per cent; the rest being contributed by manufacturers.

There are 10 States that contribute to 70 per cent of the total e-waste generated in the country, while 65 cities generate more than 60 per cent of the total e-waste in India. Among the 10 largest e-waste generating States, Maharashtra ranks first followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab. Among the top ten cities generating e-waste, Mumbai ranks first followed by Delhi, Bengaluru, Chennai, Kolkata, Ahmedabad, Hyderabad, Pune, Surat and Nagpur.

An Indian market Research Bureau (IMRB) survey of 'E-waste generation at Source' in 2009 found that out of the total e-waste volume in India, televisions and desktops including servers comprised 68 per cent and 27 per cent respectively. Imports and mobile phones comprised of 2 per cent and 1 per cent respectively.

6. Pollutants in e-Waste

Pollutants or toxins in e-waste are typically concentrated in circuit boards, batteries, plastics, and LCDs (liquid crystal displays). Pollutants and their occurrence in waste electrical and electronic equipment are:

Pollutants	**Occurrence**
Arsenic	Semiconductors, diodes, microwaves, LEDs (Light-emitting diodes), solar cells
Barium	Electron tubes, filler for plastic and rubber, lubricant additives

Brominated flame- proofing agent	Casing, circuit boards (plastic), cables and PVC cables
Cadmium	Batteries, pigments, solder, alloys, circuit boards, computer batteries, monitor cathode ray tubes (CRTs)
Chrome	Dyes/pigments, switches, solar
Cobalt	Insulators
Copper	Conducted in cables, copper ribbons, coils, circuitry, pigments
Lead	Lead rechargeable batteries, solar, transistors, lithium batteries, PVC (polyvinyl chloride) stabilizers, lasers, LEDs, thermoelectric elements, circuit boards
Liquid crystal	Displays
Lithium	Mobile telephones, photographic equipment, video equipment (batteries)
Mercury	Components in copper machines and steam irons; batteries in clocks and pocket calculators, switches, LCDs
Nickel	Alloys, batteries, relays, semiconductors, pigments
PCBs (polychlorinated biphenyls)	Transformers, capacitors, softening agents for paint, glue, plastic
Selenium	Photoelectric cells, pigments, photocopiers, fax machines
Silver	Capacitors, switches (contacts), batteries, resistors
Zinc	Steel, brass, alloys, disposable and rechargeable batteries, luminous substances

7. Environmental and Health Issues

Management of hazardous municipal waste is a challenge in itself. Added to this burden is the management of huge and growing quantities of electrical and electronic waste emerging as one of the most important environmental problems of developing countries, especially India. Approximately 2 lakh tonnes of e-waste was generated in the country in 2007. E-waste has become more of a problem than all other wastes because of the very significant health and environment hazards associated with it.

The e-waste contains a number of toxic components that can cause serious damage to environment and human and animal health if not properly discarded in an environmentally sound manner.

Effects of some of the chemicals found in e-waste on human health are given below:

Brominated flame retardants: Brominated flame retardants (BFRs) have routinely been added to consumer products for several decades in a successful effort to reduce fire-related injury and property damage. Recently, concern for this emerging class of chemicals has risen because of the occurrence of several classes of BFRs in the environment and in human biota. The widespread production and use of BFRs; strong evidence of increasing contamination of the environment, wildlife, and people; and limited knowledge of potential effects heighten the importance of identifying emerging issues associated with the use of BFRs.

These do not decompose easily in the environment, and long term exposure can cause impaired memory function and learning. Pregnant women exposed to brominated flame retardants have been shown to give birth to babies with behavioral problems as it interferes with estrogen and thyroid functioning.

Lead: Lead is a naturally-occurring element that can be harmful to humans when ingested or inhaled, particularly to children under the age of six. Found in most computer monitors and televisions, lead exposure leads to intellectual impairment in children and serious damages to human reproductive systems, the nervous system and blood. Lead poisoning can cause a

number of adverse human health effects, but is particularly detrimental to the neurological development of children.

Cadmium: The kidney is the critical target organ for the general population as well as for occupationally exposed populations. Cadmium is known to accumulate in the human kidney for a relatively long time, from 20 to 30 years, and, at high doses, is also known to produce health effects on the respiratory system and has been associated with bone disease. Found in rechargeable batteries for laptop computer and other electronic devices, can cause damage to kidneys and bones. Cadmium can be bio-accumulate in the environment and is extremely toxic to human, in particular adversely affecting kidneys and bones.

Mercury: Elemental and methyl mercury are toxic to the central and peripheral nervous systems. The inhalation of mercury vapour can produce harmful effects on the nervous, digestive and immune systems, lungs and kidneys, and may be fatal. The inorganic salts of mercury are corrosive to the skin, eyes and gastrointestinal tract, and may induce kidney toxicity if ingested.

Neurological and behavioral disorders may be observed after inhalation, ingestion or dermal exposure of different mercury compounds. Symptoms include tremors, insomnia, memory loss, neuromuscular effects, headaches and cognitive and motor dysfunction. Kidney effects have been reported, ranging from increased protein in the urine to kidney failure. Mercury (Hg), which is used in lightening devices in flat screen monitors and televisions can cause damage to the breast milk.

Hexavalent Chromium Compounds: Hexavalent chromium is a toxic form of the element chromium. Hexavalent chromium compounds are man-made and widely used in many different industries. A known carcinogen, these are used in the creation of metal housing which are typical of many electronic products. It can cause lung cancer, irritation or damage to the nose, throat, and lung (respiratory tract), irritation or damage to the eyes and skin etc.

Plastic compounds: Poly vinyl chloride (PVC) cabling is used for printed circuit boards, connectors, plastic covers and cables. When burnt or land-filled, these PVCs release dioxins that have harmful effects on human reproductive and immune systems.

8. Treatment and Disposal.

Because of the complex composition of valuable and hazardous substances, specialized, often "high-tech" methods are required to process e-waste in ways that maximize resource recovery and minimize potential harm to humans or the environment. Unfortunately, the use of these specialized methods is rare, with much of the world's e-waste traveling great distances, mostly to developing countries, where crude techniques are often used to extract precious materials or recycle parts for further use. This also leads to localized pollution of environment and is health hazards for advanced life forms.

The methods followed in general of which some are not recommended are:

1. **Land filling:** It is widely used methods for disposal of e-waste. In this method, trenches are made on the flat surfaces by removing soil from the trenches and waste material is buried in it, which is covered by a thick layer of soil. Secure landfill is made using modern technique. Here they are provided with some facilities like, impervious liner made up of plastic or clay, leachate collection basin that collects and transfer the leachate to wastewater treatment plant. The degradation processes in landfills are very complicated and run over a wide time span and can be many years.

2**. Incineration:** In this controlled and complete combustion process, the waste material is burned in specially designed incinerators at a high temperature (900-1000^{o}C). Advantage of incineration of e-waste is the reduction of waste volume and the Utilization of the energy content of combustible materials. In this method some environmentally hazardous organic substances are converted into less hazardous compounds.

3. **Recycling of e-waste:** Fridge, Washing machines, TVs, Monitors & CRT, keyboards, laptops,

modems, telephones, hard drives, floppy drives, Compact disks, mobiles, fax machines, printers, CPUs, memory chips, connecting wires & cables can be recycled.
Recycling involves dismantling i.e. removal of different parts of e-waste containing dangerous substances like PCB, Hg, separation of plastic, removal of CRT, segregation of ferrous and nonferrous metals and printed circuit boards.
Strong acids are used to remove precious metals such as copper, gold, palladium. The value of recycling from the element could be much higher if appropriate technologies are used.
4**. Re-use:** It constitutes direct second hand use or use after slight modifications to the original functioning equipment. It is commonly used for electronic equipment like computers, cell phones etc. Inkjet cartridge is also used after refilling. Old working computers can be donated to schools or organization working in the field of education. Computers beyond repairs can be returned back to the manufacturers. This method also reduces the volume of e-waste generation.
The better option is to avoid its generation. To achieve this, buy back of old electronic equipment shall be made mandatory. This can considerably reduce the volume of e- waste generation.

9. Suggested Approach for e-waste disposal

A strategy of "**Reduce, Reuse, Recycle**" should to be adopted for e-waste disposal.
Reduce the generation of e-waste through smart procurement and good maintenance.
Reuse still functioning electronic equipment by donating or selling it to someone who can still use it.
Recycle those components that cannot be repaired. Use only authorized recyclers for disposing the e-waste products.

10. THE PROCESS

E-Waste recycling process should be a balance between disassembly, mechanical separation of complex materials and metallurgical treatment.
First Stage - Manual segregation of components, where different parts of E-waste are separated.
Second Stage - The mechanical separation process is applied. In this process, ferrous, aluminum, plastic and non ferrous material are initially separated.
Third Stage - The plastics are then recycled by plastics recycling process which further processes the plastic.
Fourth Stage - The non-ferrous metals are sent to metallurgical treatment plant where the non-ferrous metals are separated into constituent metals.

11. Environmental and Health Hazards of Recycling process of e-waste

According to a news published in The Hindu report: http://www.thehindu.com/todays-paper/tp-national/tp-newdelhi/ewaste-recycling-turns-water-soil-toxic/article6259404.ece
e-Waste recycling turns water, soil toxic. A report, “Impact of e-waste Recycling on Water and Soil”, released by non-government organisation Toxics Link, revealed that toxic elements including mercury, lead, zinc, along with acids and chemicals are released during e-waste recycling and are contaminating soil and water in the surrounding of Loni and Mandoli areas of Delhi.

12. Regulations

In India, the e-waste is regulated under the E-waste (Management and Handling) Rules, 2011

issued by the Ministry of Environment & Forests, Govt. of India. These Rules apply to every producer, consumer or bulk consumer involved in the manufacture, sale, and purchase and processing of E&E equipment or components, collection center, dismantler and recycler of e-waste. Schedule-I of the Rules cover a large range of E&E products categorized into IT & Telecommunication equipment and consumer E&E goods, The Rules also prescribe requirements for Storage and transportation of e-waste, responsibilities of Producer, Collection center, Consumer/Bulk Consumer, Dismantler and Recycler.
The regulations on e-waste management in other countries include,

1. European Directive on the Restriction of the Use of certain Hazardous Substances (RoHS) in Electrical and Electronic Equipment, 2006.
2. European Directive on the Waste Electrical and Electronic Equipment (WEEE), 2003.
3. The Electronic Waste Recycling Act of 2003, California, USA

13. A better way of e-Waste Management:

I think it is Health Hazards for all life forms available on planet earth supporting proper health of our environment, which is ultimate goal on the planet earth.
I think following methods can be adopted for tackling e-waste and their management:
1. Waste Management of Technology at the very onset of development and manufacturing a piece of new electrical and electronic item.
2. Defining 'User Codal Life' of each electrical and electronic items.
3. Disallowing a new model of a product with a small or medium improvement in the previous model.
4. A time bound gap between introduction of new model and old model in the market should be made as part of regulation.
5. Encouraging repairing of a product instead of 'Use and Through' methodology.
6. Disposing e-waste not at one place but spreading over wide area on the planet earth to avoid health hazards to human health and environment. This I called 'e- Product for All and e- Waste for All'.
7. If disposal is the last resort to do, one should discourage all disposal methods except 'Deep Land Filling' i.e. 'Burying e-Waste at the Deepest Level Available at that Land'. Such method of disposal has environmental support looking at the way our land forms over millions of years.
8. Encouraging entrepreneurs to use various components of e-waste to manufacture a new product and government should give special subsidy to such manufacturing units.

Courtesy: 1. E-WASTE IN INDIA, Research Unit (LARRDIS), Rajya Sabha Secretariat, New Delhi, June 2011
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3. https://www.osha.gov/OshDoc/data_General_Facts/hexavalent_chromium.pdf
4. http://sheeltechnologies.com/e-waste-treatment-disposal-methods/