E-waste in India: a concern for environment and public health

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Abstract

Modern computerized world and progression in Information Technology (IT) has revolutionized our lifestyle drastically. Human life is highly dependent on electrical equipment; simultaneously it has also led to the production of huge amount of electronic wastes (e-wastes). Over the time, e-waste accumulation has caused heavy metal toxicity and contaminated the environment. Globally, India is among the top importer of e-wastes from other countries for recycling and extracting important metals for reuse. India has a load of almost two million tonnes of e-waste per year along with an undisclosed amount of imported e-scrap. Ever rising demand of electronic devices has forced up countries to develop regulations for proper disposal and transport of e-waste but concern remains about their strict application. Majorly, disposal of e-waste is crude and improper that causes leaching of inorganic substances (Tin, Lead, Cadmium, Nickel, Arsenic, Copper, Mercury, polychlorinated biphenyls and plastics) in the environment. Under these circumstances, it becomes mandatory to device means for proper disposal of e-wastes and focus on reduce, recycle and reuse. Herein, we highlight the status of e-wastes in India and the subsequent impact on soil quality, human health and environment.

Keywords: Disposal of e-wastes, Environ-mental pollution, E-waste, Human health, Heavy Metal Toxicity.

1. Introduction

"E-waste (electronic waste) or Waste Electrical and Electronic Equipment (WEEE) are mainly discarded, surplus, outmoded, broken electrical (electronic) devices. These also include electronic goods destined for refurbishment, reuse, resale and salvage recycling through material recovery or disposal" *(*Perkins et al 2014). Briefly, "E- waste is any such discarded electronic product which cannot be put to use further and needs recycling or may be dumped" (Heacock et al 2016). The industrial revolution and the upswing in Information Technology (IT) has tremendously changed the way of working; although this development has proved to be beneficial but the mismanagement has posed new challenges of contamination and pollution. With new handy inventions like laptops, tablets, mobile phones and other electronic gadgets; the number of electrical products consumers has increased manifolds. They have now become the most commonly used devices for various purposes at schools, offices, houses, manufacturing companies and IT sectors.

In India and most developing countries, there are fewer guidelines on e-waste disposal and therefore people lack awareness, resulting in compilation of waste electronic products from households and industries. E- waste is not completely waste as the term implies, it comprises of various elements and

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substances that can be preferably harvested and reused such as precious (gold, silver, platinum and palladium) and useful metals (aluminium, iron, copper, tin, silicon, zinc) (Pradhan, 2013). India is also one of the major importers of discarded e-scrap as it serves as substantial resource to retrieve back precious and useful metals into the production cycle.

The "e-waste trade and recycling alliances" sector has provided a source of living to a major section of the population. In India, 25,000 workers and children are working in "crude dismantling units" in national capital itself wherein approximately over 20,000 tonnes of e- waste is being handled without proper precautions. These perilous content can cause serious health-hazard and environment implications, which is of utmost concern (*The Conversation)*. This is a global challenge as the consumption and ultimately dumping, are gaining rapid speed and has emerged as major contributors to the total municipal wastes. Therefore, here is an urgent requirement of efficient and eco-friendly system for "e- waste management" (Awasthi et al 2016).

2. Sources of E-waste

E-wastes are mainly generated by wastes from the IT world, which often deals with the use of electronic devices and equipment but their usage in household is equally gaining popularity. The sources of e-waste can be computers, monitors, keyboards, printers, speakers etc; or from electronic devices used for entertainment purposes such as TVs. DVDs, and CD players, etc. It can also be from equipment or devices used for communication such as mobiles, landline phones, I-Pods, Tablets, Fax etc.; household equipment's like vacuum cleaner, microwave oven, AC, washing machine, CFL, bulbs, fluorescent tube lights etc.; audio-visual components such as VCRs, Stereo equipment etc.; monitoring and control devices; toys and sports machines; medical equipment such as CT scan, MRI etc (Osibanjo et al 2007). Out of many electronic devices, a computer itself is manufactured using many toxic components. such as heavy metals ranging from Pb in Circuit boards, Cd in batteries; Lead oxide and Barium in cathode ray tube (CRT); Brominated Flame – retardants (BFRs) dioxins and furans (highly toxic) that are released from casings (plastics and cables) while extracting valuable metals upon combustion, Hg used in flat screens and switches; polychlorinated biphenyls (PCB) used in transformers and capacitors etc. (Ramachandra et al 2004). According to Basal Action Network (BAN), millions of computers in the world have produced 2.87 billion Kgs of plastics, 716.7 million Kgs of Pb and 286,700 Kgs of Hg (Ghatge et al 2013). For instance, the average 14 -inch monitor contains 2.5 to 4 Kgs of Pb, which is known to leach and subsequently contaminate the surrounding air, water and soil (Song et al 2014).

Table 1. Toxic substances released from E-Wastes and their harmful effects

Toxic substances	**Sources**	**Potential harmful impacts**
Sulphur (S)	Found in lead acid batteries	Can cause damage to eyes, heart, kidneys, liver, throat etc.
Mercury (Hg)	In switches and circuit boards	Affect aquatic life by forming Methylated mercury (toxic) and affect central nervous system , kidneys and immunity of human beings
Lead (Pb)	Used in CRTs, microchips releases lead as powder and fumes.	Acts as neurotoxin that may affect kidneys, reproductive system and cause mental retardation in children.
Chromium (Cr) – VI (hexavalent)	Used to save computer plates metals coverings from corrosion	Causes bronchitis and lung cancer, asthma by inhaling hexavalent Chromium, can affect functioning of liver and kidneys.
Beryllium (Be)	Used in CRTs, circuit boards, and released as powder when crushed.	Carcinogenic, may cause severe pain in joints and spine may also affect bones and kidney.

Cadmium (Cd)	Used in Nickel-Cadmium batteries, light-sensitive resistors, corrosion-resistant alloys, etc	May cause leaching into the soil and adversely affect soil ecosystem by harming soil microorganisms inhalation may also damage kidney and lungs.
Brominated Flame Retardants (BFRs)	Plastic coverings of circuit boards	Affect endocrine system functioning.
Barium (Ba)	CRTs for its top cover damage the heart and vital organs like spleen	It's hazardous as short term exposure may and liver. Sometimes mild effects like muscle weakness may also occur.
Americium	Some detectors	Radioactive and carcinogenic.
Plastics including PVC	Used in manufacture of circuit boards and cables immunity.	Carcinogenic BFRs releases carcinogenic chemicals that can affect reproduction and

3. Current status of E-waste burden on India

The IT & Communication industries are increasing at the rate of approximately 20% yearly. With the increasing per capita income and advancement, India ranks 2nd largest e-waste producer in Asian continent. Ministry of External Affairs (MOEF') 2012 report states that in the last 7 years the e-waste output has jumped 8 times reaching 8 lakh tonnes. E-waste comprises of 70% of total toxic waste prevalent in landfills causing heavy metal toxicity of natural resources. Merely 40% of total e-waste produced in India are recycled through disposal and processing and remaining 60% left out at the dumping sites due to lack of efficient assortment and disposal methods (Awasthi et al 2016).

Although no definite official data is available on e-waste generation and its disposal in India, however various independent studies and estimates conducted by NGOs or governmental agencies are available. According to the data released by the Central Pollution Control Board (CPCB), India produces 0.573 million tonnes of e-waste per day. A research conducted by Electronic Industry Association of India at the electronic industry expo –"Componex Nepcon 2009", total e-waste in India was estimated around 4.34 lakh tonnes. Another report by CAG highlighted that around 4 lakh tonnes of electronic wastes were produced in the country annually (Agarwal, 2010). Manufacturers Association for Information Technology (MAIT) revealed through studies that left out / obsolete electronic items will rise drastically in the developing countries with in a decade at the global level, with computer waste in India itself showing growth by 500%. A survey by ASSOCHAM (a trade association of India), predicted that 5.2 Million tonnes of e-waste will be produced annually by the end of 2020 (https://www.downtoearth.org.in/blog/waste/recycling-of-e-waste-in-india-and-its-potential-64034).

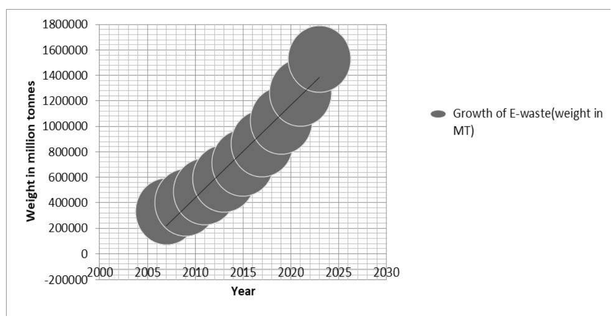

Figure 1. Year wise data of E-Waste generated in India (growth as weight in Million Tonnes)
Source: Department Of Information Technology, India

If the state wise data is taken into consideration, ten states (India) amounts to 70% of total e-waste produced in the country, while 65 cities produced more than 60% of total e-waste in India. Maharashtra tops among the ten states producing major e-waste followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab (**Figure 2**).(https://telecom.economictimes.indiatimes.com/news/maharashtra-top-e-waste-generating-state-in-india-study/64448215).

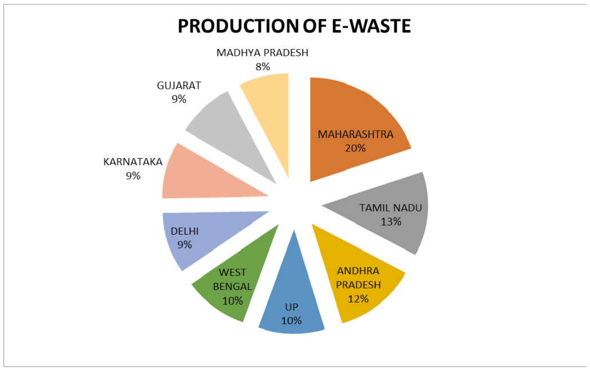

Figure 2. Top ten states generating e-waste in India (value indicated as tonnes/year)

Source: Department of Information Technology, India

The top ten cities producing e-waste are Mumbai followed by Delhi, Bengaluru, Chennai, Kolkata, Ahmedabad, Hyderabad, Pune, Surat & Nagpur (Pradhan, 2013).

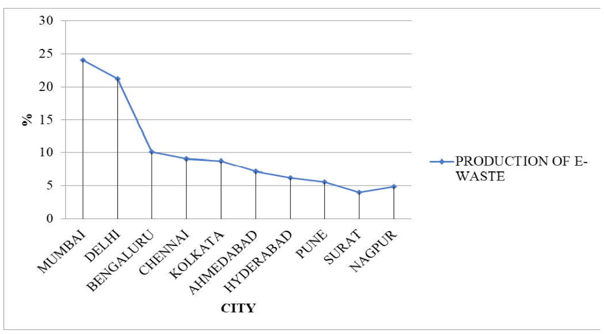

Figure 3. Major cities contributing towards e-waste generation in India

Source: Department Of Information Technology, India

All the government and private industrial sectors contribute to 70% of total e-waste produced in our country. The household e-scrap adds upon 15% of the total waste and the remaining being contributed by electrical equipment manufacturers (Joshi, 2009).

4. Different Approaches to minimize E-waste Accumulation

There are different means by which accumulation of e-wastes can be reduced such as proper disposal, re-use and re-cycling. Although disposal of e-wastes is achieved by land filling, incineration, but none of them are effective in providing complete relief from harmful effects of e-wastes (Awasthi et al 2018). Land Filling is the foremost practiced method for e-waste disposal, in which trenches are formed. Generally, even land surfaces are selected and e-waste is buried in the manmade trenches and covered by another layer of soil to form land base. Recent development in this technique involves the secure landfills, which is provided with various features of impervious liner composed of plastic or leachate collection basin that directs leachate to treatment plants for wastewater processing. But depletion of the pollutants and contaminants in landfills takes long time through a complex process. Along with this, there is a potential risk to the environment that cannot be dodged simply; particularly those caused by leaching of toxic materials into the soil by disposal of e-waste. Hg, Pb and Cd are some of the commonly found leachate in the soil used for landfills. Landfills are also vulnerable to fire resulting in production of poisonous fumes in the atmosphere. Therefore, this method of disposal of e-waste is not environment friendly since contaminants, which are volatile, and non- biodegradable such as Hg, Cd, PCBs, BFRs, etc are not depleted (Chakraborty et al 2018) by this method.

The other method of e-waste disposal is incineration which is a process of complete combustion of e-waste at very high temperature of 900-1000° C in specially designed incinerators. This helps in reduction of total volume of e-waste and utilization of energy released from combustion. This process also aids in recycling of certain metals like iron and conversion of hazardous organic substances into less hazardous chemicals. However, emission of various toxic gases from burning of Hg and Cd escapes out from flue gas cleaning chamber that are released in the atmosphere which contributes enormously to the annual release of volatile toxic substances. Hence, incineration leads to increase in the emission of toxic gases unless proper measures are taken for removal of heavy metals (Li et al 2015).

Re-use of e-waste is the second-hand use of original electronic equipment, either directly or after minor treatment / processing. This method is generally useful in reducing total volume of e-waste generated but is majorly dependent on the condition of the electrical equipment. Large MNCs and various government companies buy the used items back from the consumer, after making necessary alterations, sell it back in the market for its reuse. Apart from this, buying back of old /used electronic equipment should be encouraged in order to avoid unnecessary generation and accumulation of e-wastes. If this practice is followed vigorously it can significantly lower the quantity of e-waste generated and can surpass the need of e-waste recycling and dumping. Hence, reusing is among the most appropriate way of disposal of e-waste (https://unu.edu/publications/articles/e-waste-challenges-re-use-practices-principles-and-standards.html).

Recycling is another important procedure to reduce the harmful effects of e-wastes. Majority of electronic gadgets, wires and cables can be reprocessed. Recycling mainly employ dismantling i.e. segregation of various e-waste constituents ccomprised of hazardous chemicals such as PCBs, Hg, isolation of plastics, segregation of Iron and non-ferrous metals, CRTs and circuit boards. Recyclers involve use of acids (strong) to retrieve metals such as Cu, Au, Ag and Pb. Since, the availability of dumping sites is very scarce in India and in spite of ever increasing (beyond limitation) generation of e-waste in the developing world; recycling is the most eco-friendly method for e-waste disposal (Kurian, 2007). Recycling may substantially reduce the release of heavy metals in the environment, simultaneously reducing the entry of new metals into e-waste treatment. However, the major challenge is the effective collection of wastes containing heavy metals, which seems to be less feasible because of extravagant quantities of e-waste in today's world. However, recycling of certain heavy metals (such as Nickel, Chromium) are feasible to some extent. (https://www.thebalancesmb.com/introduction-to-electronics-e-waste-recycling-4049386)

When recycling fails to serve the purpose, mineral substitution is the other way out. This ensures that toxic, heavy metals are retrieved back for manmade circulations, thereby preventing the pollution from the source point. Various substitutes of Pb, Hg and Cd have been developed for many applications such as efforts are being made for substitutes of chromium in tanning and wood preservation (Parthsarathy et al 2017).

5. Impact of e-waste on environment and public health

E-waste disposal leads to various challenges faced on a global basis. The electronic wastes if not disposed of properly may cause contamination of air, soil and groundwater and can lead to serious health implications. The toxic metals from e-wastes (such as Hg, Pb), leaches into soil and lowers its pH, thereby, causing soil acidification and also contaminate ground water. Those parts that are not suitable for recycling and extraction process are sometimes burnt in open spaces (Krishnamoorthy et al 2018) and they release toxic fumes, which may lead to severe environmental risks such as depletion of ozone layer causing global warming and may cause various air borne diseases (Awasthi et al 2016). In addition, most of the landfills are left without proper monitoring and is a future threat to environment and human life. Sometimes major accident like the uncontrolled fires in landfills may emit some serious toxic fumes and gases in the atmosphere such as dioxins and furans, volatile metallic Hg and dimethylene Hg (Ramachandra et al 2004). For instance, GUIYU in Hong Kong; China, the world's largest hub of e-waste site of disposal, is witnessing acute shortage of pure resources due to excessive ground water contamination and people are facing serious digestives, pulmonary, neurological, respiratory and bone (Osteoporosis, Osteoarthritis) related ailments and various air borne diseases due to emission of toxic fumes from incineration of e-waste. (https://www.thehindu.com/news/international/battling-e-waste-in-chinas-industrial-hub/article19743155.ece).

It has been extensively studied that the exposure to e-waste toxicants both in direct or indirect way has devastating effects on human body (**Table 1**) (Awasthi et al 2016). High levels of contaminants have been observed in blood samples of workers in the recycling units. Recyclers work under extremely dangerous conditions; workers do their job without gloves and masks and they do not have technical expertise; they work in poorly-ventilated closed spaces, being exposed to toxic gases and chemicals.

Polybrominated diphenyl ethers (PBDEs) in e-waste affect the thyroid gland and its secretions, therefore has been linked to hypothyroidism. Exposure of perfluorooctanoic acid to pregnant females made them deliver premature babies with slow neonatal development. There are reports of miscarriage and stillbirth due to heavy metal toxicity. Moreover, Pb and other heavy metal exposure leads to neurodegenerative diseases in children (Heacock et al 2018).

6. Impact of e-waste on soil health

Soil (pedosphere) is a non-renewable natural resource (for an inch of topsoil, it takes 500 or more years to be replenished), usually referred to as finite natural resources. Soil (made of solid and porous components) contains organic matter, minerals, atmospheric gases, providing heterogeneous and conducive habitat for wide range of essential microorganisms such as bacteria, protozoa, fungi, nematodes, etc. (Mainguet 1991). This microbial life particularly, bacteria make the environment suitable by contributing significantly to the various bio-geochemical cycles (P, N_2, S, etc.). E-waste deposition in soil also leads to significant depletion of essential organic contents (macro as well as micro nutrients such as such as N_2, K, Ca, P) present in the soil. Leaching of toxic heavy metals affect the fauna as well as flora of the soil; if agricultural fields are contaminated with toxic heavy metals, it can lower the crop yield, and can cause a decline in microbial population in the soil due to exposure to toxic metals (Malhotra et al 2015). The type of bacterial community depicts the soil metabolic processes and help in accessing the soil health trends. Soil microbes play very significant role in maintaining ecological balance by decomposition and degradation of complex inorganic matter into organic ones, which is beneficial for growth of vegetation (Sangwan et al 2012). Once degraded, the recovery of soil is not possible during the entire lifespan of humans. Acidic soils (low pH) affect the soil microorganisms and disrupt the nutrient cycles.

Thus, disposal of e-waste leaches lethal heavy metals, which reasons depletion of essential nutrients in the soil, degrades soil quality, decline in microbial biomass and lowers the pH of soil and contaminates the groundwater resource, leading to abnormal growth of flora and fauna of the concerned area; thereby significantly affecting the agricultural productivity.

7. Conclusion and Future Perspectives

Developing countries like India have a crude manner of handling and disposal of e-waste. E-waste is comprised of perilous contaminants, which pose potential environment risk and has ill effects on public health especially to the people involved in e-waste management. Pregnant female workers, children and population residing around recycling units are more vulnerable. There is an utmost concern of air, water and soil pollution that will ultimately affect the mankind. It is a challenge to reduce the electrical equipment usage. The present laws for e-waste management in India need to be stringently applied for an effective e-waste disposal. It is possible by collective efforts from all the e-waste producing sectors to make a smooth chain flow of e-waste and recycling. Other ways of recycling can be adopted like the bioleaching or green process that involves the use of microorganisms that are capable of degrading or extracting metals from the e-scrap, can be explored and bioengineered.

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