International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
Index Copernicus Value (2015): 62.86 | Impact Factor (2015): 3.791

"E waste' - A Potential Threat to Health and Environment

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Abstract: ***Electronic goods have transformed the way we live and work. Burgeoning demand for these goods has made this industry the largest and fastest growing across continents. Consumers are less aware of hazards of the electronic goods and afterlife of equipments. The change in society's consumption patterns, driven by large choices and rapid product obsolescence has created huge quantities of such end-of life or discarded products to the waste stream. This waste stream of used electronics is popularly known as electronic waste or e-waste. According to a report published by GTZ in 2007, India generated 380, 000 tonnes of e-waste from discarded computers, televisions and mobile phones. But now, India is the fifth largest producer of e waste and expected to generate 52 Lakh metric tonnes of e waste to the waste stream by 2020. Most of this waste is handled and managed by the informal sector in the by lanes of large cities and small towns, where it operates in clusters, specialising in particular process or component. These groups deal with this waste in most rudimentary fashion, recovering its constituents like metals, glass and plastics, and trade them in the scrap market. E-waste recycling by ill-equipped informal sector creates unhealthy and hazardous conditions for the workers and pollutes the environment. Recycling e-waste through improper technologies can lead to severe health and environmental damages. But if environmentally sound technologies are employed, e waste recycling can benefit the environment and economy.***

Keywords: e waste trend, Issues, composition of e waste, hazardous technologies of e waste recycling, environmental and health risk, Impact of e waste

1. Introduction

Technological growth has paved way for enormous invention which flooded the market with new products changing the consumer behaviour. Consumers are less aware of the hazards of the electronic goods and afterlife of the equipments. The industries too are less responsible and committed in recycling the products which have completed the usage and reached the waste stream. The reasons for electrical and electronic equipment reaching the waste stream are manifold. Some products get obsolete as newer versions evolve. This quicker inventions and up gradations of the equipment, keeps the consumer to go for newer versions and keep them trendy and use the latest versions. Very rarely a product becomes obsolete due to its function. The speed in advancement of technology, speeds the waste stream and causes a menace to this new era problem, ` E – Waste' as it contains many hazardous substances which may cause problem both for health and environment.

Electronic Industry Boom and its impact

Electronic goods have transformed the way we live and work. Burgeoning demand for these goods has made this industry the largest and fastest growing across continents. Globalization that brought together competitive production centres and consumption markets in tandem with IT services has catalysed this growth. The industry has also made significant investments in R&D and innovation, adding newer and improved features to their products boosting demand and consumption.

In India, electronics industry has witnessed rapid growth since economic liberalisation. This trend is supported by giant strides made by Indian IT sector. The latter has been one of the key drivers of economic growth fuelling higher levels of consumption. New products and services brought shift in the pattern of governance. It ushered in an era of infrastructure reform and e-governance. This shift was marked by the application of information technology in a big way in all areas. These developments have churned out a wide gamut of e-waste from households, commercial establishments, industries and public sectors.

The change in society's consumption patterns, driven by large choices and rapid product obsolescence has created huge quantities of such end-of life or discarded products to the waste stream. This waste stream of used electronics is popularly known as electronic waste or e-waste. Growing at an alarming rate, e-waste is almost keeping a pace with the growth of electronics industry. It now makes up five percent of all municipal solid waste worldwide, nearly matching the quantity of waste from plastic packaging, it is however much more hazardous and brings in a new set of challenges associated with its management.

The consumption of PC in four largest cities (Delhi, Mumbai, Kolkata and Chennai) grew by manifold in last decade. For laptop market the growth figures are even higher - the sales jumped from 4, 31, 834 in 2005-2006 to 8.58 million units in 2016 a growth of 2000% percent. The growth in demand for telecom products has also been overwhelming; India has recently crossed one billion mobile users and now emerged as the second largest mobile phone user in the world next to China. This growth is expected to continue at least over the next decade. The advent of LCD, LED and plasma screens gave a shot in the arm of television market. Influenced by rapid technology change, availability and affordability of the products, the earlier Indian mindset of using Electrical and Electronic Equipment (EEE) till it functioned changed.

This changed consumption pattern has been responsible for the bulk of e-waste generation in the country. It's only very recent that the problems associated with such waste

have began to be identified; complete knowledge of the complexities associated with such wastes is still not within our grasp.

Electronic waste or e-waste comprises electrical and electronic goods that have reached the end of their useful life either because of product obsolescence, advancement in technology, change in fashion, style or status. E waste contains toxic substances and chemicals that can have adverse effects on the health and environment, if not handled properly.

E-waste Trend

The issue of e-waste - its hazards and complexities – was first brought into public discourse by an NGO in India. This initiated new research and dialogue among various stakeholders. Many studies and assessments have followed since. According to a report published by GTZ in 2007, India generated 380, 000 tonnes of e-waste from discarded computers, televisions and mobile phones. But now, India is the fifth largest producer of e waste and expected to generate 52 Lakh metric tonnes of e waste to the waste stream by 2020.

The global volume of e waste generated is estimated to be 130 million tonnes in 2018 from 93.5 million tonnes in 2016. (Assocham – c Kinetics Study 2016). India's e waste is growing by 30% annually. Over 95% of e waste is handled by unorganised sector and scrap dealers. Only 1.5% of the total e waste generated is recycled. E waste is projected to grow to more than 52, 00, 000 tonnes by 2020. Most of this waste is handled and managed by the informal sector in the by lanes of large cities and small towns, where it operates in clusters, specialising in particular process or component. These groups deal with this waste in most rudimentary fashion, recovering its constituents like metals, glass and plastics, and trade them in the scrap market. Scale of individual business is small and the processes dangerous and hazardous. The Indian e-waste processing has just been augmented with a very small segment of formal recyclers, who have the wherewithal for its reprocessing. Another dimension of e-waste in India is the illegal imports of such waste from developed countries. This dumping of e-waste into India is constantly rising and flourishing in spite of international regulations. The clandestine nature of illegal imports makes it difficult to quantify e-waste generated through this route.

The Issue

The current practices in e-waste management in India have a number of drawbacks like the absence of an inventory of goods sold, unhealthy conditions of informal recycling, unenforceable legislation, weak regulatory mechanism, poor awareness and the industry reluctance to address the critical issues. The consequences are that;

(i) Toxic materials enter the waste stream, adversely affecting the environment and human health, and
(ii) Resource wastage, as dumped goods have valuable materials that can be recovered and recycled.

E-waste recycling by ill-equipped informal sector creates unhealthy and hazardous conditions for the workers and pollutes the environment. As there is no organised procedure for e-waste collection in India, there is no clear data on the quantity generated and disposed of each year and the resulting extent of environmental risk.Solid waste management, which is already a mammoth task in India, has become more complicated with the immensity of e-waste. The problem is not just of quantity, but also of the toxic nature of this waste. E waste contains significant quantities of hazardous elements like lead, mercury and cadmium. Improper recycling and disposal processes involve open air burning of plastic waste, exposure to toxic, dumping of acids in rivers or streams, and widespread general dumping. The subject of e-waste recycling and disposal has captured attention at all levels of governance, and has opened a dialogue between the government organizations and the private sector manufacturers of electronic goods.

E-Waste or waste electrical and electronic equipment (WEEE) - is the term used to describe old, end-of-life or discarded appliances using electricity. It comprises wastes generated from used electronic devices and household appliances, which are not fit for their original intended use and are destined for recovery, recycling or disposal. Such waste encompasses wide range of electrical and electronic devices like computers, cell phones, televisions, digital cameras, personal stereos, large household appliances such as refrigerators, air conditioners, washing machines etc. The four main categories of e-waste, according to most definitions, are

- Large household appliances
- Small household appliances
- ICT and consumer electronics
- Lighting equipments

Composition of E waste; Its Environmental and Health Risk

Composition of e-waste is very diverse. It contains more than 1000 different substances, which fall under "hazardous" and "non-hazardous" categories. Broadly, it consists of ferrous and non-ferrous metals, plastics, glass, wood & plywood, printed circuit boards, concrete and ceramics, rubber and other items. Iron and steel constitute about 50 percent of e-waste followed by plastics (21%), non-ferrous metals (13%) and other constituents. Non-ferrous metals comprise metals like copper, aluminium and precious metals like silver, gold, platinum, palladium etc. The presence of elements like lead, mercury, arsenic, cadmium, barium, beryllium, selenium, hexavalent chromium and flame retardants beyond certain threshold quantities in e-waste classifies them as hazardous waste.

Electrical and electronic equipment contain valuable materials. Printed circuit boards contain precious metals such as gold, silver, platinum and palladium; scarce materials like indium and gallium are also used as these have specific application in new technologies (e.g. flat screens, photovoltaics). This apart, electrical and electronic equipment contain a variety of materials that can be

hazardous to human health and environment, if not disposed of in environmentally sound manner

Table 1: Material composition of the four categories of e-waste

Material	Large household appliances (%)	Small household appliances (%)	ICT and consumer electronics (%)	Lamps (%)
Ferrous metal	43	29	36	-
Aluminium	14	9.3	5	14
Copper	12	17	4	0.22
Lead	1.6	0.57	0.29	-
Cadmium	0.0014	0.0068	0.018	-
Mercury	0.000038	0.000018	0.00007	0.02
Gold	0.00000067	0.00000061	0.00024	-
Silver	0.0000077	0.000007	0.0012	-
Palladium	0.0000003	0.00000024	0.00006	-
Indium	0	0	0.0005	0.0005
Brominated plastics	0.29	0.75	18	3.7
Plastics	19	37	12	0
Lead glass	0	0	19	0
Glass	0.017	0.16	0.3	77
Other	10	6.9	5.7	5

Source: EMPA

Hazards of E-waste

E-waste contains a number of toxic substances, such as lead and cadmium in circuit boards, lead oxide and cadmium in monitor (CRTs), mercury in switches and flat screen monitors, cadmium in computer batteries, polychlorinated -biphenyls (PCBs) in older capacitors and transformers, brominated flame retardants on printed circuit boards, plastic casings and cables, and polyvinyl chloride (PVC) cable insulation that releases highly toxic dioxins and furans when burned to retrieve copper from the wires.

Due to the hazards involved, disposing and recycling e-waste has serious legal and environmental implications. When this waste is land filled or incinerated, it results in significant contamination problems. From landfills toxins leach into groundwater; if incinerated, emit toxic air pollutants including dioxins which are carcinogenic. Likewise, the recycling of computers has serious occupational and environmental implications, particularly when the recycling industry is marginally profitable at best and often cannot afford to take the necessary precautions to protect the environment and worker health.

The effects of some of these toxic metals are

Lead (Pb) - Lead is widely used in electronic goods, as a major component of solders (as an alloy with tin) in printed circuit boards and as lead oxide in the glass of cathode ray tubes (televisions and monitors), as well as in lead-acid batteries. Lead is a significant material in current CRTs, accounting for up to eight percent of the overall composition of the CRT by weight (Menad, 1999), with a 17" monitor containing as much as 1.12 kg of lead (Monchamp et. al., 2001). The toxic metal is used in several parts of the CRT monitor, including the funnel and neck glass, the sealing frit, as solder on printed wiring boards (PWBs) within the monitor, and sometimes in the front panel glass of the CRT. Lead compounds have also been used as stabilisers in some PVC cables and other products. Lead is highly toxic to all life forms, including humans. It can build up in the body through repeated exposure and has adverse effects on the nervous system. Its effects are more pronounced among developing foetuses and children.

Cadmium (Cd) - Cadmium occurs in electronics both as cadmium metal, in some switches and solder joints, and as cadmium compounds in rechargeable batteries, UV stabilisers in older PVC cables and "phosphor" coatings in older cathode ray tubes. Like lead, cadmium can accumulate in the body over time, with long-term exposure causing damage to the kidneys and bone structure. Cadmium and its compounds are known human carcinogens, primarily through inhalation of contaminated fumes and dusts.

Mercury - It is estimated that 22 percent of annual world consumption of mercury is in electrical and electronic equipment. It is used in thermostats, sensors, relays, switches (e.g. on printed circuit boards and in measuring equipment), medical equipment, lamps, mobile phones and batteries. The fluorescent tubes that are the source of light in a LCD contain mercury. Very small amounts of mercury are also found in the LCD backlights Mercury use in displays is likely to increase as its use replaces cathode ray tubes. Mercury can cause damage to various organs including the brain and kidneys. The developing foetus is highly susceptible through maternal exposure to mercury. When inorganic mercury mixes in water, it is transformed into methylated mercury. Methylated mercury easily accumulates in living organisms and concentrates through the food chain, particularly via fish.

Brominated Flame Retardants (BFRs) – Brominated flame retardants are used in the plastic housings of electronic equipment and in the circuit boards to reduce flammability. More than 50 percent of BFR usage in the electronics industry consists of tetrabromobisphenol – a TBBPA composition has 10 percent polybrominated diphenyl ethers (PBDEs) and less than one percent polybrominated biphenyls (PBB). Polybrominated diphenyl ethers (PBDEs) are one of several classes of brominated flame-retardants used to prevent the spread of fire in a wide variety of materials, including casings and components of many electronic goods. These are environmentally persistent chemicals, some of which are highly bio-accumulative and capable of interfering with normal brain development in animals. Several PBDEs are suspected endocrine disruptors, demonstrating an ability to interfere with hormones involved in growth and sexual development. Effects on the immune system have also been reported. Polychlorinated biphenyls (PCBs) are widely used in insulating fluids for electrical transformers and capacitors, as well as flame-retardant plasticisers in PVC and other polymer applications. These are highly persistent and bio-accumulative chemicals; rapidly becoming widespread in environment and building up

several thousand-fold in body tissues of wildlife. PCBs exhibit a wide range of toxic effects including suppression of the immune system, dysfunction of liver and reproductive systems, cancer, impairment of nervous system, behavioural changes etc.

Triphenyl phosphate (TPP) - TPP is one of several organo-phosphorus flame-retardants used in electronic equipment, for example in the casings of computer monitors. TPP is acutely toxic to aquatic life and a strong inhibitor of a key enzyme system in human blood. It is also known to cause contact dermatitis in some individuals and is a possible endocrine disruptor.

Hexavalent chromium/chromium VI - Chromium VI is used as corrosion protection in untreated and galvanized steel plates and as a decorative or hardener for steel housings. It easily passes through cell membranes, and is then absorbed producing various toxic effects in contaminated cells. Chromium VI can cause damage to DNA and is extremely toxic in the environment.

Barium - Barium is a soft silvery-white metal that is used in the front panel of a CRT of computer monitors to protect users from radiation. Studies have shown that short-term exposure to barium has caused brain swelling, muscle weakness, damage to the heart, liver, and spleen. Data on the effects of chronic barium exposures among humans is in adequate. Animal studies however reveal increased blood pressure and changes in the heart from ingesting barium over a long period of time.

Beryllium - In computers beryllium is commonly found on motherboards and "finger clips". Copper beryllium alloy is used to strengthen the tensile strength of connectors and tiny plugs while maintaining electrical conductivity. Beryllium has recently been classified as a human carcinogen; its exposure can cause lung cancer. The primary health concern is the inhalation of beryllium dust, fume or mist. Workers who are constantly exposed to beryllium, even in small amounts, can develop what is known as chronic beryllium disease (beryllicosis), a disease that primarily affects the lungs. Exposure to beryllium also causes a form of skin disease that is characterized by poor wound healing and warts. Studies have shown that people can develop beryllicosis years after the last exposure.

Antimony (Sb) - Antimony is a metal with a variety of industrial uses, including as a flame-retardant (as antimony trioxide) and as a trace component of metal solders. In some forms, antimony has chemical similarities to arsenic, including in its toxicity. Exposure to high levels at workplace, as dusts or fumes, can lead to severe skin problems and other health effects. Antimony trioxide is recognised as a possible human carcinogen.

Nonylphenol (NP) - Nonylphenol is a chemical most widely known as a breakdown product of nonylphenol ethoxylate (NPE) detergents, though it is reportedly also used as an antioxidant in some plastics. It is a strong endocrine disruptor, capable of causing inter sex (individuals with both male and female characteristics) changes in fish. Nonylphenol can also build up in the system through food chain, and may be capable of causing damage to human DNA and even sperm functions.

Plastics including PVC - Plastics make up 13.8 pounds of an average computer. Poly-vinyl-chloride or PVC comprises 26 percent of plastics used in electronics. PVC is mainly used for cabling and computer housings, although many computer mouldings are now made with somewhat more benign ABS plastics. PVC is used for its fire-retardant properties. As with many other chlorine containing compounds, PVC forms dioxin when burned within a certain temperature range.

Toners - One ubiquitous computer peripheral scrap is the plastic printer cartridge containing black and colour toners. The main ingredient of the black toner is a pigment commonly called carbon black - the general term used to describe the commercial powder form of carbon. Its inhalation can lead to respiratory tract irritation. The International Agency for Research on Cancer has classified carbon black as a class 2B carcinogen, possibly carcinogenic to humans. Little information exists on the hazards of colour toners. Some reports indicate that such toners (cyan, yellow and magenta) contain heavy metals.

Phosphor and additives - Phosphor is an inorganic chemical compound that is applied as a coat on the interior of the CRT faceplate. Phosphor affects the display resolution and luminance of the images that are seen on the monitor. The hazards of phosphor in CRTs are not well known or reported, but the US Navy has not minced words about the hazards involved in some of their guidelines: "NEVER touch a CRT's phosphor coating: it is extremely toxic. If you break a CRT, clean up the glass fragments very carefully. If you touch the phosphor seek medical attention immediately." The phosphor coating contains heavy metals, such as cadmium, and other rare earth metals, e.g. zinc, vanadium, etc. as additives. These metals and their compounds are very toxic. This is a serious hazard for those who dismantle CRTs by hand.

Impact of E-waste

As mentioned above, e-waste contains significant quantities of toxic metals and chemicals. If these are left untreated and disposed of in landfills or not recycled using scientifically tested methods, they leach into the surrounding soil, water and the atmosphere, and cause adverse effects to human health and environment. The potential occupational and environmental hazards of some of the components are listed below:

Table 2: Hazards of e waste recycling by informal sectors

E-waste Components	Process	Potential occupational hazard	Potential environmental hazard
Cathode ray tubes (CRTs)	Breaking and removal of copper yoke and dumping.	• Silicosis. • Inhalation or contact with phosphor containing cadmium or other metals.	Lead, barium and other heavy metals leach into groundwater, release of toxic phosphor.
Printed circuit boards (PCBs)	Disordering and removing computer chips.	• Tin and lead inhalation. • Possible brominated dioxin, beryllium, cadmium, and mercury inhalation.	Air emission of these substances.
Dismantled PCBs processing	Open air burning of waste boards to remove metals inside	• Toxicity to workers and nearby residents from tin, lead, brominated dioxin, beryllium, cadmium and mercury inhalation. • Respiratory irritation.	Tin and lead contamination of immediate environment including surface and ground waters. Brominated dioxins, beryllium, cadmium and mercury emissions.
Chips and other gold plated components.	Chemical stripping using nitric and hydrochloric acid along river banks	• Acid contact with eyes, skin may result in permanent injury. • Inhalation of mists and fumes of acids, chlorine and sulphur dioxide gases can cause respiratory irritation to severe effects including pulmonary oedema, circulatory failure and death.	Hydrocarbons, heavy metals, brominated substances, etc., discharged directly into river or left on the banks. Acidifies the river destroying fish and flora.
Plastics from Computer and peripherals	- Shredding and low temperature melting to be reutilized in poor grade plastics.	- Workers and community exposure to carcinogens like brominated and chlorinated dioxin, polycyclic aromatic Hydrocarbons (PAH)	Hydrocarbon ashes including PAHs discharged into air, water and soil.
Miscellaneous computer parts encased in rubber or plastic	Open air burning to recover steel and other metals.	Exposure to hydrocarbons including PAHs and dioxins.	Hydrocarbon ashes including PAHs discharged into air, water and soil.

Improper Recycling Technologies

Recycling e-waste through improper technologies can lead to severe health and environmental damages. But if environmentally sound technologies are employed, e waste recycling can benefit the environment and economy. Realising the severity of climate change impacts, resources recovered are major boons. E-waste, if reused and recycled in an eco-friendly way, can be a major source of raw materials thus can minimise energy intensive mining of various metals like copper, gold etc.

Hazardous Technologies

Open burning:

Since open fires burn at relatively low temperatures, its use for waste disposal is far more polluting than controlled incineration process. Inhalation of open fire emissions can trigger asthma attacks, respiratory infections, and cause other problems such as coughing, wheezing, chest pain and eye irritation. Chronic exposure to open fire emissions may lead to diseases such as emphysema and cancer. For example, open air burning of PVC releases hydrogen chloride, which on inhalation mixes with water in the lungs to form hydrochloric acid. This can lead to corrosion of the lung tissues and several respiratory complications. Often open fires burn with a lack of oxygen, forming carbon monoxide, which poisons the blood when inhaled. The residual ash becomes airborne, and is dangerous if inhaled.

Incineration: Incineration is the process of destroying waste through burning. Because of a variety of substances found in e-waste, incineration is associated with a major risk of generating and dispersing contaminants and toxic substances. The gases released during the burning and the residue ash is often toxic. This is especially true for incineration or co-incineration of e-waste with neither prior treatment nor sophisticated flue gas purification. Studies of municipal solid waste incineration plants have shown that copper, which is present in printed circuit boards and cables, acts as a catalyst for dioxin formation when flame-retardants are incinerated. These brominated flame-retardants when exposed to low temperature (600-800°C) can generate extremely toxic polybrominated dioxins (PBDDs) and furans (PBDFs). PVC, which is found in e-waste in significant amounts, is highly corrosive when burnt and also induces the formation of dioxins. Its incineration also leads to the loss of valuable elements that can be recovered if sorted and processed separately.

Land filling: Land filling is one of the most widely used methods of waste disposal. It is also common knowledge that all landfills leak. The leachate often contains heavy metals and other toxic substances that contaminate ground water resources. Even state-of-the-art landfills, which are sealed to prevent toxins from entering the ground, are not completely tight in the long-term. Older landfill sites and uncontrolled dumps pose a much greater danger of releasing hazardous emissions. Mercury, cadmium and lead are among the most toxic leachate. Mercury, for example, will leach when certain electronic devices such as circuit breakers are destroyed. Lead is found to leach from broken lead containing glass, such as the cone glass of cathode ray tubes from TVs and monitors. When brominated flame retarded plastics or plastics containing cadmium are land filled, both PBDE and cadmium may leach into soil and groundwater. Similarly, land filled condensers emit hazardous PCBs. Besides leaching, vaporisation is also a concern in landfills. For example, volatile compounds such as mercury or its compound dimethylene mercury are released through vaporisation. In addition, landfills are also prone to uncontrolled fires, which can release toxic fumes. Impacts from the state-of-the- art landfills can be minimised by conditioning hazardous materials from e waste separately and land filling only those fractions which cannot be further recycled.

2. Conclusion

The government should make EPR or extended producer responsibility mandatory for the entire manufacturer (i.e. original equipment manufacturer should be made responsible to collect the products which are in the waste stream and recycle the same) and their license should be renewed only after submitting the return on the same to the department concerned. Necessary steps should be taken to educate and sensitise the customer on various problems caused by improper disposal of e waste and make the customers too responsible by making them to dispose their waste only to the OEM. This growing menace can be controlled by proper disposal and all the e waste junk may reach the authorised recycler who adheres environmentally sound technology for the disposal of e waste and keep the environment safe for the future generation.

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