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An Insight into E-waste: Exploring its toxicity and preciousness.

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sonagrapooja3@gmail.com Abstract:

According to Associated Chambers of Commerce and Industry of India (ASSOCHAM) 2 million tonnes per annum (TPA) of E-waste is generated by India of which 12% is contributed by telecom equipment alone. Apart from India, other top listed generators of E-waste are United States, China, Germany and Japan. Considering the global rise in e-waste this review is thus intended to understand the two diametric aspects of e-waste. One is its high degree of metal toxicity and the other is the valuable treasure of precious metals that it harbours. The conventional methods of dumping and burning of e-waste is deteriorating the health of our planet. The world we are living in is getting polluted by numerous toxic metals leaching out of e-waste. The sea water, ground water, land and air are getting affected everywhere. E- waste toxicity is majorly exerting negative health effect on the urban poor involved in recycling of e- waste manually. The most vulnerable been women and children. Chromium, Lead, mercury, indium, antimony, molybdenum and vanadium are one of the several toxic and allergenic metals contained in e-waste. Most of these compounds are released during recycling of e-waste. Manual recycling of e-waste by non-formal sector of society is aware of the precious metal content of e-waste but ignorant about its devasting effect on community health and environment. Gold, platinum, palladium, silver and copper are the key precious metals inside the womb of e- waste. Thus, urban mining for pulling valuable metals for economic prospects is becoming popular among most developing countries. This review paper aims to spread awareness among consumers to understand the excess obsolescence generated because of fast replacement of electronic gadgets. As a responsible citizen we must develop a positive attitude in maintaining the health of our planet by reducing, reusing and recycling e-waste.

Keywords: *E-waste; ASSOCHAM; Gold, Lead; Obsolescence; recycle.*

1. Introduction:

E-waste is a global, interregional, and domestic problem [1]. With technological advancement, the evil face of electronic waste is spirally increasing to a greater extent. Over the last decades the electronic industry has revolutionized the world: electrical and electronic products have become ubiquitous of today's life around the planet [2]. E-waste typically includes discarded computer monitors, motherboards, Cathode Ray Tubes (CRT), Printed Circuit Board (PCB), mobile phones and chargers, compact discs, headphones, white goods such as Liquid Crystal Displays (LCD)/ Plasma televisions, air conditioners, refrigerators and so on [3]. In India, Maharashtra contributes the largest e-waste of 19.8% but recycles only about 47,810 TPA (tonnes per annum) whereas as its

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counterparts Tamil Nadu (13%) recycles about 52,427, Uttar Pradesh (10.1%) recycles about 86,130, West Bengal (9.8%), Delhi (9.5%),

Karnataka (8.9%), Gujarat (8.8%) and Madhya Pradesh (7.6%) [3].

Due to modernization and technological upgradation the market of electrical and electronic equipment is rising at an alarming rate. Increased lifestyle, new product launch, upgraded devices, shorter life span of devices and drop in prices are increasing consumers uptake for new gadgets and devices. Companies intentionally plan the obsolescence of their goods by updating the design or software and discontinuing support for older models, so that now it is usually cheaper and easier to buy a new product than to repair an old one. Meanwhile, the companies continue to profit from steady sales [4]. E-waste from computers, mobile phones, and other electronics will reach 15.4 million tons by 2020 and 27.22 million tons by 2030, growing at an average annual rate of 10.4% [5]. E-waste is categorized as hazardous waste due to the presence of toxic materials such as mercury, lead and brominated flame retardants. According to the Basel Convention e-waste also contain precious metals such as gold, copper and nickel and rare materials of strategic value such as indium and palladium. Due to this the non-formal e-waste recycler are increasing in great numbers. The impact of electronic obsolescence is not limited to a specific area but rather the impact is seen globally. The most deleterious effect is projected in urban slums where the poor specially the children and women are manually involved in recycling toxic e- waste for their earning. The unscientific disposal

E-Waste	Fe (wt%)	Cu (wt%)	Al (wt%)	Pb (wt%)	Ni (wt%)	Ag (ppm)	Au (ppm)	Pd (ppm)
TV board scrap	28	10	10	1.0	0.3	280	20	10
PC board scrap	7	20	5	1.5	1	1000	250	110
Mobile phone scrap	5	13	1	0.3	0.1	1380	350	210
Portable audio scrap	23	21	1	0.14	0.03	150	10	4
DVD player scrap	62	5	2	0.3	0.05	115	15	4
Calculator scrap	4	3	5	0.1	0.5	260	50	5
PC mainboard scrap	4.5	14.3	2.8	2.2	1.1	639	566	124
Printed circuit boards scrap	12	10	7	1.2	0.85	280	110	–
TV scrap (CRT's removed)	–	3.4	1.2	0.2	0.038	20	<10	<10
Electronic scrap	8.3	8.5	0.71	3.15	2.0	29	12	–
PC scrap	20	7	14	6	0.85	189	16	3
Typical electronic scrap	8	20	2	2	2	2000	1000	50
E-scrap sample 1	37.4	18.2	19	1.6	–	6	12	–
E-scrap sample 2	27.3	16.4	11.0	1.4	–	210	150	20
Printed circuit boards	5.3	26.8	1.9	–	0.47	3300	80	–
E-scrap (1972 sample)	26.2	18.6	–	–	–	1800	220	30
E-waste mixture	36	4.1	4.9	0.29	1.0	–	–	–

Note that "–" denotes not reported.

of e-waste is further elevating the problem of pollution. Thus, we need to step up for measures for recycling this e-waste and stop its obsolescence.

Table: 1 Various types of E-wastes and their metal content [6]

2. Developing history of e-waste and Basel Convention:

The history of electronic waste disposal generally began in the mid-70s. Since 1976, with the passage of the Resource Conservation and Recovery Act (RCRA), it has been illegal to dump e-waste in the United States [7]. The story of setting convention for e-waste in 1986, began at Northwest Incinerator in the Philadelphia where good portion of the city’s garbage ended up. Khian sea episode linked to this e-waste garbage is a notorious incident, the details of which are surprisingly murky. The facility at Philadelphia devoured the electronic trash into a fiery maw and transformed it into ash. This ash contained dangerous number of toxic elements like aluminium, arsenic, copper, lead, mercury, chromium and dioxins. In New Jersey the ash was first landfilled but later a waste hauler was contracted to dispose away 15,000 tons of ash. The aim was to dump the ash in poor countries. Surprisingly, the countries Khian sea sailed didn't give credence to accept the ash to be top soil fertilizer. For a period of 16 months the ship sailed Honduras, Morocco, Yugoslavia, Singapore, Panama, Guinea, Haiti. Apparently, the Haitian government were persuaded the ash to be a top soil fertilizer and so allowed the barge to unload 4,000 tons. When Green peace alerted Haiti officials that it was toxic ash, Haiti ordered the ash be reloaded, but the barge left. Between Singapore and Sri Lanka in November 1988, the tons of ash was disappeared. Eventually, the ship's captain admitted that the majority of the ash, reportedly as much as 10, 000 tonnes, had been dumped into the Atlantic and Indian Oceans [8].

This led to designing of International Treaty which is Basel convection on the Control of Transboundary Movements of hazardous wastes and their disposal. The purpose of this International Treaty is to reduce the movements of hazardous waste between nations. Majorly, the aim was to prevent dumping of hazardous waste from developed to less developed countries. This led to culmination of Basel convention which was open for signature on March 22, 1989. It entered into force on May 5, 1992. The rate at which these mountains of obsolete electronic products are growing will reach crisis proportions unless the electronics corporations making and selling these devices own up to their responsibilities [9]. Green peace has been diligent in documenting e-waste export impacts in Asia and Africa specifically Accra and Korforidua, Ghana. For the past decade, the southern eastern town of Guiyu, nestled in China's main manufacturing zone, has been a major hub for the disposal of e-waste [10].

3.Conventional Methods of metal recovery from e-waste:

Pyrometallurgical process:

Pyrometallurgical processes for recovering metals from various waste materials have been used over the last three decades. Smelting in furnaces, incineration, combustion, and pyrolysis are typical e-waste recycling processes [11]. Pyrometallurgy uses high temperature in furnaces to bring about physical and chemical transformations in the e-waste material to recover metals. Thus, recovery of metals from waste electrical and electronic equipment has already been highlighted as important due to the increased consumption worldwide with the advancements in "state of the art" products [12].

The major limitation for pyrometallurgy processes is attributed to a long settling time that is needed for the isolation of slag and metal collection. Pyro process which releases toxic gases (dioxins/furans) and volatile metals, dust, Cl_2, Br_2, SO_2 and CO_2 together with Pb, Hg, Cr, Cd and flame retardants [13]. In addition, high temperatures (1800–2000°C) required for this procedure in the blast furnace and the partial separation of metals are considered main drawbacks of the pyrometallurgical process [14]. Also, pyrometallurgical method are high in energy consumption and costs. Although it is the most extensive method being applied for e- waste management, metal recovery of individual species is limited [12].

Hydrometallurgical processes:

The recovery of precious metals using hydrometallurgical process is the most active form adopted by most electronic waste recyclers. Previously cyanide was used for extraction of valuables from metal ores. But due to its toxicity it is now prohibited. Nowadays, acid combinations are preferred for mobilization of metals from e-waste. Extensive work is done on recovery of gold using hydrometallurgical process. Also leaching of critical elements like indium is well studied. The main steps in hydrometallurgical processing consist of a series of acid or caustic leaches of gold containing material. The solutions are then subjected to separation and purification procedures such as precipitation of impurities, solvent extraction, adsorption and ion-exchange to isolate and concentrate the metals of interest [15]. Nitric (HNO3) and sulfuric (H2SO4) acids as well as cuprous chloride or ammonium sulphate systems, at suitable oxidant conditions, are potential leaching agents described in literature for Silver recovery. In terms of the cost consumption, the main advantages of the acid leaching process include lower capital (e.g., no expensive equipment and cheaper materials of construction) and lower operating costs (e.g., lower energy requirement and less maintenance) [16]. Despite hydrometallurgical process been cost effective with high metal recovery rate, it holds intense drawbacks. Its slow leaching kinetics and large amount of liquid waste that is produced puts this process at a standstill.Biological Leaching of E-waste:

Bioleaching is a promising technology which utilizes microorganisms to recover metals from low-grade ores and e-waste [17]. Biohydrometallurgy is based on similar principles where the lixiviants are biologically produced. The leaching rates of hydrometallurgical processes are relatively faster than those of biohydrometallurgical processes, whereas biological processes are more environmentally friendly and cost-effective [18]. Chemolithoautotrophic bacteria are commonly used for metal recovery from e-waste, such as *Acidithiobacillus ferrooxidans, Leptospirillum ferrooxidans, Acidithiobacillus thiooxidans,* and so on [19]. The two-step process is also suggested for metal leaching involving fungal isolates. This process will mitigate the toxic effect of e-waste.

Hybrid technique for metal extraction:

Recently, hybrid technologies have also been applied, which integrate chemical (more efficient) with biological (more environmentally friendly) processes thus taking the benefits of both chemical and biological leaching [18]. In these processes, biogenic leachate excretion is enhanced, catalysed or supplemented by chemical processes. In case when biological leaching is insufficient, chemical leaching compensates the oxidative capacity that is required to leach metals.

4. Health and environmental effect of e-waste

In mobile phones there are many myriad toxins such as As, Sb, Be, Cd, Cu, Pb, Ni, and Zn. These kinds of chemicals are considered as Persistent Bioaccumulative Toxins (PBTs) and they pose potential risks for the environment when not properly treated [20]. High and prolonged exposure to these chemicals/ pollutants emitted during unsafe e-waste recycling leads to damage of nervous systems, blood systems, kidneys and brain development, respiratory disorders, skin disorders, bronchitis, lung cancer, heart, liver, and spleen damage [3].One of the reports on e- waste dumping site at Mandoli Industrial area, Delhi revealed that the soil contained As (17.08mg/Kg), Cu (115.50 mg/Kg), Pb (2645.31mg/Kg), Se (12.67 mg/Kg) ad Zn (776.84 mg/Kg). Along with this, it was reported that e- waste has high potential to accumulate heavy metals in the native plant samples of *Cynodon dactylon* [21].

An e-waste scrap yard of 20 acres at Accra, Ghana is constantly under heat swirls and smoke billowing across the dumpsite. A recent study on lactating mothers of Ghana suggested that e-waste pollution is getting into breast milk thus putting the new born at high risk. Guiyu is known to be the largest e-waste capital on the planet involving over 75% of the local households and an additional 100,000 migrant workers. Green Peace sampled the soil and found to contain high amount of Cu and Pb making the environmental impact more apparent at Guiyu dumping site. A detailed study conducted by Professor Huo Xia [22], Shantou University Medical College found 165 tested Guiyu children (<6 years) to have Pb in their blood. 81.8% of the kids had blood lead level (BLL) to be over 10µg/dL and the average reading for BLL increased with increase in age. Reported adverse effects of e-waste include: fetal loss, prematurity, low birthweight, and congenital malformations; abnormal thyroid function and thyroid development; neurobehavioral disturbances; and genotoxicity [23].

Also, air pollution is a major concern as illegal market handlers burn the e-waste in open air which further releases harmful brominated retardants into the air. The most vulnerable to suffer from this toxicity of e-waste are the urban poor especially women and children who get exposed during the dismantling of scrap e-waste.ecious metal content of e-waste:

The electronic devices that surround you on a daily basis are built with many components that contain precious metals of gold, silver, copper, and palladium [24]. E-waste is rightly termed as 'secondary ore' for harbouring these precious metals like Ag, Au, and Pt. It is also a mine of base metals like Cu, Al and Ni which are present in significant amount. When such electronic waste is dumped in the ground a substantial amount of precious metals is also getting lost.

In electronics industry, gold and silver are used as contacts, bonding wires and switches, while palladium is used in computer hard disk drives [25]. According to National Institute for Materials Science (NIMS), over 6800 tonnes of gold (16% of the world reserves) and 60,000 tonnes of silver (22%) were found in urban mines [26]. Environmentally sustainable recovery of precious metals from e-waste is also expected to have a significant economic impact [27]. In 2016, the estimated value of recoverable materials in global e-waste was $64.6 billion, but only 20 percent of it was properly recycled to enable recovery of the valuable materials. Much of the rest is dumped in landfills where toxic chemicals can leach from the e-waste and end up contaminating the water supply [4].

Conclusion:

E- waste is a global critical issue crippling worldwide. In urban slums e-waste is handled by unskilled and untrained workers. They carry out unsafe practices which has a detrimental effect on their health as well as environment. In undeveloped nations the most vulnerable to be affected are women and children. They handle e-waste manually, burn it in open air, expose themselves to acid baths, and also dispose it in water bodies and landfill it. According to the law of conservation of mass, “Matter cannot be created or destroyed, it only changes form”. Thus, any waste produced within an ecosystem, cycles back into the system and it does not get vanished. Apparently, the e-waste that is landfilled and disposed into water bodies will find a way to reach our food chain. The repercussions of these unscientific disposal and handling practices are calamitous. The health sacrifice of urban poor in developing countries for capital benefit is condemned. Nevertheless, even with improvements done in the past period, shortfalls in comprehensive safe recovery process is observed. As a community we must resist buying a new electronic product. If unrepairable recycle responsibly. Remember the 3 R’ rule i.e. Reduce, Reuse and Recycle. It can lower the burden of e-waste on our planet.

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