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REVIEW ARTICLE

A Focus on E-Waste: Effects on Environment and Human Health

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Abstract

Electronic wastes can cause widespread environmental damage due to the use of toxic materials in the manufacture of electronic goods. Hazardous materials such as lead, mercury and hexavalent chromium in one form or the other are present in such wastes primarily consisting of Cathode ray tubes (CRTs), Printed board assemblies, Capacitors, Mercury switches and relays, Batteries, Liquid crystal displays (LCDs), Cartridges from photocopying machines, Selenium drums (photocopier) and Electrolytes. Sustainable waste management is crucial to reducing the environmental harm of resource depletion and waste disposal currently ravaging the planet. Due to human ingenuity and advances in technology, the human population is exponentially increasing, living longer, and using more resources than ever before documented. However, fear of the actual and perceived dangers of waste, combined with social norms attached to waste, have precluded society from making changes in the waste system. Information alone is unable to change attitudes and norms. The emotions which hinder change need to be addressed and incorporated into educational programs, such as through the use of art and ritual.

What exactly is e-waste?

Waste from used *electrical* and *electronic equipment* - commonly known as e-waste or WEEE - is one of the fastest growing solid waste streams around the world today.[1] More clearly, "Electronic waste" may be defined as *discarded computers*, *office electronic equipment*, *entertainment device electronics*, *mobile phones*, *television sets* and *refrigerators*. This definition includes used electronics which are destined for reuse, resale, salvage, recycling, or disposal. Others define the *re-usables* (**working and repairable electronics**) and *secondary scrap* (copper**,** steel**,** plastic**,** etc.) to be "commodities", and reserve the term "waste" for residue or material which is dumped by the buyer rather than recycled, including residue from reuse and recycling operations.[2]

E-WASTE: A PROBLEM

The rapid uptake of information technology around the world, coupled with the advent of new designs and technologies at regular intervals is causing the early obsolescence of much electrical and electronic equipment (EEE). [1] Informal processing of electronic waste in developing countries may cause serious health and pollution problems, though these countries are also most likely to reuse and repair electronics. Used electronics contain lead, mercury, barium, arsenic etc. none of it good. Some electronic scrap components, such as CRTs, may contain contaminants such as lead, cadmium, beryllium, or brominated flame retardants. [2]

Fig.1 Discarded electronic equipments

Every day, millions of tonnes of refrigerators, televisions, mobile phones and computers are discarded around the world. Together, these are called electronic waste or e-waste. These are very complex things, containing

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metals like copper, tin, cadmium, mercury and lead, as well as plastics and wood. Disposing of them is now a major international problem. E-wastes are not degradable by *soil bacteria*. Nor can they cannot be destroyed by burning. When they are dumped in landfills, they occupy too much space and leak out dangerous chemicals into the air or soil. If these enter sources of drinking water like rivers or wells, they can cause serious health problems in humans, animals and plants alike.[3]

Dave Kruch, CEO of Cash For Laptops, regards electronic waste as a "rapidly expanding" issue. Technical solutions are available, but in most cases a legal framework, a collection system, logistics, and other services need to be implemented before a technical solution can be applied.[4] Display units (CRT, LCD, LED monitors), Processors (CPU chips, RAM), and audio components have different useful lives. Processors are most frequently outdated (by software) and are more likely to become "e-waste", while display units are most often replaced while working without repair attempts, due to changes in display technology. An estimated 50 million tons of E-waste are produced each year. The USA discards 30 million computers each year and 100 million phones are disposed of in Europe each year. The Environmental Protection Agency estimates that only 15-20% of e-waste is recycled, the rest of these electronics go directly into landfills and incinerators. [2]

According to a report by UNEP *(**United Nations Environment Programme**)* titled, "Recycling - from E-Waste to Resources," the amount of e-waste being produced - including mobile phones and computers - could rise by as much as 500 percent over the next decade in some countries, such as India. [2] The United States is the world leader in producing electronic waste, tossing away about 3 million tons each year. China already produces about 2.3 million tons (2010 estimate) domestically, second only to the United States. And, despite having banned e-waste imports, China remains a major e-waste dumping ground for developed countries. [5]

ELECTRONIC WASTE SUBSTANCES [2, 6]

Some computer components can be reused in assembling new computer products, while others are reduced to metals that can be reused in applications as varied as construction, flatware, and jewelry.

- Substances found in large quantities include epoxy resins, fiberglass, PCBs, PVC (polyvinyl chlorides), thermosetting plastics, lead, tin, copper, silicon, beryllium, carbon, iron and aluminium.
- Elements found in small amounts include cadmium, mercury, and thallium.
- Elements found in trace amounts include americium, antimony, arsenic, barium, bismuth, boron, cobalt, europium, gallium, germanium, gold, indium, lithium, manganese, nickel, niobium, palladium, platinum, rhodium, ruthenium, selenium, silver, tantalum, terbium, thorium, titanium, vanadium, and yttrium.

Almost all electronics contain lead and tin (as solder) and copper (as wire and printed circuit board tracks), though the use of lead-free solder is now spreading rapidly.

DISPOSAL AND TOXICITY

There are growing concerns that most of the e-waste generated in developed countries is ending up in developing countries that are economically challenged and lack the infrastructure for environmentally sound management of e-waste. This results in adverse socio-economic, public health and environmental impact of toxins in e-waste. A study conducted in soil, air dust and human hair collected from an e-waste recycling site in Bangalore, India, clearly found increased concentrations of trace elements such as lead, zinc, silver, cadmium and copper compared to reference sites. A further study in China on human scalp hair, assessing the extent of heavy metal exposure to workers and residents in areas with significantly high e-waste recycling operations, found higher levels of cadmium, copper and lead confirming the previous findings. [7]

A report by *Toxics Link* found that 70% of the e-waste collected at recycling units in New Delhi, India, was actually exported or dumped by developed countries and about 50–80% of the e-waste collected for recycling in the western U.S. is being exported to Asia, about 90% of which is sent to China for recycling. [8, 9] However, the recycling techniques in these countries are often crude and do not have the appropriate facilities; the processes include toner sweeping, dismantling of electronic equipment, selling computer monitors to copper recovery operations, plastic chipping and melting, burning wires to recover copper, heating circuit boards over honeycombed coal blocks, and

using acid chemical strippers to recover gold and other metals.[10, 11] In addition, open burning of unwanted e-waste and their open dumping has been found universally. Such unregulated salvaging operations and optional dumping of the e-waste have resulted in severe and complex contamination of the surrounding environment by toxic chemicals such as heavy metals (Cd, Pb, Cu and Hg), as well as persistent organic compounds such as polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). These compounds could expose the workers and local residents through inhalation, dermal exposure, and even oral intake (of contaminated food), with the health risk being highest for the workers. Once taken into the body, these compounds are stored in certain tissues, leading to intoxication episodes that can be described as acute or long-term intoxications and producing illness when the levels reach critical values. [12] Table.1 summarizes the health effects of certain constituents in e-wastes.

China and India are not the only countries impacted by e-waste. A number of other countries in Asia including Philippines, Hong Kong, Indonesia, Sri Lanka, Pakistan, Bangladesh, Malaysia and Vietnam and also a number of countries in Africa including Nigeria, Kenya, Senegal and Ghana are the latest targets for dumping e-waste generated in advanced economies. Managing e-waste in these countries is not easy given that most developing countries have neither a well-established system for separation,

Table 1: Effects of E-Waste constituent on health [13]

Source of e-wastes	**Constituent**	**Health effects**
Solder in printed circuit boards, glass panels and gaskets in computer monitors	*Lead (PB)*	o Damage to central and peripheral nervous systems, blood systems and kidney damage. o Affects brain development of children.
Chip resistors and semiconductors	*Cadmium (CD)*	o Toxic irreversible effects on human health. o Accumulates in kidney and liver. o Causes neural damage. o Teratogenic.
Relays and switches, printed circuit boards	*Mercury (Hg)*	o Chronic damage to the brain. o Respiratory and skin disorders due to bioaccumulation in fishes.
Corrosion protection of untreated and galvanized steel plates, decorator or hardner for steel housings	*Hexavalent chromium (Cr) VI*	o Asthmatic bronchitis. o DNA damage.
Cabling and computer housing	*Plastics including PVC*	Burning produces dioxin. It causes o Reproductive and developmental problems; o Immune system damage; o Interfere with regulatory hormones
Plastic housing of electronic equipments and circuit boards.	*Brominated flame retardants (BFR)*	o Disrupts endocrine system functions
Front panel of CRTs	*Barium (Ba)*	Short term exposure causes: o Muscle weakness; o Damage to heart, liver and spleen.
Motherboard	*Beryllium (Be)*	o Carcinogenic (lung cancer) o Inhalation of fumes and dust. Causes chronic beryllium disease or beryllicosis. o Skin diseases such as warts.

storage, transportation, treatment and disposal of waste nor any effective enforcement related to managing e-waste. Thus, co-disposal of e-waste with domestic waste in open dumps is generally practiced in many developing countries causing severe damage to the environment and human health. [1]

OTHER CONTAMINANTS

E-waste also contains brominated flame retardants (BFRs) such as polybrominated biphenyls (PBB) and polybrominated diphenylethers (PBDEs) which are used in printed circuit boards, connectors, covers and cables. A recent comprehensive review conducted by A. Sepulveda et al., where scientific data related to concentrations of lead (Pb), PBDEs, polychlorinated dioxins and furans were monitored around e-waste recycling areas in China and India. This highlighted the very high levels of the aforementioned compounds in air, dust, soil and water samples, which at times considerably exceeded the concentration levels found in other industrial urban areas. These findings are further confirmed by studies conducted by Ni et al. where they found high concentrations of above compounds in e-waste recycling sites in China. [1]

E- WASTE PROCESSING AREAS

Guiyu in the Shantou region of China, Delhi and Bangalore in India as well as the Agbogbloshie site near Accra, Ghana have electronic waste processing areas. Uncontrolled burning, disassembly, and disposal causes a variety of environmental problems such as groundwater contamination, atmospheric pollution, or even water pollution either by immediate discharge or due to surface runoff (especially near coastal areas), as well as health problems including occupational safety and health effects among those directly and indirectly involved, due to the methods of processing the waste. Thousands of men, women, and children are employed in highly polluting, primitive recycling technologies, extracting the metals, toners, and plastics from computers and other electronic waste. Recent studies show that 7 out of 10 children in this region have too much lead in their blood. [2]

METHODS OF DEALING WITH E-WASTE [14]

We can deal with the e-waste in three easy ways.

- Reduce,
- Reuse and
- Recycle.

The first is the hardest. Let's not buy a new phone or TV till the one you have is worn out completely. But then, when we see new models advertised all around us, it's hard to resist temptation. Furthermore Proper control over the materials used in the manufacturing process is an important way to reduce waste generation (Freeman, 1989). By reducing both the quantity of hazardous materials used in the process and the amount of excess raw materials in stock, the quantity of waste generated can be reduced.

The second way is to offer them to someone to reuse. The next time we buy a new computer or gaming console, let's donate the old one to a charitable organization. They will use them to teach those less fortunate than us.

And lastly, we can help by recycling. The lead, cadmium, mercury etc. that are present in discarded electronics can be extracted for several other uses. Many electronics stores now have collection points where we can dispose of old phones, PCs etc. These are then shipped to recycling plants.

CONCLUSION

The above mentioned threats from the ever growing e-waste stream can only be minimized by producing less of it through application of concepts such as green chemistry and design for environment where alternatives to toxic materials can be found. Good examples of this include the development substitution of toxic raw materials with less toxic materials as in the case of Pb-free soldering and the development of halogen-free BFRs in electronics manufacture.

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