

E-Waste: An Impending Challenge

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Driven by the rapidly changing technologies and increasing quantities of end-of-life electronic equipment, electronic waste is emerging as a transnational problem. Industrial nations are shipping millions of obsolete computers yearly to developing countries. The large material flow can be toxic as well as beneficial. This article analyses the flow of obsolete computers to Pakistan and discusses the potential ecological and health impacts of inadequate e-waste management practices. Legislation, regulatory action and public awareness can help avoid the health and environment risks across Pakistan. Adoption of modern recycling technology, on the other hand, can help transform the problem into a multi-million opportunity. However, this requires government support in the form of necessary legislation and strict regulatory actions. Global cooperation – necessary funding and technology transfer – should also be sought.

Abbreviations used in this text:

BFR: Brominated Flame Retardants	CFC: Chlorofluorocarbon
PBB: Polybrominated biphenyls	PBDE: Polybrominated diphenyl ethers
PCB: Polychlorinated biphenyl	PCDD: Polychlorinated dibenzo-p-dioxins
PCDF: Polychlorinated dibenzofurans	PVC: Polyvinyl chloride

Introduction

Electronic waste, e-waste, or e-scrap, may be defined as electronic devices destined for recycling or disposal. Rapid technological developments in electronics industry are resulting in large numbers of electronic items being scrapped and becoming electronic waste (e-waste). E-waste includes a broad range of devices; these include televisions, VCRs, stereo equipment, mobile phones, other handheld devices, and computer components. The United States Environmental Protection Agency (EPA) refers to obsolete computers as “hazardous household waste”¹.

In the U.S. alone, 1.5 billion pounds e-waste was generated during 2006. The total annual global volume of e-waste is about 40 million metric tons. The rate of growth of e-waste is three times that of other municipal waste. Although e-waste makes a small fraction of municipal waste (only 1-4% percent), it may be responsible for as much as 70 percent of the heavy metals in landfills, including 40 percent of all lead².

Management of electronic waste is of great concern largely due to the toxicity and carcinogenicity of some of the substances. Toxic substances in electronic waste may include lead, mercury, and cadmium. Carcinogenic substances in electronic waste may include PCBs. Electronic waste may have up to 38 separate chemical elements. Many of the plastics used in electronic equipment contain flame retardants making their recycling more difficult and more hazardous³.

Table 1: Typical E-Waste Composition

Substance	Occurrence in e-waste
Halogenated compounds:	
PCB	Condensers, transformers.
TBBA*	Fire retardants for plastics (thermoplastic components, cable insulation)
PBB	
PBDE	TBBA is presently the most widely used flame retardant.
CFC	Cooling unit, insulation foam.
PVC	Cable insulation.
Heavy (and other) metals:	
Arsenic	Small quantities as gallium arsenide in light emitting diodes.
Barium	In CRT getters.
Beryllium	Power supplies containing silicon controlled rectifiers and x-ray lenses.
Cadmium	NiCd-batteries, CRT screens, printer inks and toners, printer drums.
Chromium VI	Data tapes, floppy-disks.
Lead	CRT screens, batteries, printed wiring boards.
Lithium	Li-batteries.
Mercury	Fluorescent lamps that provide backlighting in LCDs, in some alkaline batteries and mercury wetted switches.
Nickel	Rechargeable Ni-Cd batteries or Ni-MH batteries, electron gun in CRT.
Rare Earth elements (Yttrium, Europium)	Fluorescent layer (CRT-screen).
Selenium	Older photocopying-machines (photo drums).
Zinc sulphide	Interior of CRT screens, mixed with rare earth metals.
Others:	
Toner dust	Toner cartridges for laser printers / copiers.
Radio-active substances:	
Americium	Medical equipment, fire detectors, active sensing element in smoke detectors.

Nature of the Threat

Electronic appliances are composed of a host of materials that can be toxic as well as valuable⁴. Typically 80 % of the waste (by weight) is made up of various alloys of iron, aluminum, plastics and glass. Many metals that appear in small quantities are quite expensive. This makes recycling of e-waste an attractive business opportunity. On the other hand, if waste streams are mishandled, the presence of some of the hazardous substances such as lead and arsenic poses serious risks to environment and to the health of recycling workers at various stages of processing. Table 1 shows the typical material composition of e-waste and the origin of its various components.

Many materials present in the e-waste (mostly printed circuit boards) in small quantities are very valuable. These include gold, silver, platinum and palladium as well as rare metals like indium and gallium. Substances found in large quantities (constituting more than 80% of the weight) include: epoxy resins, fiberglass, PCBs, PVC, thermosetting plastics, lead, tin, copper, silicon, beryllium, carbon, iron and aluminum. Cadmium, mercury, and thallium occur in relatively small quantities⁵. The substances found in only 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. Table-2 provides the composition of a desktop computer (including a CRT screen).

Table-2 Composition of a Desktop Computer with a CRT screen

Range of Amount Present	Materials
4-7 Kg	Aluminum, iron, plastics, silica (glass)
1.5-2 Kg	Lead, copper
0.25-0.5 Kg	Nickel, tin, zinc
< 0.1Kg	(~550 g) Antimony, beryllium, barium, cobalt, cadmium, manganese, tantalum, titanium, silver. (~125g) Yttrium, bismuth, chromium, arsenic, mercury. (~50 g) Indium, gallium, germanium, gold, ruthenium, selenium. (~ 5-6 g) Europium, niobium, vanadium , palladium

Hazards Involved

The presence of toxic substances makes the e-waste a hazardous material. Table 3 provides a list of toxic materials present in the e-waste and their effects on human health⁶. The impact of e-waste disposal on the environment and health depends on the nature of e-waste management practices followed. Uncontrolled burning, processing, and disposal can trigger serious health problems especially among those directly exposed. Thousands of workers are currently employed in extracting the metals, toners, and plastics from computers and other electronic waste.

The waste management practices can be classified into conventional (primitive) techniques and (cleaner) modern technologies. The conventional practices include some unsafe and wasteful methods. The practices continue in developing countries where strict health and environment standards are lacking. The cleaner recycling technologies comply with higher environmental and occupational safety standards⁷.

The conventional technologies of waste management include landfills, open-air-burning and incineration. Many of the materials found in e-waste generate hazardous toxic substances on burning that are dispersed in the atmosphere. This is particularly true for open-air burning, which releases several toxins including various carcinogens and neurotoxins, e.g. dioxins and furans into the air.

The copper in the e-waste can catalyze the production of dioxins, PBDDs, and PBDFs. The release of resultant pollutants can trigger a host of illnesses in humans. It can also result in loss of property. In landfills such leachate can contaminate ground water resources. The vaporization of volatile

compounds is yet another environmental concern. It was on account of these concerns that some European countries banned the disposal of electronic waste in landfills in the 1990s.

The modern e-waste disposal processes work on the principle of increased cost-effective processing of bulk electronic waste. This involves sorting, concentrating and refining.

Sorting avoids dilution and/ or contamination with toxic substances during the downstream processes. As a first step, materials are classified as metals, plastics and glass. This is followed by physical/ mechanical processing of classified waste to obtain concentrates of recyclable materials in a dedicated fraction. In the final step, the e-waste is refined to extract the raw materials with minimal environmental impact.

A recent report from a scrap computer recycling plant shows that employing the available recycling technology can recover 94.75 % of useful materials (by weight) from the main machines (CPU, IC boards, DVD/ CD drive, hard disk, etc.) and 45.99.% (by weight) from scrapped monitors⁸.

Table 3: Toxic substances in E-waste

Material	Toxicity
Arsenic	Skin diseases, lung cancer, decreased nerve conduction velocity
Barium	Brain swelling, muscle weakness, damage to heart, liver and spleen.
Beryllium	Lung cancer (beryllicosis), skin disease
BFRs	Severe hormonal disorders
Cadmium	Lung cancer, kidney damage, pulmonary emphysema and bone diseases.
CFCs	Skin cancer, deleterious to ozone layer
Chromium(VI)	Irritating to eyes, skin and mucous membranes, DNA damage
Dioxins* (PCDD, PCDF)	Impairment of the immune system
Lead	Vomiting, diarrhea, convulsions, coma, even death.
Mercury	Brain and liver damage if ingested or inhaled.
PCB	Cause cancer, damage to immune system, reproductive system, nervous system, endocrine system etc.
PVC*	(on combustion) respiratory problems.
Selenium	Hair loss, nail brittleness, and neurological abnormalities

** From combustion of wastes*

Environmental Colonialism

Because electronic and electrical products are laden with chemicals harmful to human health and the environment, their disposal is often governed by strict regulations in developed countries. Increased regulation of electronic waste management has raised disposal costs. This provides an incentive to export unscreened electronic waste to Afro-Asian countries, avoiding the processing expenses. Around 80% of the e-waste in U.S. is exported to Asia and Africa. But U.S. is not the only country dumping e-waste in Asia. Many consignments from European Union, Japan and South Korea, as well as the US that sought to sneak through customs and illegally dump e-waste have been intercepted^{9,10}.

Guiyu in China, and Delhi and Bangalore in India, are main e-waste processing centers. Other dumping grounds include Pakistan, Philippines, Nigeria and Ghana. In Pakistan, Lahore and Karachi are the main activity centers in terms of e-waste dumping¹¹⁻¹⁵.

There have been attempts to restrict the flow of hazardous e-waste to developing countries. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal commonly known as The Basel Convention is an international treaty designed to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries. The Basel Convention was adopted in 1989 and entered into force in 1992¹⁶. Another significant effort in this direction was The Basel Ban Amendment, of 1995. United States is currently the only OECD country that has not ratified the original Basel Convention, or the Basel Ban Amendment¹⁷.

In spite of these efforts illegal e-waste dumping in developing countries continues. Lack of legislation, inadequate strategies and poor implementation of law in developing countries are some of the many reasons for the unlawful flow of hazardous e-waste.

The consequence and impact of unsafe practices of e-waste recycling can be comprehended by the following case study.

A Case study: Guiyu

Guiyu is located in the west of the coastal city of Shantou, in Eastern Guangdong province of People's Republic of China. The Lianjiang River runs through the region. E-waste recycling at Guiyu began around 1995. Today Guiyu is regarded as the global electronic-waste capital. Nearly 150,000 Guiyu workers are associated with e-waste processing. While an average e-waste processing worker, earns merely US\$0.30 an hour, the town reports revenues of \$75 million from processing 1.5 million tonnes of e-waste every year.

Recycling practices at Guiyu remain primitive. These include “cooking” of circuit boards to remove chips and solders, burning of wires and other plastics to collect metals such as copper, use of highly corrosive acid baths to extract gold from the microchips, and dusting of printer toner out of cartridges. Workers are exposed to the dioxin-containing ash. The soil has been badly contaminated with heavy metals. The water is undrinkable. Visitors to the city experience headaches and a metallic taste in the mouth. The concentration of dioxin at Guiyu has been reported to be the highest ever recorded.

Early this year, a Chinese government report revealed that 80% of Guiyu's children suffered from lead poisoning. A study conducted by Hong Kong Baptist University since 2003 concluded early this year that the level of PBDE flame retardants at an e-waste combustion site in Guiyu was more than 16,000 times higher than at a control site. The research has established that PBDEs can be persistent, bio-accumulative, and toxic and can cause liver and neuro-developmental toxicity and affect thyroid hormone levels. Today Guiyu is world's second most polluted spot, next only to Lake Karachay^{11, 18, 20}.

Strategies Adopted in the Developing Countries

In developed countries many efforts have been made to face the impending challenge of e-waste. The EU directives on Waste Electrical and Electronic Equipment (WEEE)²⁰ and Reduction of Hazardous Substances (RoHS)²¹ are aimed at preventing the generation of hazardous waste, and require the substitution of several heavy metals (e.g. lead, mercury, cadmium, and chromium-VI) and brominated flame retardants (e.g. PBB or PBDE) in new electrical and electronic equipment marketed since July 1, 2006.

Extended Producer Responsibility (EPR)²² is yet another effort to further the same objectives. Its purpose is to make manufactures responsible for their products, especially when they become obsolete. Corporations have started offering low-cost to no-cost recycling. Since 2001, China has banned the import of e-waste.

Pakistan is a signatory to the Basel Convention. The computers and other obsolete electronic goods are however imported under the pretext of 'second-hand equipment'. Barely a small percentage of the items imported are usable. In practice, after removing the working machines and usable parts the bulk of the consignment is sent to the recycling industry. The Basal Convention in essence is flouted. The unregulated and unsafe waste management practices let hazardous materials in the waste to disseminate into the environmental resources. The bulk solid waste is dumped in the landfill and the effluents arisen from the recycling processes are dumped into the Lyari river and ultimately into the Arabian Sea contaminating the marine ecosystem.

Working conditions in Pakistan are certainly not better than China. This issue to this point has received little attention from government and non-governmental environmental bodies in the country. Fortunately, Pakistan is still not a major e-waste dumping ground. However, the situation is likely to change in the near future. It is feared that with the ever escalating generation of e-waste and strict legislation making recycling financially less attractive in the developing countries and a ban on e-waste exports to China, the e-waste brokers will try to find new markets. Consequently, e-waste flow to Pakistan can swell exponentially.

To date no scientific study has been made to assess the impact of e-waste processing to our environment. There is no reliable data available on the volume of used electronic components imported and the fraction of it recycled or dumped as solid waste. There is a dire need to determine the detrimental impact of e-waste processing on public health. This necessitates expeditious measures and a rational strategy to avoid transforming Karachi and Lahore to yet another Guiyu.

Conclusions

1. Rapid technology change and low initial cost have resulted in a fast-growing electronic waste problem.
2. The technological innovations and tidal wave of new consumers is bound to increase the pace of e-waste generation.
3. Legislation, regulatory action and public awareness can help avoid a likely health and environment catastrophe²³.
4. Adoption of modern recycling technologies can help transform the problem into a multi-million opportunity.
5. To the best estimates of the authors, Pakistan is not equipped yet to face this challenge; a lot of homework is needed in several areas. The private sector lacks the necessary skills and resources to meet a challenge of this complexity and magnitude. The only way to cope with the situation is a well-coordinated public-private joint effort. Government support as well as technical/financial help from developed countries will be essential for environment friendly recycling of e-waste in Pakistan.

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