Review

E-Waste Management in Developing Countries: Current Practices, Challenges, Disposal, and Impact on Human Health & Environment

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E-Waste Management in Developing Countries: Current Practices, Challenges, Disposal, and Impact on Human Health & Environment

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Abstract: Information and telecommunications technology (ITT) have expanded into many aspects of modern life and have positively affected human life even in the most remote areas of developing countries. The rapid growth in ITT has led to an improvement in the capacity of computers but simultaneously to a decrease in the product's lifetime as a result of which increasingly large quantities of e-waste are generated annually. It contains hazardous components that if it is not properly managed, can have adverse environmental and health effects. The management of e-waste poses significant challenges in developing countries. Due to the lack of adequate infrastructure, e-waste is burned or dumped in open areas. Informal and inefficient recycling practices are generally employed which further exacerbate pollution and health risks. So, the implementation of e-waste management, adequate recycling, and waste disposal facilities have become crucial concerns. This article reviews the concept of e-waste generation, challenges, disposal, and its impact on human health & environment in detail.

Keywords: e-waste; management; developing countries; challenges; human health

1. Introduction

Electrical waste (e-waste) is one of the fastest-growing solid waste streams worldwide (Bhardwaj et al. 2023a). It is growing at a rate of 3-5% per annum or ~ three times faster than other individual waste streams (Schwarzer et al. 2005). It includes common items, such as computers, televisions, mobile phones, iPods, printers, fluorescent lamps, power tools, toys, etc. These items basically cover most of the small and large appliances used in households and industries in modern society. E-waste contains a large number of toxic substances, including plastics, and heavy metals such as lead (Pb), nickel (Ni), chromium (Cr), cadmium (Cd), arsenic (As), and mercury (Hg). It also contains polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDEs), which are used in connectors, covers, and cables. Cd, Pb, and Hg are present in the central processing units (CPU) and antimony (Sb), silver (Ag), Cr, zinc (Zn), Pb, tin (Sn), and copper (Cu) are present in printed circuit boards (PCB) (Herat and Agamuthu 2012). Pb is used mainly in cathode ray tubes (CRTs) in monitors, tin–lead solders, cabling, and fluorescent tubes (Herat 2008c). These hazardous constituents may negatively impact on human health and the environment if e-waste is not properly managed. Several hazardous pollutants have been reported from the different samples that were collected from various e-waste recycling sites (Table 1).

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Table 1. The Occurrence of Hazardous Pollutants in the Different Samples Collected from Different E-Waste Recycling Sites.

S. No.	E-waste category	Examples of electronic products
1	Temperature exchange equipment	Refrigerators, freezers, air conditioning equipment, dehumidifying equipment, heat pumps, radiators containing oil and other temperature-exchange equipment
2	Equipment containing screens that have a surface greater than 100 cm2	Screens, televisions, liquid crystal display (LCD) photo frames, monitors, laptops, notebooks
3	Lamps	Straight fluorescent lamps, compact fluorescent lamps, fluorescent lamps, high-density discharge lamps, low-pressure sodium lamps, light emitting diode (LED)
4	Large equipment (any external dimension greater than 50 cm)	Washing machines, clothes dryers, dishwashing machines, cookers, electric stoves, electric hot plates, musical equipment, large printing machines, copying equipment, large medical devices, etc.
5	Small equipment (no external dimension more than 50 cm)	Vacuum cleaners, carpet sweepers, microwaves, irons, toasters, electric knives, electric kettles, electric shavers, scales, calculators, radio sets, video cameras, video recorders, hi-fi equipment, toys, smoke detectors, etc.
6	Small information technology and telecommunication equipment (no external dimension more than 50 cm)	Mobile phones, global positioning systems, pocket calculators, routers, personal computers, printers, telephones

The wide variety of products from mechanical devices to highly integrated systems and the accelerating technological innovations are the major causes of the increase in e-waste (Yla-Mella et al. 2004). Due to rapid advancement in technological innovations and economic development, the useful life of electronic products is relatively shorter (Hossain et al. 2015). Electrical equipment was classified into brown goods (computers, mobile phones, etc.) and white goods (refrigerators, air conditioners, etc.) (Widmer et al. 2005). The growing quantities of e-waste depend on the disposal of electrical and electronic equipment (EEE). In developing countries, increased population, rapid urbanization, and industrial growth exacerbate e-waste issues. Most of the e-waste is buried, burnt in the open area or dumped into surface water bodies due to a lack of adequate infrastructure to manage waste safely. E-waste is divided into six categories that are presented in Table 2.

Table 2. Six Different Categories of E-Wastes.

S. No.	Type of Samples	Hazardous Pollutants	E-Waste Recycling Site	References
1	Sediment	PCBs, PAHs, and heavy metals	Nanguan River, Taizhou, East China	Chen et al. 2010
			Wenling, Taizhou, China	Tang et al. 2010b
		Heavy metals	Bangalore, India	Ha et al. 2009
		PCDD/Fs	China	Ren et al. 2010
		Dechlorane plus (DP)	South China	Yu et al. 2010
2	Soil	PCBs, PAHs, and heavy metals	Taizhou, East China	Tang et al. 2010a

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		Heavy metals	Guiyu, Guangdong province, China	Li et al. 2011a
3	Soils and vegetables		Longtang, Guangdong province, China	Luo et al. 2011
		PBDEs	South China	Wang et al. 2011b
4	Air	PCDD/Fs	China	Wen et al. 2011
		Dechlorane plus (DP)	China	Chen et al. 2011
5	Surface Dust	PBDEs and PCDD/Fs	Southeast China	Leung et al. 2011
6	Mangrove wetland	PBDE	India	Binelli et al. 2007
7	Hair	Heavy metals	Longtang, South China	Zheng et al. 2011
		PCDD/Fs, and PBDEs	Eastern China	Ma et al. 2011
8	Placenta	Heavy metals	Guiya, China	Guo et al. 2010
9	Urine		Taizhou, Zhejiang province, Southeast China	Wang et al. 2011a
			Taizhou, China	Wang et al. 2010
10	Human	PCBs, BFRs, PBDEs and HBCDs	Ghana	Asante et al. 2011
		PBBs, PBDEs, and PCBs	Zhejiang Province, China	Zhao et al. 2008
11	Children's blood	PCDD/Fs, PCBs, PBDEs and organochlorine pesticides	Zhejiang, China	Shen et al. 2010
12	Breast milk	PCBs, and BFRs	Vietnam	Tue et al. 2010a
13	Umbilical cord blood	PBDEs	Guiyu, China	Wu et al. 2010
14	Thyroid gland	PBDEs, dioxins, and PCBs	China	Zhang et al. 2010a
15	Skin	PCBs	Taizhou area, China	Xing et al. 2011
16	Chicken tissue, and eggs	PBDEs	Southeast China	Qin et al. 2011
17	Fish		Guiya area, China	Luo et al. 2007a

Darby and Obara (2005) studied the level of e-waste in the United Kingdom (UK) and stated that more than 90% of EEE is landfilled and incinerated. The United States of America (USA) is believed to produce the largest amount of e-waste in the world. In the USA, around 5 million tonnes of e-waste were in storage and 2.37 million tonnes of e-waste were ready for disposal in 2009 (United States Environmental Protection Agency 2011). In the European Union (EU), the total generation of e-waste was estimated to be 9.3 million tonnes, which included 40 million personal computers and 32 million televisions in 2005 (United Nations University 2007a). As per the study by Computer Aid International (2010), 12 million tonnes of e-waste were predicted to grow by 2020. In China, ~ 83 million units of EEE were found as scrap in 2007 and were supposed to reach 227 million units by 2012 (Veenstra et al. 2010). In Japan, around 12.9 million units of EEE were found as scrap in 2008 (Ministry of Environment, Japan 2010).

In Canada, ~ 5 million units of EEE are disposed of every year (Deathe et al. 2008). In Korea, over 3 million computers and 15 million mobile phones reached their end-of-life in 2004 (Hyunmyung & Yong-Chul 2006). According to the study by Canning (2006), over 130 million mobile phones in the USA and 105 million mobile phones in Europe were thrown away each year. The United Nations (UN) (2009) predicted that e-waste will jump by 200–400% in South Africa and China; while in India, it will jump by 500% in 2020. The UN also predicted that e-waste from discarded mobile phones will be 7 times higher in China and 18 times higher in India. The UN also estimates that e-waste from discarded personal computers increase 4–8 folds by 2020 in developing countries like Senegal and

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Uganda. The aim of this study is to present a review of e-waste, its management, challenges, disposal, and impact on human health and the environment in developing countries.

2. E-Waste Management

The management of e-waste is a priority because of its major challenges. Nowadays the quantity of e-waste generated is a major concern for researchers globally. Due to the increased population and rapid development, the demand for e-waste management in developing countries is aggravated. Traditional waste management systems affect not only the local environment and public health but also the environment of neighboring countries (Murad and Siwar 2007). The large amounts of e-waste generated and the availability of land at a low cost are other factors that support a traditional approach to the disposal of e-waste. There are growing concerns that most of the e-waste generated in developed countries is ending up in developing countries that are economically challenged (Hossain et al. 2011).

Many developed countries have legislation that mandates the principle of extended producer responsibility (EPR) i.e. taking back expired electronic products from customers. EPR is a method of integrating sustainable development principles into international trade based on an international environmental law principle known as the "Polluter Pays Principle" (Kibert, 2004). Key issues in effective e-waste management in developing countries include a change in government attitudes, specific legislation addressing e-waste, control over e-waste dumping, implementation of EPR, and the transfer of technology for sound e-waste recycling.

3. Challenges and Disposal of E-waste

There are two processes of recycling, i.e. formal and informal. The informal process is widely practiced, and in this process, e-waste is burned and disassembled in open spaces to recover valuable components such as steel, aluminum, and copper (Leung et al., 2006; SEPA, 2011). The recycling of e-waste is a complex process. The informal recycling sector is very active in Asian countries such as China, India, Pakistan, Vietnam, and the Philippines and some African countries such as Nigeria, and Ghana for the disposal of e-waste (Nnorom and Osibanjo, 2008a). Osibanjo and Nnorom (2007) identified that the primary challenges faced by developing countries revolve around the escalating rate of e-waste production and its inadequate management. There are several challenges which are as follows:

(i) Threats from inadequate handling are greater.
(ii) Formal recycling systems are lacking.
(iii) Recycling legislation is either weak or absent.
(iv) Inventory assessment of e-waste is poor or does not exist.

Brigden et al. (2005) conducted a study near e-waste recycling sites in China and India and found high levels of Pb, polybrominated diphenyl ethers (PBDEs), polychlorinated dibenzodioxins and furans (PCDD/Fs) and polybrominated dibenzodioxins and furans (PBDD/Fs) in samples of air, dust, sediments, and freshwater. A similar study was conducted by Brigden et al. (2008) in Ghana, which found high levels of Pb, bis (2-ethylhexyl) phthalate (DEHP), and dibutyl phthalate (DBP) in the samples collected from the e-waste recycling sites. Several pollutants such as pesticides, heavy metals, and DEHP were reported in the water/soil and sediment samples by the researchers in different studies (Bhardwaj and Jindal 2020; Bhardwaj et al. 2021; Bhardwaj et al. 2023b).

4. Impact on Human Health and Environment

E-waste creates a massive risk to the health of animals and humans, and it also affects the environment. Due to the mismanagement of e-waste, harmful toxic components can cause harm to the environment as well as human health. Direct or indirect exposure to such harmful toxic contaminants takes place through skin contact, inhalation, ingestion, etc. E-waste disposal is a significant hazard because improper disposal creates a high risk for infectious diseases (Murad and Siwar, 2007). Due to the dumping of e-waste in open sites, harmful substances enter the food chain

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through bioaccumulation and cause several diseases (Alam et al. 2023). Researchers studied the contamination level in PET bottled water samples and described thoroughly the migration of the contaminants from plastic items to water bodies (Bhardwaj and Sharma 2021; Bhardwaj 2022). Xue et al. (2015) quantitatively assessed the environmental impact of processing PCBs, and Song et al. (2012a) investigated the environmental impact of cathode ray tube televisions in China. The toxic substances can leach into the soil, contaminating it and affecting plant growth (Bhardwaj et al. 2023c). These chemicals and heavy metals can seep into water bodies, causing water pollution. This affects aquatic life and various habitats that can ultimately impact human communities that rely on these resources. Burning or dismantling e-waste releases toxic fumes and particles into the environment, which affects flora and fauna. People residing in the vicinity have been observed to be affected with various problems like respiratory problems (such as lung irritation, and asthma) neurological disorders, developmental delays, organ damage, skin rashes, burns, eye irritation, etc (Parvez et al. 2021; Bhardwaj and Vikram 2023; Bhardwaj et al. 2023d).

5. Conclusion and Recommendations

E-waste has evolved into a significant global concern, posing both social and environmental threats to numerous developing countries. The proper handling and disposal of e-waste have emerged as major challenges for many nations worldwide. Particularly, developing countries encounter various complexities related to the generation, cross-border transportation, and effective management of e-waste. There is a pressing need to implement comprehensive legislation for effective e-waste management in developing countries. This legislation will also advocate that the export of e-waste should only occur if the receiving country possesses adequate capacity to manage e-waste in a way that protects health and the environment.

As per the critical review, the following recommendations might be beneficial to minimize e-waste:

- The government should formally integrate informal recycling into its municipal waste management system.
- Provision must be made by the government for sufficient funding to support the collection, storage, recycling, and/or disposal of e-waste.
- The authority should provide training to recycling participants as well as enhance existing recycling facilities for e-waste.
- The authorities should conduct an awareness program for workers to educate them about the impacts of e-waste on human health and the environment.
- Developing countries should create and maintain an inventory assessment of e-waste.
- Robust legislation must be established in developing countries to regulate and control the impact of e-waste.
- Alternative or new techniques should replace traditional techniques to minimize e-waste.
- EPR principles should be adopted and included in the legislation of developing countries.
- Producers, importers, and retailers should be mandated to bear the cost of collecting, recycling, and disposing of e-waste.
- Standards and a certification system should be established for second-hand appliances and recycling and disposal enterprises to ensure safety and environmentally sound practices.

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