Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2023, 10(11s):74-83

Research Article ISSN: 2394 - 658X

E-Waste- E-Cycle Management

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Received: 2/08/2023; Accepted 01/09/2023; Published 25/10/2023

ABSTRACT

Electronic waste or e-waste describes discarded electrical or electronic devices. It is also commonly known as waste electrical and electronic equipment (WEEE) or end-of-life (EOL) electronics. [1] Used electronics which are destined for refurbishment, reuse, resale, salvage recycling through material recovery, or disposal are also considered e-waste. Informal processing of e-waste in developing countries can lead to adverse human health effects and environmental pollution. The growing consumption of electronic goods due to the digital revolution and innovations in science and technology, such as bitcoin, has led to a global e-waste problem and hazard. The rapid exponential increase of e-waste is due to frequent new model releases and unnecessary purchases of electrical and electronic equipment (EEE), short innovation cycles and low recycling rates, and a drop in the average life span of computers [2].

Electronic scrap components, such as CPUs, contain potentially harmful materials such as lead, cadmium, beryllium, or brominated flame retardants. Recycling and disposal of e-waste may involve significant risk to the health of workers and their communities [3].

Key words: e-waste, electronic, pollution, revolution, lead, cadmium, beryllium, brominated, flame, retardants

INTRODUCTION

E-waste or electronic waste is created when an electronic product is discarded after the end of its useful life. The rapid expansion of technology and the consumption driven society results in the creation of a very large amount of e-waste.

In the US, the United States Environmental Protection Agency (EPA) classifies e-waste into ten categories:

1. Large household appliances, including cooling and freezing appliances
2. Small household appliances
3. IT equipment, including monitors
4. Consumer electronics, including televisions
5. Lamps and luminaires
6. Toys
7. Tools
8. Medical devices
9. Monitoring and control instruments and
10. Automatic dispensers

These include used electronics which are destined for reuse, resale, salvage, recycling, or disposal as well as re-usables (working and repairable electronics) and secondary raw materials (copper, steel, plastic, or similar). The term "waste" is reserved for residue or material which is dumped by the buyer rather than recycled, including residue from reuse and recycling operations, because loads of surplus electronics are frequently commingled (good, recyclable, and non-recyclable). Several public policy advocates apply the term "e-waste" and "e-scrap" broadly to apply to all surplus electronics. Cathode ray tubes (CRTs) are considered one of the hardest types to recycle [4-5].

Using a different set of categories, the Partnership on Measuring ICT for Development defines e-waste in six categories:

1. Temperature exchange equipment (such as air conditioners, freezers)
2. Screens, monitors (TVs, laptops)
3. Lamps (LED lamps, for example)
4. Large equipment (washing machines, electric stoves)
5. Small equipment (microwaves, electric shavers) and
6. Small IT and telecommunication equipment (such as mobile phones, printers)

Products in each category vary in longevity profile, impact, and collection methods, among other differences [6]. Around 70% of toxic waste in landfills is electronic waste [7].

CRTs have a relatively high concentration of lead and phosphors (not to be confused with phosphorus), both of which are necessary for the display. The United States Environmental Protection Agency (EPA) includes discarded CRT monitors in its category of "hazardous household waste" [8] but considers CRTs that have been set aside for testing to be commodities if they are not discarded, speculatively accumulated, or left unprotected from weather and other damage. These CRT devices are often confused between the DLP Rear Projection TV, both of which have a different recycling process due to the materials of which they are composed.

The EU and its member states operate a system via the European Waste Catalogue (EWC) – a European Council Directive, which is interpreted into "member state law". In the UK, this is in the form of the List of Wastes Directive. However, the list (and EWC) gives a broad definition (EWC Code 16 02 13*) of what is hazardous electronic waste, requiring "waste operators" to employ the Hazardous Waste Regulations (Annex 1A, Annex 1B) for refined definition. Constituent materials in the waste also require assessment via the combination of Annex II and Annex III, again allowing operators to further determine whether waste is hazardous [9].

Debate continues over the distinction between "commodity" and "waste" electronics definitions. Some exporters are accused of deliberately leaving difficult-to-recycle, obsolete, or non-repairable equipment mixed in loads of working equipment (though this may also come through ignorance, or to avoid more costly treatment processes). Protectionists may broaden the definition of "waste" electronics in order to protect domestic markets from working secondary equipment.

The high value of the computer recycling subset of electronic waste (working and reusable laptops, desktops, and components like RAM) can help pay the cost of transportation for a larger number of worthless pieces than what can be achieved with display devices, which have less (or negative) scrap value. A 2011 report, "Ghana E-waste Country Assessment", [10] found that of 215,000 tons of electronics imported to Ghana, 30% was brand new and 70% was used. Of the used product, the study concluded that 15% was not reused and was scrapped or discarded. This contrasts with published but uncredited claims that 80% of the imports into Ghana were being burned in primitive conditions.

E-waste is considered the "fastest-growing waste stream in the world"[11] with 44.7 million tonnes generated in 2016- equivalent to 4500 Eiffel towers [6]. In 2018, an estimated 50 million tonnes of e-waste was reported, thus the name 'tsunami of e-waste' given by the UN [11]. Its value is at least $62.5 billion annually [11].

Rapid changes in technology, changes in media (tapes, software, MP3), falling prices, and planned obsolescence have resulted in a fast-growing surplus of electronic waste around the globe. Technical solutions are available, but in most cases, a legal framework, a collection, logistics, and other services need to be implemented before a technical solution can be applied.

Display units (CRT, LCD, LED monitors), processors (CPU, GPU, or APU chips), memory (DRAM or SRAM), and audio components have different useful lives. Processors are most frequently out-dated (by software no longer being optimized) and are more likely to become "e-waste" while display units are most often replaced while working without repair attempts, due to changes in wealthy nation appetites for new display technology. This problem could potentially be solved with modular smartphones (such as the Phonebloks concept). These types of phones are more durable and have the technology to change certain parts of the phone making them more environmentally friendly. Being able to simply replace the part of the phone that is broken will reduce e-waste [12]. An estimated 50 million tons of e-waste are produced each year [13]. 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 [14-15].

Fig. 1 Electronic waste at Agbogbloshie, Ghana

In 2006, the United Nations estimated the amount of worldwide electronic waste discarded each year to be 50 million metric tons [16]. According to a report by UNEP 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 [17]. The United States is the world leader in producing electronic waste, tossing away about 3 million tons each year [18]. 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 [18].

Fig. 2 An iPhone with a damaged screen

Society today revolves around technology and by the constant need for the newest and most high-tech products we are contributing to a mass amount of e-waste [19]. Since the invention of the iPhone, cell phones have become the top source of e-waste products. Electrical waste contains hazardous but also valuable and scarce materials. Up to 60 elements can be found in complex electronics [20]. Concentration of metals within the electronic waste is generally higher than a typical ore, such as copper, aluminium, iron, gold, silver, and palladium [21]. As of 2013, Apple has sold over 796 million iDevices (iPod, iPhone, iPad). Cell phone companies make cell phones that are not made to last so that the consumer will purchase new phones. Companies give these products such short lifespans because they know that the consumer will want a new product and will buy it if they make it [22]. In the United States, an estimated 70% of heavy metals in landfills comes from discarded electronics [23-24].

While there is agreement that the number of discarded electronic devices is increasing, there is considerable disagreement about the relative risk (compared to automobile scrap, for example), and strong disagreement whether curtailing trade in used electronics will improve conditions, or make them worse. According to an article in Motherboard, attempts to restrict the trade have driven reputable companies out of the supply chain, with unintended consequences [25].

DISCUSSION

A recent study about the rising electronic pollution in the USA revealed that the average computer screen has five to eight pounds or more of lead representing 40 percent of all the lead in US landfills. All these toxins are persistent, bioaccumulative toxins (PBTs) that create environmental and health risks when computers are incinerated, put in landfills or melted down. The emission of fumes, gases, and particulate matter into the air, the discharge of liquid waste into water and drainage systems, and the disposal of hazardous wastes contribute to environmental degradation [26]. The processes of dismantling and disposing of electronic waste in developing countries led to a number of environmental impacts as illustrated in the graphic. Liquid and atmospheric releases end up in bodies of water, groundwater, soil, and air and therefore in land and sea animals – both domesticated and wild, in crops eaten by both animals and humans, and in drinking water [27].

One study of environmental effects in Guiyu, China found the following [28]:

- Airborne dioxins – one type found at 100 times levels previously measured
- Levels of carcinogens in duck ponds and rice paddies exceeded international standards for agricultural areas and cadmium, copper, nickel, and lead levels in rice paddies were above international standards
- Heavy metals found in road dust – lead over 300 times that of a control village's road dust and copper over 100 times

The Agbogbloshie area of Ghana, where about 40,000 people live, provides an example of how e-waste contamination can pervade the daily lives of nearly all residents. Into this area—one of the largest informal e-waste dumping and processing sites in Africa—about 215,000 tons of secondhand consumer electronics, primarily from Western Europe, are imported annually. Because this region has considerable overlap among industrial, commercial, and residential zones, Pure Earth (formerly Blacksmith Institute) has ranked Agbogbloshie as one of the world's 10 worst toxic threats (Blacksmith Institute 2013) [29].

A separate study at the Agbogbloshie e-waste dump, Ghana found a presence of lead levels as high as 18,125 ppm in the soil [30]. US EPA standard for lead in soil in play areas is 400 ppm and 1200 ppm for non-play areas [31]. Scrap workers at the Agbogbloshie e-waste dump regularly burn electronic components and auto harness wires for copper recovery, [32] releasing toxic chemicals like lead, dioxins and furans [33] into the environment. Researchers such as Brett Robinson, a professor of soil and physical sciences at Lincoln University in New Zealand, warn that wind patterns in Southeast China disperse toxic particles released by open-air burning across the Pearl River Delta Region, home to 45 million people. In this way, toxic chemicals from e-waste enter the "soil-crop-food pathway," one of the most significant routes for heavy metals' exposure to humans. These chemicals are not biodegradable— they persist in the environment for long periods of time, increasing exposure risk [34].

In the agricultural district of Chachoengsao, in the east of Bangkok, local villagers had lost their main water source as a result of e-waste dumping. The cassava fields were transformed in late 2017, when a nearby Chinese-run factory started bringing in foreign e-waste items such as crushed computers, circuit boards and cables for recycling to mine the electronics for valuable metal components like copper, silver and gold. But the items also contain lead, cadmium and mercury, which are highly toxic if mishandled during processing. Apart from feeling faint from noxious fumes emitted during processing, a local claimed the factory has also contaminated her water. "When it was raining, the water went through the pile of waste and passed our house and went into the soil and water system. Water tests conducted in the province by environmental group Earth and the local government both found toxic levels of iron, manganese, lead, nickel and in some cases arsenic and cadmium. "The communities observed when they used water from the shallow well, there was some development of skin disease or there are foul smells," founder of Earth, Penchom Saetang said. "This is proof, that it is true, as the communities suspected, there are problems happening to their water sources [35]."

RESULTS

Electronic waste is emerging as a serious public health and environmental issue in India [36]. India is the "Third largest electronic waste producer in the world"; approximately 2 million tons of e-waste are generated annually and an undisclosed amount of e-waste is imported from other countries around the world [37-38].

Fig. 2 Discarded electronic waste.

Annually, computer devices account for nearly 70% of e-waste, 12% comes from the telecom sector, 8% from medical equipment and 7% from electric equipment. The government, public sector companies, and private sector companies generate nearly 75% of electronic waste, with the contribution of individual household being only 16% [39].

E-waste is a popular, informal name for electronic products nearing the end of their "useful life." Computers, televisions, VCRs, stereos, copiers, and fax machines are common electronic products. Many of these products can be reused, refurbished, or recycled. There has been an upgrade to this E-waste garbage list to include gadgets like smartphones, tablets, laptops, video game consoles, cameras and many more. India had 1.012 billion active mobile connections in January 2018. Every year, this number is growing exponentially [40].

According to ASSOCHAM, an industrial body in India, the Compound Annual Growth Rate of electronic waste is 30%. With changing consumer behavior and rapid economic growth, ASSOCHAM estimates that India will generate 5.2 million tonnes of e-waste by 2020 [41-42].

While e-waste recycling is a source of income for many people in India, it also poses numerous health and environmental risks. More than 95% of India's e-waste is illegally recycled by informal waste pickers called kabadiwalas or raddiwalas. These workers operate independently, outside of any formal organization which makes enforcing e-waste regulations difficult-to-impossible. Recyclers often rely on rudimentary recycling techniques that can release toxic pollutants into the surrounding area. The release of toxic pollutants associated with crude e-waste recycling can have far reaching, irreversible consequences [43-44].

Electronic waste recycling, electronics recycling or e-waste recycling is the disassembly and separation of components and raw materials of waste electronics; when referring to specific types of e-waste, the terms like computer recycling or mobile phone recycling may be used. Like other waste streams, re-use, donation and repair are common sustainable ways to dispose of IT waste.

Since its inception in the early 1990s, more and more devices are recycled worldwide due to increased awareness and investment. Electronic recycling occurs primarily in order to recover valuable rare earth metals and precious metals, which are in short supply, as well as plastics and metals. These are resold or used in new devices after purification, in effect creating a circular economy. Such processes involve specialised facilities and premises, but within the home or ordinary workplace, sound components of damaged or obsolete computers can often be reused, reducing replacement costs.

Recycling is considered environmentally friendly because it prevents hazardous waste, including heavy metals and carcinogens, from entering the atmosphere, landfill or waterways. While electronics consist a small fraction of total waste generated, they are far more dangerous. There is stringent legislation designed to enforce and encourage the sustainable disposal of appliances, the most notable being the Waste Electrical and Electronic Equipment Directive of the European Union and the United States National Computer Recycling Act [45]. In 2009, 38% of computers and a quarter of total electronic waste was recycled in the United States, 5% and 3% up from 3 years prior respectively [46].

Obsolete computers and old electronics are valuable sources for secondary raw materials if recycled; otherwise, these devices are a source of toxins and carcinogens. Rapid technology change, low initial cost, and planned obsolescence have resulted in a fast-growing surplus of computers and other electronic components around the globe. Technical solutions are available, but in most cases a legal framework, collection system, logistics, and other services need to be implemented before applying a technical solution. The U.S. Environmental Protection

Agency, estimates 30 to 40 million surplus PCs, classified as "hazardous household waste", [47] would be ready for end-of-life management in the next few years. The U.S. National Safety Council estimates that 75% of all personal computers ever sold are now surplus electronics [48].

In 2007, the United States Environmental Protection Agency (EPA) stated that more than 63 million computers in the U.S. were traded in for replacements or discarded. Today, 15% of electronic devices and equipment are recycled in the United States. Most electronic waste is sent to landfills or incinerated, which releases materials such as lead, mercury, or cadmium into the soil, groundwater, and atmosphere, thus having a negative impact on the environment.

Many materials used in computer hardware can be recovered by recycling for use in future production. Reuse of tin, silicon, iron, aluminium, and a variety of plastics that are present in bulk in computers or other electronics can reduce the costs of constructing new systems. Components frequently contain copper, gold, tantalum, [49-50] silver, platinum, palladium, and lead as well as other valuable materials suitable for reclamation [51-52].

Computer components contain many toxic substances, like dioxins, polychlorinated biphenyls (PCBs), cadmium, chromium, radioactive isotopes and mercury. A typical computer monitor may contain more than 6% lead by weight, much of which is in the lead glass of the cathode ray tube (CRT). A typical 15 inch (38 cm) computer monitor may contain 1.5 pounds (1 kg) of lead [53] but other monitors have been estimated to have up to 8 pounds (4 kg) of lead [54]. Circuit boards contain considerable quantities of lead-tin solders that are more likely to leach into groundwater or create air pollution due to incineration. In US landfills, about 40% of the lead content levels are from e-waste [55]. The processing (e.g. incineration and acid treatments) required to reclaim these precious substances may release, generate, or synthesize toxic byproducts.

Export of waste to countries with lower environmental standards is a major concern. The Basel Convention includes hazardous wastes such as, but not limited to, CRT screens as an item that may not be exported transcontinentally without prior consent of both the country exporting and receiving the waste. Companies may find it cost-effective in the short term to sell outdated computers to less developed countries with lax regulations. It is commonly believed that a majority of surplus laptops are routed to developing nations [56]. The high value of working and reusable laptops, computers, and components (e.g. RAM) can help pay the cost of transportation for many worthless commodities. Laws governing the exportation of waste electronics are put in place to govern recycling companies in developed countries which ship waste to Third World countries. However, concerns about the impact of e-recycling on human health, the health of recycling workers and environmental degradation remain [57]. For example, due to the lack of strict regulations in developing countries, sometimes workers smash old products, propelling toxins on to the ground, contaminating the soil and putting those who do not wear shoes in danger. Other procedures include burning away wire insulation and acid baths to resell circuit boards. These methods pose environmental and health hazards, as toxins are released into the air and acid bath residue can enter the water supply [58].

CONCLUSIONS

E-cycling or "E-waste" is an initiative by the United States Environmental Protection Agency (EPA) which refers to donations, reuse, shredding and general collection of used electronics. Generically, the term refers to the process of collecting, brokering, disassembling, repairing and recycling the components or metals contained in used or discarded electronic equipment, otherwise known as electronic waste (e-waste). "E-cyclable" items include, but are not limited to: televisions, computers, microwave ovens, vacuum cleaners, telephones and cellular phones, stereos, and VCRs and DVDs just about anything that has a cord, light or takes some kind of battery [59].

Investment in e-cycling facilities has been increasing recently due to technology's rapid rate of obsolescence, concern over improper methods, and opportunities for manufacturers to influence the secondary market (used and reused products). Higher metal prices can result in more recycling taking place [60-66]. The controversy around methods stems from a lack of agreement over preferred outcomes.

World markets with lower disposable incomes, consider 75% repair and reuse to be valuable enough to justify 25% disposal. Debate and certification standards may be leading to better definitions, though civil law contracts, governing the expected process are still vital to any contracted process, as poorly defined as "e-cycling".

The e-waste disposal occurring after processing for reuse, repair of equipment, and recovery of metals may be unethical or illegal when e-scrap of many kinds is transported overseas to developing countries for such processing. It is transported as if to be repaired and/or recycled, but after processing the less valuable e-scrap becomes e-waste/pollution there. Another point of view is that the net environmental cost must be compared to and include the mining, refining and extraction with its waste and pollution cost of new products manufactured to replace secondary products which are routinely destroyed in wealthier nations, and which cannot economically be repaired in older or obsolete products.

As an example of negative impacts of e-waste, pollution of groundwater has become so serious in areas surrounding China's landfills that water must be shipped in from 18 miles (29 km) away [61]. However, mining of new metals can have even broader impacts on groundwater. Either thorough e-cycling processing, domestic processing or overseas repair, can help the environment by avoiding pollution. Such e-cycling can theoretically be a sustainable alternative to disposing of e-waste in landfills. In addition, e-cycling allows for the reclamation of potential conflict minerals, like gold and wolframite, which requires less of those to be mined and lessens the potential money flow to militias and other exploitative actors in third-world that profit from mining them.

Supporters of one form of "required e-cycling" legislation argue that e-cycling saves taxpayers money, [62] as the financial responsibility would be shifted from the taxpayer to the manufacturers. Advocates of more simple legislation (such as landfill bans for e-waste) argue that involving manufacturers does not reduce the cost to consumers, if reuse value is lost, and the resulting costs are then passed on to consumers in new products, particularly affecting markets which can hardly afford new products. It is theorized that manufacturers who take part in e-cycling would be motivated to use fewer materials in the production process, create longer lasting products, and implement safer, more efficient recycling systems [63]. This theory is sharply disputed and has never been demonstrated.

Countries have developed standards, aimed at businesses and with the purpose of ensuring the security of Data contained in 'confidential' computer media [NIST 800-88: US standard for Data Remanence][HMG CESG IS5, Baseline & Enhanced, UK Government Protocol for Data Destruction]. National Association for Information Destruction (NAID) "is the international trade association for companies providing information destruction services. Suppliers of products, equipment and services to destruction companies are also eligible for membership. NAID's mission is to promote the information destruction industry and the standards and ethics of its member companies" [67]. There are companies that follow the guidelines from NAID and also meet all Federal EPA and local DEP regulations.

The typical process for computer recycling aims to securely destroy hard drives while still recycling the byproduct. A typical process for effective computer recycling:

1. Receive hardware for destruction in locked and securely transported vehicles.
2. Shred hard drives.
3. Separate all aluminum from the waste metals with an electromagnet.
4. Collect and securely deliver the shredded remains to an aluminum recycling plant.
5. Mold the remaining hard drive parts into aluminum ingots.

The Asset Disposal and Information Security Alliance (ADISA) publishes an ADISA IT Asset Disposal Security Standard that covers all phases of the e-waste disposal process from collection to transportation, storage and sanitization's at the disposal facility. It also conducts periodic audits of disposal vendors [68].

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