Management of e-Waste in the South African Construction Industry – A Literature Review

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Abstract

In complacence with the ever-growing industrialization of different sectors, more specifically the construction sector, electrical and electronic waste management is becoming a global challenge in the construction industry posing significant environmental and health challenges. E-waste, if managed effectively, will release significant economic, resource and ecological benefits. Most of the construction companies have no information about electronic waste management, electronic devices that come from the seller while damaged are sent back to the supplier for exchange. Electronics that could not be repaired are sold to scrap yards and some are sent directly into the dumpsite, however, there were some electronic wastes stored inside the premises and others stored at the back of the premises directly into the ground, which decomposes and possibly affect the environment. The construction companies feel that it is the government's responsibility to provide money for electronic waste management otherwise there is no way they could manage e-waste in their business because it will not be profitable or else the users must take care of their electronic waste. The secondary data was collected through a detailed review of extant literature. In contrast, the primary data was collected using a qualitative method through interviewing the construction professionals. Twelve industry professionals were invited to participate in an interview but ten were present and able to participate, representing an 83% response rate. This paper seeks to assess how electrical and electronic waste are managed in the South African construction industry.

Keywords
Construction industry, electrical and electronic waste, disposal and dumpsites

Introduction
This study focuses on the assessment of e-waste management in the built environment in South Africa. Information and communication technologies (ICT) have led to high levels of e-waste (Heeks et al. 2015). It has been observed that e-waste has been increasing both in developing countries as a consequence of organic ICT development as well as a consequence of advancements in ICT in other developed countries (Osibanjo et al. 2016; Arya and Kumar 2020). Due to these developments, e-waste management in developing countries, such as South Africa, has become critical. There is a close connection between electronic products and people's daily lives as economic and technological development accelerates, China is one of the countries with the most consumption capacity. E-waste is being generated at a rapid rate as electronic products are rapidly upgraded (Wei and Liu 2012). The UN's Global E-Waste Monitor (2020) reports that the amount of e-waste generated worldwide in 2019 increased by 21 percent in just five years, with Asia producing 24.9 million tons of e-waste and Africa's 2.9 million tons. In parallel with the growth of the consumption of electrical and electronic products in China, the recycling market for electronic waste is also growing. The government, producers, recyclers, and consumers in a market economy jointly build e-waste recycling and

utilization. Through fine and reasonable separation, it is only possible to effectively treat e-waste, recycle, and utilize resources by connecting the classification with terminal treatment and resource utilization (Chen 2021).

Literature Review

2.1 E-waste Overview

The term '*e-waste*' refers to electrical and electronic wastes that have reached their end-of-life. According to Bhuie et al. (2004) and Cairns (2005), this waste electrical and electronic equipment (WEEE) includes wastes from electrical and electronic equipment as well as sub-assemblies, components, and consumables, which may be deemed as unwanted or obsolete by their users. Even though reference is made to WEEE as waste, it is important to note that such reference can be misleading, since WEEE can also include some electronics, which may still be reused in secondary e-products markets rather than being disposed of. According to Cairns (2005), there is a positive correlation between WEEE and growth in information and communication technology (ICT). That means, as ICT adoption and take-up increases, the level of WEEE also rises since the majority of WEEE comes from ICT-based products such as televisions, cell phones and routers. Bhuie et al. (2004) further argued that there is a positive relationship between the manufacturing, use and level of WEEE. Given the positive influence of ICT on the quality of life and socio-economic development, it is apparent that such benefits need to be balanced with the increasing levels of WEEE. Take the United States for instance, an estimated 9% of obsolete electronics (those bought by consumers between 1980 and 2004) which amount to around 180 million electronics units have been reported to still be in storage across the country, still waiting to be disposed of (Kahhat et al. 2008). These goods represent between 34 and 52% of total e-waste by quantity or 24% of total USA WEEE by weight. In 2005 alone, the U.S.A. disposed of just over 1.72 million metric tons of WEEE into landfills, with only about 0.30 million metric tonnes being (Kahhat et al. 2008). Overall, there is a need for ways to deal with e-waste in countries such as South Africa. Consequently, this paper assesses the waste management of electronics in the built environment, and the impacts of e-waste on the economy, environment and health.

2.2 Definitions of Electronic Waste

Before moving further with the review of the literature, it is necessary to define what e-waste means in the context of this paper. That is necessary since the term e-waste and its variations such as WEEE will be used extensively in this paper. Table 1 presents some literature on the definition of e-waste as adopted by the EU WEEE Directive. The definitions are drawn from various sources such as EU Directive 2002/96/EC (European Parliament and of the Council on Waste Electrical and Electronic Equipment 2003).

Table 1. Definition of e-waste

Reference	**Definition**	**Discussion**
EU WEEE Directive (2003)	"Electrical or electronic equipment which is waste including all components, sub-assemblies, and consumables, which are part of the product at the time of discarding. Directive 75/442/EEC, Article 1(a) defines waste as any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force."	Here the WEEE Directive (2003) does two things, namely defining e-waste, also emphasising what waste is. The definition implies that any part of electronic equipment is at the time of disposal. The key here is "when" the e-product item is disposed of as that determines what should be classified as e-waste. However, this definition does not differentiate part of the e-product which may not be an e-waste yet at the time of disposal, but will still be available for reuse, either in new e-products or in the secondary market – market for second-hand e-products.

Puckett et al. (2002)	"E-waste encompasses a broad and growing range of electronic devices ranging from large household devices such as refrigerators, air conditioners, cell phones, personal stereos, and consumer electronics to computers which have been discarded by their users."	This definition is important in that it gives examples of the e-products which can give rise to e-waste. Also, the term discarding means that e-waste can only arise when the products have reached their EOL. The time of classification, is, therefore, similar to that envisaged in the EU WEEE Directive (2002) definition.
Organisation of economic cooperation and development OECD (2001)	"Any appliance using an electric power supply that has reached its end of- life."	This definition is slightly vague. An electric vehicle, for instance, uses an electric power supply, but it is doubtful that the disposal of a motor vehicle which has reached its EOL can be classified as the disposal of e-waste. The definition, however, gives provision for reuse in that it simply talks of the fact that the appliance should have reached EOL. That means whatever happens to such an appliance does not change the classification of such an appliance as e-waste.
Sinha-Ketriwal (2004)	"An electrically powered appliance that no longer satisfies the current owner for its original purpose."	This definition is similar to that of OECD (2001) in its reference to 'electrically powered' and 'appliance.' The definition, however, takes the user's perspective and identifies an e-product as e-waste if it no longer satisfies the needs of the user. A key part of the definition is its reference to the 'current user.' This implies that an e-product can be an e-waste to the current user and a useful product to the next user.
StEP (2005)	"E-waste refers to the reverse supply chain which collects products no longer desired by a given consumer and refurbishes for other consumers, recycles, or otherwise processes wastes."	This definition focuses on the destination of the e-product which is no longer desired by a given consumer. It also focuses on the 2Rs and a D in the 3RD criteria (reduce, recycle, reuse, and disposal).

2.3 E-waste Situation in the RSA Construction Industry
South Africa still has a developing system of e-waste management. SAEA (2017), with the exponential growth of the adoption of ICT, e-waste is poised to become one of the major wastes the country will have to deal with. The current e-waste debate in South Africa is centred on:

- E-waste disposal in landfills, and
- E-waste exportation

Each of these is discussed in detail in the following paragraphs.

2.4 E-waste Disposal in Landfills
According to the South African Environmental Agency (SAEA 2017), for the period between 2013 and 2015, less than 50% of e-waste, which had reached its EOL, reached South Africa. Before evaluating the safety of landfills as disposal places, it is important to note that the proportion of EOL e-waste going to landfills was significantly lower

than the 80% reported in the USA according to the U.S. EPA as early as 2007. Thus, South Africa needs to increase its level of EOL waste, which is taken to landfills.

Then the question of safety should be answered. Are e-waste landfills safe for the environment, people's health, and the economy? A study by the UN's Global E-Waste Monitor (2020), found that e-waste contains hazardous elements such as chromium, lead, mercury, and cadmium. Studies are still scarce on having a better understanding of the fate and transport of these hazardous elements to landfill and post-landfill. In the USA, the Toxicity Characteristics Leaching Procedure (TCLP) test found that lead was highly leachable and could contaminate water for drinking (Intrakamhaeng et al. 2020; Townsend et al. 2011). Figure 1 shows the disposal of e-waste in landfills in South Africa. While the e-waste is presumed to be in a landfill, the e-waste is uncovered by soil. This means that toxins can still vapour into the sky and others can leach into the soil. Either way, this causes health hazards.

Figure 1. Disposal of e-waste in landfill
Source: AFRIK 21 (2022).

2.5 Exportation of e-waste in the Built Environment

Another sticking issue in South Africa relates to the importation and exportation of e-waste. E-waste is exported to countries in the regions where secondary markets for South African second-hand products flourish. South Africa, on the other hand, also imports second-hand e-products from other countries, such as China, USA, and Japan. In the US, e-waste exportation has been receiving attention from activists who feel that it is unfair for US companies to export e-waste to developing countries since such countries have very limited capacities to manage the waste and eventually dispose of it. This act by the USA contravenes the Basel Convention Agreement, which prohibits the exportation of e-waste or provides for the exporting country to notify the importing country that e-waste is being traded. That is also in line with the U.S. EPA (2008) requirements. A study by the Basel Action Network (BAN) and the Silicon Valley Toxics Coalition (SVTC), found that 80% of the US e-waste, which is earmarked for recycling purposes, has been exported to developing countries (Network 2002).

Due to limited capacities to manage this e-waste, studies have found that the e-waste from developed countries was part of the major contributors to environmental hazards in developing countries such as South Africa. A study in Guiyu, Guangdong Province, China, concluded that these wastes were causing contamination of freshwater sources and sediments with heavy metals mainly due to acid-leaching processes (Wong et al. 2007). Contamination of air and soils with polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/Fs), polychlorinated dibenzo-p-dioxins (PCDD) and polycyclic aromatic hydrocarbons (PAHs) mainly caused by open burning sites (Tue et al. 2013; Liu et al. 2022). Human health impacts, such as high lead blood levels found in Guiyu's children (Zeng et al. 2016). Those in other developing countries such as South Africa, India and Ghana (Network, 2002; Tue et al. 2013; Liu et al. 2022) corroborated these findings.

1. Research Methodology

To achieve that, qualitative data was collected through in-depth interviews and photography by the researcher. The results of the interviews and photography are discussed in this section. Photos collected through photography will be used to illustrate the state of e-waste management in Standerton. This study exploits existing literature from published research journals and conference proceedings to understand the management of e-waste in the built environment. This study reviewed the literature on e-waste disposal, e-waste exportation, and the impact of e-waste on the environment, health and the economy.

2. Findings and Discussions

The results of the study are presented in this section. As a reminder, this study aimed to assess the status of electronic waste recycling, reuse and disposal in Standerton, and its impacts on the environment, human health, and the economy. To achieve that, qualitative data was collected through in-depth interviews and photography by the researcher. The results of the interviews and photography are discussed in this section. Photos collected through photography will be used to illustrate the state of e-waste management in Standerton. The sample of this study consisted of 10 participants as discussed in Section 3. The sample was made up of 5 female and 5 male electronic retail shop owners or electronic retail shop managers in Standerton. The equal gender split was aimed at getting perspectives from both female and male participants.

Themes

As discussed in Section 3, thematic analysis was used to analyse research data.

4.1 E-waste economic, environmental and health influences

In this section, the review turns to the impact of e-waste on the economy, environment, and people's health. The focus is on e-waste along their entire value chain focusing on e-waste reused, recycled, and disposed of.

Influence on the environment

It was discussed in the previous section that the TCLP (Toxicity Characteristic Leaching Procedure) test of e-waste, which found itself in landfills, would still contain leachable toxins. According to Spalvins, Dubey and Townsend (2008), e-waste on dumping sites and landfills contains heavy metals concentrations exceeding the environmental limits set by many regulatory bodies. In the same study, the authors found that the toxic waste in e-waste was toxic for aquatic organisms. In addition, a study conducted by Niu and Li (2007), concluded that plants which used water or soil with traces of e-wastes had stunted growth and were less healthy than those which did not come into contact with such e-wastes. Also, Ladou and Lovegrove (2008), conducted a study to investigate the impact of burning e-waste on the environment. The study found that burning e-waste increases the mobility of heavy metal particles in such wastes. Because of that burning, the rate of air pollution and the extent of heavy metals in the air was found to be higher than when e-waste is not burnt.

What is clear from the discussion above is that e-waste, if not managed well in the built environment, will have a negative impact on the environment, including its fauna and flora.

4.1.2 E-waste influences to health

Several studies on the health impacts of e-waste have reported that people's exposure to the toxic substances from e-waste increases the prevalence of cancer and non-cancer risk cases (Adenuga et al. 2022; Zhan and Xu 2014; Li and Achal 2020). Among workers such as children, exposure to lead-based toxins, and other heavy metals was found to have a negative impact on the health of pre-school and elementary school children in China and the USA (Zeng et al. 2019; Collin et al. 2022; Zheng et al. 2023). Ádám et al. (2021), in particular, found that in-utero exposures to e-waste-based chemicals affected unborn babies. Some of the health effects of e-waste-based toxins on unborn babies' health are related to abnormal methylation of seventy-nine genes due to high concentrations of heavy metals. Other conditions included "calcium ion binding, cell adhesion, embryonic morphogenesis, as well as in signalling pathways which are related to NFkB activation, adherens junction, TGF beta and apoptosis" (Zeng et al. 2019).

Some effects identified in people of all age groups were retarded brain neuron development in children and distorted brain functioning in adults. Children who are exposed to excessive e-waste-based toxins were also found to suffer

from poor sensory coordination (Cai et al. 2019). Huo et al. (2019) conducted a similar study and concluded that excessive exposure to heavy metals found in e-wastes was associated with an "increase in maternal urinary metabolites of PAH was significantly associated with decrease of weight, head circumference, BMI, and Apgar 1 score among new-borns, therefore affecting neonatal development."
Overall, it is evident to the reader that exposure to e-waste and its related toxins can lead to several health issues. The evidence shows that the negative health impacts are prevalent in people of all ages, without exception – from embryos to adults.

4.1.3 E-waste impact on the economy
The effects of e-waste management on the economy can also be inferred from the foregoing discussion. High rates of recycling mean that the rate of resource depletion is significantly minimised. In addition, reusing e-products can create a thriving secondary market locally and internationally. A typical example is the thriving secondary market in China for e-waste from the USA. Also, recycling can create a thriving intermediate market for e-waste. We have seen that in countries such as South Korea recycling companies charge between US$8 and US$21, inclusive. This is significant and can go a long way towards creating jobs for unemployed youth. Recycling and reusing create jobs for the unemployed. The ILO (2019), explain that the recycling and waste management market employs about 6.5% of the global workforce.

4.4 Presentation and Discussion of Results
This section presents and discusses the results. The results are also compared to existing literature.

4.4.1 Theme 1: E-waste management

4.4.1.1 No Waste Management Plan
Participants were asked to explain how stakeholders in the construction industry, manage e-waste. Some participants indicated that their construction sites did not have a defined e-waste management plan, to start with. The majority said something along the lines of:

> *Honestly, it is the first time someone asks me about how we manage e-waste. We don't sell broken products here. If we have broken products, they are sent back to their original suppliers. Therefore, we don't have any plan to manage e-waste because we don't encounter it* (I3).

I1 reinforced that belief by stakeholders in the construction and showed that:

> *We can't have a plan to manage what's not broken. What we sell are brand new electronic products. Why then can we be expected to have an e-waste management plan. Such a plan, in all honesty, will be redundant.*

This response shows that there is no incentive for construction to manage e-waste. There is a misconception that e-waste should only be managed by those who meet broken e-products. This is contrary to Jody et al. (2011), who showed that effective e-waste management requires everyone within the e-product's value chain. Even the EU-WEEE Directive (2003) requires that e-waste be managed holistically by everyone within the e-waste value chain.

4.4.1.2 Consumers and manufacturers have the responsibility
Nine of the ten interviewees said something to the effect that the responsibility of managing e-waste lies with consumers and manufacturers. For instance, I5 said:

> *Consumers are responsible for disposing of their electronic products safely. Why should we bother to go to their homes to tell them how to dispose of their TVs or Microwave? It's none of our business.*

I7 also argued that the responsibility lies with consumers because construction companies will not have any profit incentive to manage e-waste:

> *If you want my honest opinion, I will say no one can compensate contractors for that additional cost of following up on electronic products way after they have been sold. Look, we are SMME's and following up on those products will have a significant negative impact on our bottom line. Profitability, I mean to say.*

Similar concerns were shared by I4 who argued:

> *My friend* (sick), *this is a small construction company where we are trying to make ends meet. Tell me then, why should we be expected to dispose of waste for goods that we would have sold and be able to buy new products? For manufacturers, that is understandable. They are large; they can recycle some of the material to make new products.*

These responses by contractors indicate that they feel that either supplier should be responsible for managing e-waste. However, that contradicts provisions such as the PC3R (2008) and recommendations from academics such as Yoshida et al. (2007) to the effect that contractors, because they meet the final consumer, can be an important link in the e-waste management supply chain by encouraging customers to recycle, reuse or safely dispose of their electronic gadgets which may have reached their end-of-life.

4.4.1.3 Value chain has no incentive to collectively manage
It was clear from the interview responses that the current set-up of the e-waste and e-products value chain does not provide any incentive for properly managing e-waste. For instance, I8 had the following to say:

> *I don't get anything from telling labourers to manage their e-waste. I need incentives from either the government or suppliers to be actively involved in managing e-waste. If suppliers pay us a stipend for every e-waste returned, or if the government give us a tax incentive, I don't see any reason why I cannot actively manage e-waste.*

I10 also had the following to say:

> *I pay full price for my electronic products to suppliers. Why can I be made to spend more on e-waste management when I won't be able to recover that?*

These sentiments were also shared by the majority of interviewees who indicated, that "managing e-waste should be linked to some incentives," (I4), so that, "contractors won't be double taxed" (I5) by being required to "pay suppliers" (I7) and paying "taxes to the government without any incentives" (I1) for managing e-waste.

What is clear from the discussion is that the e-waste supply chain does not provide any incentive to participants, particularly contractors, to manage e-waste. According to Widmer et al. (2005), without providing proper incentives to supply chain participants, it is difficult to achieve the level of e-waste management required to deal with the threats of climate change and threats to human lives.

4.4.2 Theme 2: Reduce, Recycle, Reuse, Disposal

Contractors were asked how e-waste was being reused, recycled, and disposed of by their employees. The responses are discussed here.

4.4.2.1 Reduce
Responses on how contractors were reducing e-waste were mixed. Some honestly felt that contractors and the supply chain in general, were not doing enough to manage e-waste. For example, I2's response was typical for interviewees in this category:

> *Honestly, I don't think we are doing enough to reduce e-waste. The pace at which technology changes means that electronic gadgets are becoming obsolete very quickly and consumers move to the next and new model. What do we do with the old? Sometimes it ends up in the dumpsite. And when it's locked, it finds itself in the house of a low-income consumer. Either way, the waste will eventually be found in the dump site. We can do more.* (I2)

However, there were those who felt that retailers were doing their best to reduce e-waste:

We sell our products in their original packaging. *We make it a point that discuss the 3Rs* [reduce, recycle, and reuse] *on the products. This is effective as far as where we can end. We can't do more than that. It is then up to the buyers to decide if they want to follow that advice or not.*

Reducing e-waste is an important step in managing e-waste. Therefore, without clear responsibilities being set on who should manage e-waste, it is difficult to achieve the goals set by the government and reach international standards. There is a need for clear responsibilities to be set for all the participants within the e-waste supply chain.

4.4.2.2 Recycle
Five of the ten participants said something to the effect that recycling on e-waste was non-existent in Standerton. I5 summed up this view:

> *I don't think the term recycle really exists in Standerton. Go to a dumpsite now and you will see thousands of e-waste fragments lying there.*

The author went to the dumpsite and took the following photo:

Figure 2. E-waste at Standerton dumpsite; 2B-2D: E-waste in Standerton retailer's storeroom
Source: Author's photos

Figure 2. A. a plastic TV casing lies idle in a dumpsite. This is a recyclable item which could be recycled rather than put in a dumpsite. Additional photos which were taken from the dumpsite are shown below. All of them show e-waste of varying forms.

In addition, some participants indicated that their contractors sometimes simply put some e-waste in storerooms without any plan to recycle them. One participant (I5) showed the research the following:

Figure 2B-2D, the e-waste can be seen being cluttered around a storeroom where e-waste was being stored. Most of the e-waste which were in this workshop such as printers and old personal computer desktops were recyclable, and it was not clear why such items were lying there idle when they could be recycled. I3 also had a similar storeroom and indicated that some of the items had been lying there for over some years and no one had taken the initiative to recycle. The following images illustrate the contents of that storeroom.

What is evident from the images and responses above is that recycling efforts are still limited. It is necessary to educate retailers on the importance and benefits of recycling. For instance, having a storeroom which must be maintained only to keep recyclable items is a waste of resources – security and space which could be used for other purposes. This needs to be emphasised to retailers.

3. Conclusion

This paper has reviewed the literature available on e-waste management. The section started by providing an overview of e-waste and defining e-waste, before moving on to reviewing the literature on the situation in the South African built environment. Furthermore, the paper reviewed the literature on the importance of e-waste on the economy, health of persons and the environment. Therefore, the industry needs to take manage waste accordingly so that it doesn't threaten the health and safety of the communities.

Reference list

Ádám, B., Göen, T., Scheepers, P.T., Adliene, D., Batinic, B., Budnik, L.T., Duca, R.C., Ghosh, M., Giurgiu, D.I., Godderis, L. and Goksel, O., From inequitable to sustainable e-waste processing for reduction of impact on human health and the environment. *Environmental Research*, vol. 194, pp.110728, 2021.

Adenuga, A.A., Amos, O.D., Olajide, O.D., Eludoyin, A.O. and Idowu, O.O., Environmental impact and health risk assessment of potentially toxic metals emanating from different anthropogenic activities related to E-wastes. *Heliyon*, vol. 8, no. 8, 2022.

Arya, S., and Kumar, S., E-waste in India at a glance: Current trends, regulations, challenges and management strategies. *Journal of Cleaner Production*, vol. 271, 122707, 2020.

Bhuie, A. K., Ogunseitan, O. A., Saphores, J. D., & Shapiro, A. A., Environmental and economic trade-offs in consumer electronic products recycling: a case study of cell phones and computers. *In IEEE International Symposium on Electronics and the Environment, 2004*. Conference Record. pp. 74-79, 2004.

Cai, H., Xu, X., Zhang, Y., Cong, X., Lu, X. and Huo, X., Elevated lead levels from e-waste exposure are linked to sensory integration difficulties in preschool children. *Neurotoxicology*, vol. 71, pp.150-158, 2019.

Cairns, C. N., E-waste and the consumer: improving options to reduce, reuse and recycle. *In Proceedings of the 2005 IEEE International Symposium on Electronics and the Environment*, pp. 237-242, IEEE. 2005.

Chen, C., Construction of Electronic Waste Recovery and Utilization System from the Perspective of Circular Economy. *In IOP Conference Series: Earth and Environmental Science*, vol. 632, no. 5, pp. 052014. IOP Publishing. 2021.

Collin, M.S., Venkatraman, S.K., Vijayakumar, N., Kanimozhi, V., Arbaaz, S.M., Stacey, R.S., Anusha, J., Choudhary, R., Lvov, V., Tovar, G.I. and Senatov, F., 2022. Bioaccumulation of lead (Pb) and its effects on human: A review. *Journal of Hazardous Materials Advances*, vol. 7, pp.100094.

European Parliament and of the Council on Waste Electrical and Electronic Equipment., DIRECTIVE 2002/96/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 January 2003 on waste electrical and electronic equipment (WEEE). EUR-Lex — Access to European Union law — choose your language. https://eur-lex.europa.eu/resource.html?uri=cellar:ac89e64f-a4a5-4c13-8d96-1fd1d6bcaa49.0004.02/DOC_1&format=PDF. 2003

Global E-waste Monitor (GEM) 2020., E-Waste Monitor, https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf

Heeks, R., Subramanian, L., and Jones, C., Understanding e-waste management in developing countries: Strategies, determinants, and policy implications in the Indian ICT sector. *Information Technology for Development*, vol. 21, no. 4, pp. 653-667, 2015.

Huo, X., Wu, Y., Xu, L., Zeng, X., Qin, Q. and Xu, X., Maternal urinary metabolites of PAHs and its association with adverse birth outcomes in an intensive e-waste recycling area. *Environmental Pollution*, vol. 245, pp.453-461. 2019.

Intrakamhaeng, V., Clavier, K. A., and Townsend, T. G., Hazardous waste characterization implications of updating the toxicity characteristic list. *Journal of hazardous materials*, vol. 383, 121171, 2020.

Jody, B.J., Daniels, E.J., Duranceau, C.M., Pomykala, J.A. and Spangenberger, J.S., 2011. End-of-life vehicle recycling: state of the art of resource recovery from shredder residue.

Kahhat, R., Kim, J., Xu, M., Allenby, B., Williams, E., and Zhang, P., Exploring e-waste management systems in the United States. *Resources, conservation and recycling*, vol. 52, no. 7, pp. 955-964, 2008.

Ladou, J., and Lovegrove, S., Export of electronics equipment waste. *International journal of occupational and environmental health*, vol. 14, no. 1, pp.1-10, 2008.

Li, W. and Achal, V., Environmental and health impacts due to e-waste disposal in China–A review. *Science of the Total Environment*, vol. 737, pp.139745, 2020.

Liu, M., Li, H., Chen, P., Song, A., Hu, J., Sheng, G. and Ying, G., PCDD/Fs and PBDD/Fs in sediments from the river encompassing Guiyu, a typical e-waste recycling zone of China. *Ecotoxicology and Environmental Safety*, vol. 241, pp.113730, 2022.

Network, B. A., Exporting harm: the high-tech trashing of Asia. http://www. ban. org/E-waste/technotrashfinalcomp. pdf. 2002.

Niu, X. and Li, Y., Treatment of waste printed wire boards in electronic waste for safe disposal. *Journal of Hazardous Materials*, vol. 145, no. 3, pp.410-416, 2007.

Organization for Economic Cooperation and Development, Extended Producer Responsibility: A Guidance Manual for Governments, Organization for Economic Cooperation and Development, Paris, France, 2001.

Osibanjo, O., Nnorom, I. C., Adie, G. U., Ogundiran, M. B., and Adeyi, A. A., Global Management of Electronic Wastes: Challenges Facing Developing and Economy-in-Transition Countries. *Metal Sustainability: Global Challenges, Consequences, and Prospects*, pp. 52-84,2016.

Puckett, J, Byster L, and Westervelt S, Exporting Harm. The high-tech trashing of asia, the basel action network (BAN) and Silicon Valley Toxics Coalition (SVTC) 2002. http://www.ban.org/E-waste/technotrashfinalcomp.pdf.

Sinha-Ketriwal, D. The management of electronic waste: A comparative study on India and Switzerland. St. Gallen, University of St. Gallen. Master in Environmental Engineering 2004.

Spalvins, E., Dubey, B., and Townsend, T., Impact of electronic waste disposal on lead concentrations in landfill leachate. *Environmental science & technology*, vol. 42, no. 19, pp. 7452-7458, 2008.

StEP. What is e-waste? Solving the e-waste problem (StEP). http://www.step-initiative. org/initiative/what-is-e-waste.php2010.

Townsend, T.G., Environmental issues and management strategies for waste electronic and electrical equipment. *Journal of the Air & Waste Management Association*, vol. 61*, no.* 6, pp.587-610, 2011.

Tue, N.M., Takahashi, S., Subramanian, A., Sakai, S. and Tanabe, S., Environmental contamination and human exposure to dioxin-related compounds in e-waste recycling sites of developing countries. *Environmental Science: Processes & Impacts*, vol. 15, no. 7, pp.1326-1331, 2013.

Wei, L., and Liu, Y., Present status of e-waste disposal and recycling in China. *Procedia Environmental Sciences*, vol. 16, pp. 506-514, 2012.

Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M. and Böni, H., Global perspectives on e-waste. *Environmental impact assessment review*, vol. 25, no. 5, pp.436-458, 2005.

Wong, M.H., Wu, S.C., Deng, W.J., Yu, X.Z., Luo, Q., Leung, A.O.W., Wong, C.S.C., Luksemburg, W.J. and Wong, A.S., Export of toxic chemicals–a review of the case of uncontrolled electronic-waste recycling. *Environmental pollution*, vol. 149, no. 2, pp.131-140, 2007.

Yoshida, A., Tasaki, T. and Terazono, A., Material flow of used PCs in Japan. In *Proceedings of the 2007 IEEE International Symposium on Electronics and the Environment*, pp. 46-51, IEEE. 2007.

Zeng, X., Xu, X., Boezen, H. M., and Huo, X., Children with health impairments by heavy metals in an e-waste recycling area. *Chemosphere*, vol. 148, pp. 408-415. 2016

Zeng, Z., Huo, X., Zhang, Y., Hylkema, M.N., Wu, Y. and Xu, X., Differential DNA methylation in newborns with maternal exposure to heavy metals from an e-waste recycling area. *Environmental research*, vol. 171, pp.536-545, 2019.

Zhan, L. and Xu, Z., Assessment of heavy metals exposure, noise and thermal safety in the ambiance of a vacuum metallurgy separation system for recycling heavy metals from crushed e-wastes. *Waste management & research*, vol. 32, no. 12, pp.1247-1253, 2014.

Zheng, K., Zeng, Z., Tian, Q., Huang, J., Zhong, Q. and Huo, X., Epidemiological evidence for the effect of environmental heavy metal exposure on the immune system in children. *Science of The Total Environment*, vol. 868, pp.161691, 2023.