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Exploring Electronic Waste Situation in Africa: A review

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Abstract: In recent years African countries are grappling with the increase of electronic waste (e-waste) which poses challenge to environment and human health. However, factors influencing electronic waste situation in Africa have not been explored and thus not well understood. To fill the gap, this paper aims at exploring e-waste situation in Africa and analysing factors influencing the situation. To address the objective, a systematic literature review was adopted. Findings show that the amount of e-waste has been increasing in both developed and developing countries over time. Although there are common factors associated with the increase of e-waste, some factors are unique to Africa. These are: reduced cost of used items, taxi incentives for importation of electronic devices and increased use of ICT devices in various sectors. Furthermore, findings show that developed and developing countries differ in terms of the risks posed by the e-waste and this difference is dependent on how e-waste is managed. Based on the findings, it can be concluded that the situation of e-waste in Africa is somehow different from developed world both in terms of the factors influencing the situation and ways of managing e-waste. In order to deal with e-waste situation, African countries need to improve awareness of their people, establish and capacitate institutions for dealing with e-waste and invest in technologies for managing e-waste.

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Recently, there has been a renewed scientific and political interest on electronic waste (e-waste) management following ever-increasing accumulation of e-wastes globally (Awasthi and Li, 2017; Montalvo *et al*., 2016). Such increase in e-waste, among other reasons, has mainly been attributed to fast changes in Information and Communication Technology (ICT) and increases in demand of both for electronic and electric equipment (Matsakas, 2017). Most literature indicate that increased interest in the e-waste topic is justified on several aspects including health and environment concerns, income, employment and circular economic grounds (Ahirwar and Tripathi, 2021; Shahabuddin *et al*., 2023). Data security has also appeared in some literature as an important aspect to consider when addressing scholarship on the topic (Gumbo and Kalegele, 2015). Also, the justification for e-wastes stems from its components, which include both hazardous and valuable materials. Hazardous materials have adverse effects on human health and the environment when they are not properly handled and processed (Montalvo *et al*., 2016; Shahabuddin *et al*., 2023). On the other hand, e-waste can also include minerals, whose processing has been termed as urban

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mining. In fact, some studies have shown that e-waste may contain higher amounts of minerals than what can be extracted from conventional mineral ores (Murthy and Ramakrishna, 2022). Furthermore, there is a link between awareness sensitization on e-waste and achieving sustainable development goal (SDG) (Bhat, 2023). Proper awareness on e-waste management helps to cater for SDG goals, namely: Goal 3 (Good health and Well-being), Goal 6 (Clean water and Sanitation), Goal 11 (Sustainable Cities and Communities) and Goal 12 (Responsible Consumption and Production). To-date, e-waste topic has covered an understanding of the concept, global trend of e-waste, reasons for increasing volume and quantity of the materials, e-waste management practices (notably, collection and recycling), concerns of e-wastes, potential solutions for challenges of e-wastes and opportunities of e-wastes. Despite this extensive coverage of the topic, literature on e-wastes covering Africa is still scant compared to other continents such as Europe, America, Asia, Australia and Oceania. In particular, there is insufficient information on factors influencing the situation of e-waste and its management practices in Africa. While this paper acknowledges the state of the art on e-waste globally, it fills the research gap for Africa by exploring the situation of e-waste in Africa, the factors influencing the situation and the management practices.

The concept of electronic waste: E-waste can be understood as a waste of electronic and electrical equipment (WEEE), which are at the end of life and consists of both hazardous and valuable parts (Srivastava, 2020). On the other hand, Asiimwe and Ake (2012) define the concept of e-waste as electronic equipment that is considered to be hazardous and does not, in its functional state, serve any purpose to any intending user unless the equipment is refurbished. Overall, literature seems to converge on the concept of waste electronic and electrical equipment (WEEE), which are at the end of their life (Otieno and Omwenga, 2015; Gumbo and Kalegele 2015; Srivastava, 2020). Examples of WEEE to mention just a few include computers, television, mobile phones, calculating machines, printers and scanners, digital cameras, fluorescent tubes, and bulbs, photocopiers, fridges and freezers, washing machines, cookers, air conditioners, microwaves, irons, vacuum cleaners, grinders and blenders hot and cold dispensers. Other examples of EEE include lawnmowers, electrical saws, electric trains, and racing cars. Still, EEE includes dialysis machines, ultrasound machines, cardiology equipment, respiratory ventilators, and money dispensers (Srivastava, 2020). These WEEE has been classified into various categories which are household appliances, lighting equipment, electrical and electronic tools, consumer equipment, medical devices, IT and telecommunication equipment, toys and leisure equipment, monitoring instruments and automatic dispensers (Chen *et al*., 2015; Ahirwar, 2021). With respect to the contribution of EEE to e-waste, literature shows that computers have largely contributed to e-waste generation in Sub-Saharan Africa (Maphosa and Maphosa, 2020). Also, literature reports that computers and mobile phones contributed more to e-waste in East Africa (UNPAN, 2003; UNPAN, 2010).

The concept of e-waste management and recycling: Management of e-waste involving recycling are among the strategies practiced for reducing the generation of e-wastes. Therefore, conception of where e-waste management and recycling processes begin and end is paramount for undertaking and handling the processes. However, the concepts of management and recycling of e-waste are somewhat not clearly discerned in literature. Wath *et al*., (2010) regard e-waste management as the process of collection of e-waste, pre-treatment, further treatment at facilities and sending e-waste to dumping sites. On the other hand, recycling is conceived to include collection of e-waste, processing of e-waste, and recovery of valuable substances (Meskers *et al*., 2009). Maphosa and Maphosa (2020) provide an impression that e-waste management and recycling are distinct processes. Other scholars regard the process of collection, washing, sorting, pre-treatment and treatment of e-waste as the recycling process (see Shahabuddin *et al*., 2023). Largely, literature shows that both e-waste management and recycling constitute a stage of e-waste collection, thus, in this paper we argue that e-waste management and recycling are overlapping concepts in meaning. To clarify further we assert that "*all recycling activities constitute e-waste management processes but not all e-waste management activities are recycling"*. For instance, the collection followed by immediate dumping of e-waste on landfill sites or open burning are e-waste management activities but are not recycling. That means, in situations where recycling is not available, still non-recycling e-waste management activities can be taking place. Analytically, the collection of e-waste is placed into formal collection, which is conducted by government recognized bodies, and informal collection involving individuals and companies (Chi *et al*., 2014). Formal collection of e-waste is desirable as the WEEEs are channelled to facilities that ensure safe processes in handling them. In contrast, informal collection of e-waste leads to poor quality management and recycling processes that do not properly manage emissions of hazardous

materials of e-waste thereby posing health, environmental and information security threats (Chi *et al*., 2011; Pradhan and Kumar, 2014; Gumbo and Kalegele, 2015). Pre-treatment is another important step of e-waste management (recycling) process. Depending on the level of technology, type and design of WEEE, pre-treatment can be done manually or mechanically. Manual separation is mostly common in developing countries whereas mechanical techniques are predominant in developed world. This activity involves separating valuable from non-valuable substances. It involves the dismantling of WEEEs into their useful components such as metal, plastic, wood, and batteries, which are further mechanically grounded into small-sized particles (Cui and Forssberg, 2003; Meskers *et al*., 2009). The ground substances are further processed to obtain final products for recycling, which can include the acquisition of minerals or plastic for making bottles (Li *et al*., 2007). Extraction of useful metals from e-waste involves various techniques including thermal treatment and liquid chemicals such as acids, alkaline and cyanide, which are hazardous and toxic. Extraction processes using solvent chemicals also produce toxic substances (fumes) such as doxin, furans and volatile metals, which pollute the surrounding air (Hageluken, 2006). This means that an improper recycling process can lead to health and environmental hazards in the same way as dumping and landfilling after the collection of e-waste (Orlins and Guan, 2016).

Components of electronic wastes: It is estimated that WEEEs contain over 1000 different parts including metals, glass, plastic, wood, printed circuit boards (PCBs), ceramic, organic compounds and others, which are added to EEE for various purposes (Balde *et al*., 2017; Srivastava, 2020; Ahirwar and Tripath, 2021; Shahabuddin *et al*., 2023). The merits of adding metals and organic compounds to EEE include the provision of mechanical strength, improving electric and thermal properties, increasing resistance to fire and weathering (Ahirwar and Tripath, 2021). Apart from containing hazardous components (Gumbo and Kalegele, 2017; Asiimwe and Ake, 2012), e-waste also contains some precious metals which upon processing (urban mining) can produce a higher amount of minerals. For instance, it has been reported that 1.5 kg of gold and 210 kg of copper can be mined from one metric ton of circuit board of WEEE (Bazargan *et al*., 2012). Comparing the same amount and unit of raw materials, WEEE contains 300 times more amount of gold and 40 times more amount of copper than what is contained in the conventional mineral ores (Shahabuddin *et al*., 2023). Conclusively, e-waste can contain valuable metals such as gold, platinum, palladium, copper, silver, iron, aluminium and cobalt.

MATERIALS AND METHODS

Search strategy: This paper is based on a systematic literature review using the PRISMA method described by Moher *et al*. (2009). The schematic literature search route which was followed by the authors is shown in Figure 1. It acts as roadmap to guide the process of exhaustive and comprehensive literature mapping as well as rigorous scholarly literature search, review and selection as per predefined criteria. To explore the factors influencing e-waste situation in Africa, we reviewed literature from different continents and then focused to Africa. We performed literature searches in Google scholar using various combinations of the search terms "E-waste", "management", "factors", "status", "situation", "Africa", "Asia", "Europe", and "America". The search was done to include articles published from 2007 to 2022. The initial search generated about 17,300 results.

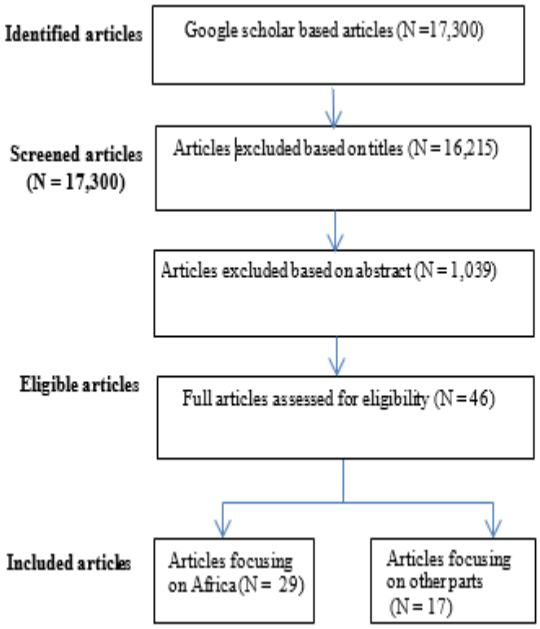

Fig 1: Schematic literature search of appropriate articles based on the PRISMA flow diagram (Adapted from Moher *et al*. 2009)

Inclusion and exclusion criteria: In order to review the literature of interest, the inclusion and exclusion criteria were specified in advance. Articles were included if the title combined keywords/phrases relevant to the paper including "E-waste", "Factors", "E-waste situation", "E-waste management", "E-waste recycling", "Africa", "Europe", "America", "Asia", "Australia" and "Oceania". Based on this criterion, a total of 16,215 articles did not meet the inclusion criterion thus were excluded. Another criterion used was assessment of the abstract whereby

an appropriate study design for the research question was expected to be used and explicitly stated in the abstract. Going through the abstract, a total of 1,039 did not meet this criterion therefore were also excluded.

Review of relevant studies: By applying the set criteria, a total of 46 studies met the inclusion criteria and were reviewed by the authors. Further assessment showed that a total of 29 studies focused on Africa and the remaining (17 studies) focused on other continents, notably Europe, America, Asia, Australia and Oceania. The review analysed dimensions and factors influencing e-waste with particular focus on Africa.

RESULTS AND DISCUSSION

E-waste situation: The trend: Within the last ten years literature has documented the global trend of e-waste for the years 2014, 2016 and 2019. They show that amount of e-waste in the year 2014 was about 42 Mt (Balde *et al*., 2015) whereas the estimate of e-waste in the year 2016 was about 45 Mt (Balde *et al*, 2017). In 2019, e-waste was estimated at about 54 million tons (Mt) (Forti *et al*., 2020). That means, globally, e-waste had increased by about 107% from 2014 to 2016 and increased by 120% from 2016 to 2019 and increased by 129% from 2014 to 2019. Comparing data across continents, Africa generated the lowest amount of e-waste per inhabitant in 2019 compared to other places in the globe (Forti *et al*., 2020; Shahabuddin *et al*., 2023). The highest contributor of e-waste per inhabitant on the global scale was Europe. The amount of e-waste per inhabitant generated by different continents in the year 2019 was as follows: Europe (16.2 kg/inhabitant); Oceania (16.1 kg/inhabitant); America (about 13 kg/inhabitant; Asia (about 6 kg/inhabitant and Africa (about 3 kg/inhabitant (Shahabuddin *et al*., 2023; Forti *et al*., 2020). In terms of gross amount of e-waste, Asia generated the highest amount of gross amount of e-waste whereas Oceania generated the lowest (Table 1). As indicated in Table 1, literature shows that the amount of e-waste has been increasing in both developed and developing countries over time (Mohammed, 2022). For instance, e-waste accumulation has increased by 6% from the year 2014 to the year 2019 (Balde *et al*., 2017, 2015). The major reasons of the growing volumes of e-waste are: short life span of electronic products, population growth, economic development and changing of consumption patterns (Bhutta *et al*., 2011; Alamerew and Brissaud, 2018). However, some factors are unique to Africa. These are: reduced cost of used items (some of which are close to or have reached their end of life), taxi incentives for importation of electronic devices and increased use of ICT devices in various sectors such as education (Asiimwe and Glonlund, 2012; Otieno and Omwenga, 2015).

Table 1: Production of e-wastes in five continents

Continent	% Gross amount of e-waste (Million Tons)	Ranking gross amount of e-waste	Ranking amount e-waste inhabitant
Asia	46.4	1	4
America	24.4	2	3
Europe	22.4	3	1
Africa	5.4	4	5
Oceania	1.3	5	2
Total	**100**		

Source: Adapted from Ahiwar and Tripathi (2021) and Shahabuddin et al. (2023)

E-waste situation: Risks and management practices: In terms of risks posed, literature shows that levels of e-waste pollutants in various ecosystems such as water, air, soil, dust, fish pose risks not only to e-waste workers but also to the general population and future generations as well (Orisakwe *et al*., 2019). However, the risks posed by e-waste vary globally depending on how e-waste is managed[1]. In developed countries such as Germany, United States of America, Japan and China , management of e-waste have been formalized whereby e-waste is handled outside homes, health and environmental hazards are minimized, and data security is ensured (Adanu, *et al*., 2020; Cahill *et al*., 2011). In those countries, municipalities and producers of EEE lead the management and recycling of e-waste. Such formalization in China is reflected on a number of established formal recycling centres, which amount to about 110 (Ghosh *et al*., 2016). Translation of policies and institutions guiding management and recycling of e-waste into practice in developed countries have resulted in the situation whereby manufacturers take responsibility of managing e-wastes through the extended producer responsibility (EPR) (Fraige *et al*., 2012). This practice allows consumers of electronic and electric equipment to return back EEE upon reaching their end of life (Adanu, *et al*., 2020; Cahill *et al*., 2011). Such situation is associated with high level of awareness on e-wastes of people, institutions formulated to guide management of e-waste, advanced technologies in dealing with e-waste including infrastructure, and availability of skilled manpower in dealing with e-waste (Maphosa and Maphosa, 2020; Matsakas *et al*., 2017; Gumbo and Kalegele, 2015; Otieno and Omwenga, 2015; Asiimwe and Gronlund, 2012).

On the other hand in Africa, with notable exception of a few countries such as Uganda (Nuwematsiko et al., 2021) much of WEEEs continue to lay at homes and offices due to host of factors such as lack of institutions guiding the management of the material and the lack of processing facilities of e-waste (Otieno and Omwenga, 2015). Also, technologies used for managing e-waste include manual dismantling, open burning and acid leaching to extract useful metals. Poor technology for managing e-waste lead to the situation of environmental pollution and posing health issues (Maphosa and Maphosa, 2020). The dumping and landfilling practices are connected to release of lead, mercury and cadamium (heavy metals) which pollute the environment (Boaten, 2011). Exposure to heavy metals has been reported to affect surrounding communities to e-waste site in South Africa (Machete, 2017). Also, e-waste dumping and landfill sites in Agbogbloshie in Ghana and Alaba and Elukwatin in Nigeria have been reported to posed health issues such as respiratory, skin and cancer problems. Also, open burning of e-waste in Ghana were reported to pose health issues including eye irritation, skin laceration, respiratory and allergic problems (Asampong, 2015; Peluola, 2016; Burns *et al*., 2019; Acquah *et al*., 2019).

Factors influencing e-waste situation: Various factors influence e-waste situation in Africa and developed countries. Literature shows that developed countries have formulated and enacted policies and institutions which guide management of e-waste (Mphosa and Maphosa, 2020; Khan, *et al*., 2014; Wang *et al*., 2013). Also, awareness of people about e-wastes is high in developed countries (Awasthi *et al*., 2016). Furthermore, developed countries have both advanced technologies and infrastructure for managing and recycling e-wastes coupled with sufficient and required human capacity to manage the wastes (Mphosa and Maphosa, 2020). In contrast, awareness on e-waste among people in developing countries is low (Awasthi *et al*., 2016). For example, a study conducted in Tanzania among ICT experts and non-experts showed that the majority of respondents had limited awareness of e-waste management (about 55%), whereas about 45% of them had awareness of WEEEs management (Gumbo and Kalegele, 2015). Furthermore, there is low level of technologies and insufficient infrastructure for managing and recycling of WEEES in developing countries (Maphosa and Maphosa, 2020; Gumbo and Kalegele, 2015). Literature reports that due to poor technologies, cases of use of stones, harmers and chisels to extract useful parts are found in Africa (Acqual *et al*. 2019). Also, open burning of e-waste without any protection measure to separate useful from not useful parts in some developing countries such as Ghana (Nnorom and Osibanjo, 2011; Lambrechts, 2016; Peluola, 2016; Adanu *et al*., 2020). Likewise, lack of institutions and inadequate capacity in most developing countries have contributed to illegal flow of e-wastes from developed to developing countries, which have at times amounted to 80% of the total e-waste produced in developed countries (Yu *et al*., 2017). This is notwithstanding the fact that three strategies (3Rs) on Reduce, Reuse and Recycling are suggested to reduce generation of e-waste as well as changing waste into resource in both developed and developing countries (Ahirwar and Tripathi, 2021). E-wastes movement within African countries has also been reported to occur from countries such as Nigeria, South Africa, Tunisia, Zimbabwe, Mozambique and DRC Congo (Doyon-Martin, 2015). In East African countries Tanzania inclusive, governments have not enacted institutions that are specifically aimed at addressing e-wastes. Matters of e-waste are addressed using environmental related laws, which do not focus on e-waste in particular. The countries have also been found to have ratified international conventions that guide management of solid waste generally. Such efforts however, have not been able to effectively reverse the e-waste related challenges (Asimwe and Gronlund, 2012; Mombo and Bigirwa, 2017). Over-all, lack of institutions and inadequate capacities of African governments to handle e-waste have influenced e-waste management in these countries is mainly under informal sector (Otieno and Omwenga, 2015).

A conceptual framework of factors influencing e-waste situation: From the findings, an attempt has been made to develop a conceptual framework for guiding further studies on factors influencing e-waste situation in Africa and beyond. As depicted in Figure 2, e-waste constitutes two dimensions pointed by arrowed dotted lines. The dimensions include factors influencing e-waste situation and situation of e-waste. The factors influencing e-waste situation are the level of awareness, available technologies for the management of e-waste, institutions guiding management of e-waste, and capacity of actors dealing with e-waste. On the other hand, e-waste situation include forms of managing e-wastes (formal, informal), e-waste related environment situation, e-waste related health situation, e-waste data security situation and e-waste employment opportunities. From Fig. 2, it can be deciphered that improved factors influencing e-waste situation is associated with better situation of e-waste in the form of improved ways of handling of the wastes, less environmental hazards, less human health issues, minimal data insecurity and decent e-waste related employment opportunities. In other words, a

low level of improvement in factors influencing e-waste situation leads to poor situation of e-waste.

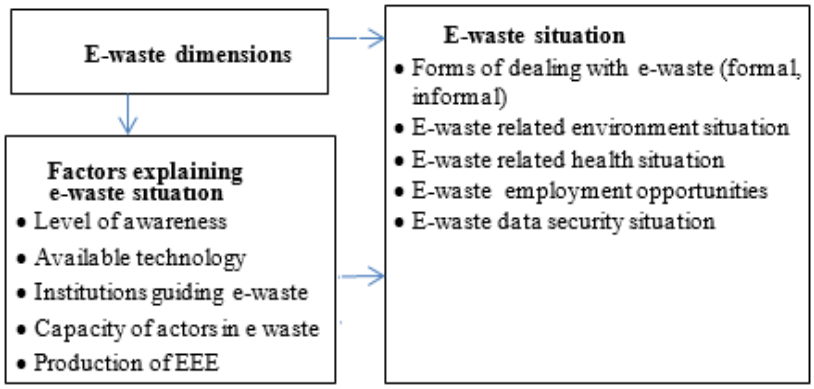

Figure 2: *Factors influencing e-waste situation in Africa*
Source: Authors' construction

Conclusion: The paper aimed at exploring the situation of e-waste and factors influencing it in Africa. It shows that e-waste is increasing in Africa and is a threat to both environment and human health. However, most African countries lack institutions for guiding the management of the e-waste. This has resulted into the prominence of informal sector in managing e-waste. Therefore, this paper contributes to the literature by analysing the situation of e-waste and developing a conceptual framework of the factors influencing the e-waste situation in Africa. The main factors identified include low awareness, absence or limited institutions to oversee the activities related to e-waste and low technologies for dealing or managing e-waste.

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REFERENCES

Acquah, AA; D'Souza, C; Martin, B; Arko-Mensah, J; Nti, AA; Kwarteng, L; Fobil, JN (2019). Processes and challenges associated with informal electronic waste recycling at Agbogbloshie, a suburb of Accra, Ghana. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. 63(1): 938-942, Sage CA: Los Angeles, CA: Sage Publications.

Adanu, S; Gbedemah, F; Attah, K (2020). Challenges of adopting sustainable technologies in e-waste management at Agbogbloshie, Ghana. Heliyon, 6(8). https://doi.org/10.1016/j.heliyon.2020.e04548

Ahirwar, R; Tripathi, AK (2021). E-waste management: A review of recycling process, environmental and occupational health hazards, and potential solutions. *Environ. Nanotech. Monit. Manage. 15*, 100409.

Alamerew, YA; Brissaud, D(2018). Modelling and assessment of product recovery strategies through systems dynamics. *Procedia CIRP, 69*: 822-826.

Asampong, E; Dwuma-Badu, K; Stephens, J; Srigboh, R; Neitzel, R; Basu, N; Fobil, JN (2015). Health seeking behaviours among electronic waste workers in Ghana. *BMC Public Health*. 15(1): 1–9

Asiimwe, EN; Åke, G (2012). E-waste management in East African community. In *Handbook of research on E-Government in emerging economies: adoption, e-participation, and legal frameworks* (pp. 307-327). IGI Global.

Awasthi, AK; Zeng, X; Li, J (2016). Comparative examining and analysis of e-waste recycling in typical developing and developed countries. *Procedia Environ. Sci. 35*: 676-680.

Awasthi, AK; Li, J (2017). Management of electrical and electronic waste: a comparative evaluation of China and India. *Renew. Sustain. Energy Rev*. 76: 434–447.

Balde, CP; Forti, V; Gray, V; Kuehr, R; Stegmann, P (2017). The Global E-waste Monitor 2017: Quantities, Flows, and Resources. United Nations University, International Telecommunication Union, and International Solid Waste Association, Bonn, Geneva, and Vienna, p. 116.

Balde, CP; Wang, F; Kuehr, R; Huisman, J (2015). The Global E-waste Monitor 2014: Quantities, Flows and Resources. United Nations University, Tokyo & Bonn, p. 79.

Bazargan, A; Lam, KF; McKay, G (2012). Challenges and opportunities of e-waste management. In: E-waste management, types and challenges. Edited by Yuan Chun Li and Banci Lian Wang, Nova *Science*, Publihsers Inc.

Bhat, V (2023). E-waste management and Achieving SDG-Challenges in Indian Context. In *IOP Conference Series: Earth. Environ. Sci.* 1161 (1): 012008

Bhutta, MKS; Omar, A; Yang, X (2011). Electronic waste: a growing concern in today's environment. *Econ. Res. Inter*. 2011. DOI:10.1155/2011/474230

Boaten, O. (2011). Ghana burns its health away. New African, 506 (May 2011). Accessed at https://newafricanmagazine.com/2799/#:~:text=But%20their%

Burns, KN; Sayler, SK; Neitzel, RL (2019). Stress, health, noise exposures, and injuries among electronic waste recycling workers in Ghana. *J. Occup. Med. Toxico*. 14(1): 1. DOI: 10.1186/s12995-018-0222-9

Cahill, R; Grimes, SM; Wilson, DC (2011). Extended producer responsibility for packaging wastes and WEEE-a comparison of implementation and the role of local authorities across Europe. *Waste Manage. Res.* 29(5): 455–479.

Chen, M; Huang, J; Ogunseitan, OA; Zhu, N; Wang, YM (2015). Comparative study on copper leaching from waste printed circuit boards by typical ionic liquid acids. *Waste Manage. 41*, 142-147. DOI: 10.1016/j.wasman.2015.03.037

Chi, X; Streicher-Porte, M; Wang, MY; Reuter, MA (2011). Informal electronic waste recycling: A sector review with special focus on China. *Waste Manage. 31*(4): 731-742.

Chi, X; Wang, MY; Reuter, MA (2014). E-waste collection channels and household recycling behaviors in Taizhou of China. *J. Cleaner Product. 80:* 87-95. DOI: 10.1016/j.jclepro.2014.05.056

Cui, J; Forssberg, E (2003). Mechanical recycling of waste electric and electronic equipment: a review. *J. Hazard. Mat. 9* (3): 243-263.

Doyon-Martin, J (2015). Cybercrime in West Africa as a result of transboundary e-waste. *J. Appl. Sec. Res* 10(2):207–220.

Forti, V; Balde, CP; Kuehr, R; Bel, G (2020). The Global E-waste Monitor 2020: Quantities, Flows and the Circular Economy Potential. United Nations University, United Nations Institute for Training and Research – co-hosted SCYCLE Programme, International Telecommunication Union, and International Solid Waste Association Bonn, Geneva and Rotterdam, p. 120.

Fraige, FY; Al-khatib, LA; Alnawafleh, HM; Dweirj, MK; Langston, PA (2012). Waste electric and electronic equipment in Jordan: Willingness and generation rates. *J. Environ. Plan. Manage.* 55(2):161–175.

Ghosh, SK; Debnath, B; Baidya, R; De, D; Li, J; Ghosh, SK; Zheng, L; Awasthi, AK; Liubarskaia, MA; Ogola, JS'; Tavares, AN (2016). Waste electrical and electronic equipment management and Basel Convention compliance in Brazil, Russia, India, China and South Africa (BRICS) nations. *Waste Manage. Res.* 34(8):693–707

Gumbo, M; Kalegele, K (2015). E-Waste Management: Awareness, Strategies, Facilities, Sources and Treatment in Tanzania. *Inform. Knowledge Manage*. 5(4): 17-28

Hageluken, C. (2006). Improving metal returns and eco-efficiency in electronics recycling-a holistic approach for interface optimisation between pre-processing and integrated metals smelting and refining. In *Proceedings of the 2006 IEEE International Symposium on Electronics and the Environment, 2006.* (pp. 218-223). IEEE.

Khan, S; Lodhi, S; Akhtar, F; Khokar, I (2014). Challenges of waste of electric and electronic equipment (WEEE). *Manage. Environ. Quality*. 25(2):166–185.

Lambrechts, D (2016). Environmental crime in SubSaharan Africa – A review and future challenges. *Politikon*. 43(2): 155–158

Li, J; Lu, H; Guo, JIE; Xu, Z; Zhou, Y (2007). Recycle technology for recovering resources and products from waste printed circuit boards. *Environ. Sci. Technol. 41*(6): 1995-2000.

Machete, F (2017). Environmental health risks associated with e-waste exposure in Badplaas, Carolina and Elukwatini landfills, Republic of South Africa. *Afr. J. Sci. Tech. Innovation and Develop*. 9(6):679–684. DOI: 10.1080/20421338.2017.1355602

Maphosa, V., Maphosa, M. (2020). E-waste management in Sub-Saharan Africa: A systematic literature Review. *Cogent Bus. Manage*. 7:1, 1814503, DOI: 10.1080/23311975.2020.1814503

Matsakas, L (2017) Green conversion of municipal solid Wastes into fuels and chemicals. *Elec. J Biotechnol*, 26: 69–83

Meskers, CEM; Hagelüken, C; Salhofer, S; Spitzbart, M (2009). Impact of pre-processing routes on precious metal recovery from PCs. In *Proceedings of EMC*. 2:527-540

Mohammed, SI (2022). E-Waste Management in Different Countries: Strategies, Impacts, and Determinants. In *Advances in Green Electronics Technologies in 2023*. IntechOpen.

Moher, D; Liberati, A; Tetzlaff, J; Altman, DG; PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of internal medicine*. *151*(4):264-269.

Mombo, F; Bigirwa, D (2017). The role of Sub-Saharan Africa Countries waste charges on sustainable city development. *International Journal of Waste Resources*, 7(1): 1-6

Montalvo, C; Peck, D; Rietveld, E (2016). A longer lifetime for products: benefits for consumers and companies. Accessed at https://policycommons.net/artifacts/2060050/a-longer-lifetime-for-products/2813141/

Murthy, V; Ramakrishna, S (2022). A review on global E-waste management: urban mining towards a sustainable future and circular economy. *Sustainability*, *14*(2), 647. **https://doi.org/10.3390/su14020647**

Nnorom, IC; Osibanjo, O (2011). Determination of metals in printed wiring boards of waste mobile phones. *Toxicol. Environ. Chem.* 93(8):1557–1571.

Nuwematsiko, R; Oporia, F; Nabirye, J; Halage, AA; Musoke, D; Buregyeya, E. (2021). Knowledge, perceptions, and practices of electronic waste management among consumers in Kampala, Uganda. *J. Environ. Public Health. 2021*. DOI: 10.1155/2021/3846428

Orisakwe, OE; Frazzoli, C; Ilo, CE; Oritsemuelebi, B (2019). Public health burden of e-waste in Africa. *J. Health. Pollut. 9*(22):190610.

Orlins, S; Guan, D. (2016). China's toxic informal e-waste recycling: local approaches to a global environmental problem. *J. Cleaner Prod. 114*: 71-80.

Otieno, I; Omwenga, E (2015). E-Waste Management in Kenya: Challenges and Opportunities. *J. Emerg. Trends. Comput. Inform. Sci.* 6 (12): 661-665

Peluola, A (2016). Investigation of the implementation and effectiveness of electronic waste management in Nigeria. *Modeling Earth Systems. Environ*. *2*:1-6.

Pradhan, JK; Kumar, S (2014). Informal e-waste recycling: environmental risk assessment of heavy metal contamination in Mandoli industrial area, Delhi, India. *Environ. Sci. Pollut. Res. 21*:7913-7928.

Shahabuddin, M; Uddin, MN; Chowdhury, JI; Ahmed, SF; Uddin, MN; Mofijur, M; Uddin, MA (2023). A review of the recent development, challenges, and opportunities of electronic waste (e-waste). *International Journal of Environmental Science and Technology*. *20*(4), 4513-4520.

Srivastava, D (2020). Review on E-waste along with its management. *European Journal of Molecular & Clinical Medicine. 7*:1323-1328.

UNPAN (2003). Global E-Government Survey 2003. Accessed at: https://publicadministration.un.org/egovkb/en-us/reports/un-e-government-survey-2003

UNPAN (2010). Global E-Government Survey 2010. Accessed at: https://joinup.ec.europa.eu/sites/default/files/document/2014-12/UN%20E-Government%20Survey%202010%20-%20Part%20II.pdf

Wang, F; Kuehr, R; Ahlquist, D; Li, J (2013). E-waste in China: A Country Report. United Nations University/StEP Initiative. Accessed at: http://www.step-initiative.org.

Wath, SB; Vaidya, AN; Dutt, PS; Chakrabarti, T (2010). A roadmap for development of sustainable E-waste management system in India. *Sci. Total Environ*. 409(1):19-32.

Yu, EA; Akormedi, M; Asampong, E; Meyer, CG; Fobil, JN (2017). Informal processing of electronic waste at Agbogbloshie, Ghana: Workers' knowledge about associated health hazards and alternative livelihoods. *Global Health Promotion*. 24 (4):90–98.