Assessment of Heavy Metal Contamination on Soil around E-Waste Dumpsite in Onitsha, Nigeria.

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ABSTRACT

Electronic waste (e-waste) has become an issue of major importance as production technology rapidly develops and changes, and more unknown components of the waste enter the municipal waste stream. The absence of a structured management system and laxity in environmental laws and regulations in Anambra State have led to an increased influx of e-waste into the state. It has created an avenue for uncontrolled and crude methods of recovering valuable metals from waste. These e-wastes are dismantled, some are burnt without prior knowledge of their composition and noxious matters are released into the environment. This study aimed to establish an understanding of the extent of heavy metals contamination on the soil around e-waste dumpsite in Ochanja in Onitsha, Anambra State with a view to generating baseline data on the extent of contamination of heavy metals from e-waste. Experimental research design was adopted and primary data were obtained through the collection of four different soil samples at varying distances within Ochanja e-waste dumpsite , the study Area. The collected soil samples were analyzed using Atomic Absorption SpectrophotometerAAS(GBC932AA) for the following heavy metals; Lead(Pb), Cadmium(Cd) Hexavalent chromium(Cr),Copper(Cu), Aluminium(Al) and Nickel(Ni). The result of the analysis showed that Al and Cr had maximium average value of 393.65mg/kg and 161.70mg/kg,followed by Pb(111.4mg/kg),Cu(102.37mg/kg),Cd(11.79mg/kg) and Ni(6.43mg/kg).The heavy metal concentrations in the soil were generally above 100mg/kg with exception of Cadmium (11.79mg/kg) and Nickel(6.43mg/kg),while the average concentrations of Al,Cu and Cd are above USEPA standard of 300mg/kg,50mg/kg and 3mg/kg respectively. The significant heavy metals found in soil samples in and around the dumpsites in the study area likely resulted from poor management of e-waste in the dumpsite in the study area. This is an indicator that the negative health impact of these heavy metals should be further investigated to avert any health and environmental consequences in the study area.

Keywords: E-waste, Heavy Metals, Soil, Contamination, Environment, Dumpsite.

1.0: INTRODUCTION

Electronic waste (e-waste) may be defined as discarded computers, office electronic equipment, entertainment device electronics, mobile phones, television sets, and refrigerators. This definition includes used electronics destined for reuse, resale, salvage, recycling, or disposal. Developed countries have replaced massive amounts of obsolete electronic equipment and home appliances with newer versions, creating a huge e-waste problem for the global environment. Uncontrolled burning, disassembly, and disposal cause various environmental issues, such as groundwater contamination, atmospheric pollution, or even water pollution, either by immediate discharge or through surface runoff. Men, women, and children are employed in the highly polluting, primitive recycling technologies of extracting metals, toners, and plastics from computers and other e-waste. The surge in information technology and the proliferation of devices have increased the generation of electronic waste (Kiddee, Naidu, and Wong, 2013). Hence, electronic waste (e-waste) has emerged as a critical global environmental and health issue because of its massive production volume and insufficient management policy in many countries (Okorhi, Omotor, Aderemi, and Abang, 2017).

In most Nigerian cities, informal recyclers utilise harmful methods, such as burning electronic equipment to melt plastic and recover metals, thereby releasing carcinogens and neurotoxins into the air, contributing to smog. Consequently, in countries where environmental enforcement laws may not be sufficient, high concentrations of trace metals can be discharged from e-waste, thus causing widespread ecological damage to people and their immediate environment. Onitsha Main Market in Anambra State, Nigeria, is a dumping ground for electronic appliances and equipment from home and abroad. There is a lack of awareness of the hazardous nature and management of e-waste in Anambra State; hence e-wastes are disposed off alongside municipal wastes with their toxic constituents, most of which end up in open dumpsites, unlined landfills and unauthorised dismantling clusters leaving the environment exposed to the poisonous contents (Okoye and Odoh, 2014).

Some electronics contain heavy metals such as mercury found in fluorescence tubes and flat-screen monitors, cadmium in rechargeable batteries and resistors, and lead in lead batteries and cathode ray tubes, just to mention a few. When the compost from an e-waste dumpsite is used as manure, some heavy metals are subject to bioaccumulation and may cause risk to human health when transferred to the food chain. Exposure to heavy metals may cause blood and bone disorders, kidney damage, decreased mental capacity, and neurological damage (Citiamba, 2007).

Nnorom (2009) speculated that the lack of awareness of the e-waste hazards and danger associated with improper disposal techniques are the major hindrances towards eliminating the e-waste problem. Similarly, Sivathanu (2016) opined that awareness of the toxic effects on human health, environmental hazards, proper disposal of e-waste, management by stakeholders and convenience of recycling were the five significant factors influencing consumers' preference towards appropriate ewaste disposal and management. Ignorance about the dangers of e-waste to human health is no doubt a fundamental factor militating against its proper disposal and management. Thus, adequate awareness of the health and environmental effects of e-waste can stimulate the individual perception of the problem and the eventual reaction to the issue.

Human exposure to heavy metals occurs through three primary routes, i.e. inhalation, ingestion and skin absorption. The environmental problem with heavy metals is that they are unaffected during the breakdown of organic waste and have toxic effects on living organisms when they exceed a certain concentration. Concentrations of metals in plants, water, animal, and human bodies reflect the high concentration of heavy metals in soils. Consequently, when pollutants from e-waste are washed into surrounding water bodies by rain or flood, there will be a change in the level of heavy metal concentration and nutrient concentration of the water bodies(Chan and Wong, 2013).

The effects of informal crude recycling activities are not usually considered by stakeholders, probably because the body of knowledge on the impact of e-waste recycling is still emerging. Although several studies have been carried out in several e-waste recycling sites in Ghana, China and India on the composition of e-waste, the toxicity of e-waste as well as the risk to human health and the environment by the improper recycling of e-waste (Leung et al., 2008; Li et al., 2011; Zeng et al, 2013); only a few studies have been carried out in Anambra State, Nigeria in particular, to determine the concentration of the resultant contaminants from the e-waste activities (Adaramodu et al., 2012; Olafisoye et al., 2013; Ofudje et al., 2015) and most of the studies lack in-depth empirical analysis.

Currently, there is a shortage of literature on the pollution or contamination caused by e-waste in Anambra State. The exposure pathways have not been identified nor understood, and the environmental and human health effects are relatively unknown. Therefore, this paper aims to establish a basic understanding of the extent of contamination of heavy metals due to improper ewaste management, to generate baseline data on the concentration of heavy metals from e-waste on the soil around e-waste dump sites in Onitsha, Nigeria. The data obtained through this study will help in advocacy for the preservation of the environment through an environmentally sound e-waste management system in Nigeria.

2.0: LITERATURE REVIEW

E-waste combines a broad and increasingly growing range of electronic devices, such as large household devices (refrigerators, air conditioners) and mobile devices (Benedicta, 2012). Thus,e-waste has many definitions, and each definition depends on the interpretation of an electronic device's usefulness (Benedicta, 2012). The United Nations Environmental Programme (2007) stated that waste generated from discarded Electrical and Electronics Equipment (EEE) is commonly divided into 3 main categories: large household appliances (refrigerators and washing machines), information technology (IT) and Telecom (personal computers, monitors, and laptops), and consumer equipment (TVs, DVD players, mobile phones, mp3 players, and leisure and sporting equipment)(Gupta,2014). Adediran and Abdulkarim (2012) stated that there is no internationally standardized or agreed definition of e-waste; hence, each country or organization comes up with their customized description.

The Organisation for Economic Co-operation and Development (OECD, 2001) defines e-waste as any appliance using an electric power supply that has reached its end-of-life. According to the EU Initiative (UNEP, 2007), "Electrical and Electronics Equipment (EEE) means equipment which is dependent on electrical currents or electromagnetic fields to work properly and equipment for the generation, transfer and measurement of such current and fields designed for use with a voltage rating not exceeding 1000 volts for alternating current and 1500 volts for direct current." The EU Directive (2006) defines e-waste as any substance or object the holder disposes of or is required to dispose of under the provision of the National Law in force.

Terada (2012), in a review of her article titled "Recycling the Electronic Waste in Nigeria:" Putting Environmental and Human Rights at Risk", defined e-waste as the disposal of electronic goods such as cell phones, mp3 players, televisions, and computers. A piece of equipment is not considered a waste when it can still be repaired, sold or given away, given out in exchange for a new one, donated for charity purposes, sent out for refurbishing or returned to a retailer under the organisations' return policies. On the other hand, a piece of equipment is considered waste if it does not satisfy the above situations (UK Environmental Agency, 2012). Electronic waste is therefore an unwanted electronic or electrical appliance such as old and outdated computers, laptops, televisions, cellular phones, mp3 players, telecommunication equipment, keyboards, mouse, photocopiers, typewriters, etc. (Ogbomo *et al*., 2012). While electronic products may contain reusable and valuable materials, most of the ewaste components are hazardous and toxic, hence unsafe for the environment (Adediran and Abdulkarim, 2012).

2.1: Sources of E-Waste

Vijarania, Gupta and Gambhir (2017), identified the sources of e-wastes in emergent countries to include e-waste from certain urban countries, new product sales in the country, and second-hand products used in the country. E-waste accumulates nearly three times faster than other waste (Cucchiella, Adamo, Koh and Rosa, 2015). For example, between 20 and 50 million tonnes of Waste Electronic and Electrical Equipment (WEEE) are generated yearly (Wang, Zhang and Guan ,2016). Akuru and Okoro (2010), concluded that due to the lack of financial resources available to most people in developing countries, much of the growth in the information communication technology (ICT) sector in developing countries has been fuelled by the importation of 'hand-me-down' used equipment from rich, developed countries, whose consumers are all too happy to find buyers for it. The study further stated that as a result, many brokers and businesses have sprung up to channel used equipment from developed to developing countries, thereby encouraging the production of e-waste(Benebo,2009).

An estimated 500 containers of "second-hand" electronics are imported to Nigeria every month from Europe, with each container holding 500 to 800 computers and monitors, representing about 400,000 arrivals every month (Terada, 2012; Puckett, Westervelt, Gutierrez, and Takamiya, 2005). The exporting countries of Used Electrical and Electronic Equipment (UEEE) to Nigeria are European Union (45%), USA (45%), the remaining 10% is from other locations such as Japan, Korea, Malaysia and Singapore (Benebo, 2009; Puckett, Westervelt, Gutierrez, and Takamiya, 2005), with Ikeja Computer Village, near Lagos, being the site where thousands of vendors repair and sell these used electronics (Schmidt, 2006; Terada, 2012).

Many factors contribute to the surge in e-waste, such factors include the short lifecycle of electronic equipment, low recycling, high cost of recycling (Rabani and Thakur, 2020), and the continuous upgrading of electronic equipment, as affluent societies demand the latest technology (Wang, Ren, Dong, Zhang and Wang 2019). According to Opara (2013), it costs about "€3.50 (US$5.30 or N848.00)" to properly dispose of an old Cathode Ray Tube (CRT) monitor in Germany, but it costs only about "€1.50 (US$2.27 or N363.43)" to place it on a container ship to Nigeria or Ghana. Thus, the purported "building bridge over the digital divide" serves as a cover for the actual bridge that doubles as toxic waste pipelines" to some of the poorest communities and countries in the world" (Puckett *et al*., 2005). Therefore, the so-called "digital divide" only helps to open up "a digital dump" in developing countries, especially Nigeria. In most cities in Nigeria, there are neither organized e-waste collection centers nor e-waste management infrastructure (Puckett, *et al*., 2005).

2.2: Environmental Effects of E-Waste

Electrical and electronic goods contain a variety of metals, many of which are toxic to humans and ecosystems. Hossain, Hamadan and Rahman (2015), in a study titled "E-waste: A Challenge for Sustainable Development", concluded that the proper management (collecting, storage, recycling, and disposing) of these wastes is important because there are hazardous chemicals in the waste, such as Aluminium (Al), Arsenic (As), Bismuth (Bi), Cadmium (Cd), Chromium (Cr), Mercury (Hg), Nickel (Ni), Lead (Pb) and Antimony (Sb). Furthermore, the combustion of these e-wastes releases Polycyclic Aromatic Hydrocarbons (PAHs), Brominated Flame Retardants (BFRs), Polybrominated Diphenyl Ethers (PBDEs), Polychlorinated Biphenyls (PCBs) and Polychlorinated Dibenzo-Dioxins and Furans (PCDD/Fs) gases that affect some or all bio-physical environments (soil, atmosphere, aquatic).

Osibanjo and Nnorom (2007), in their article titled "The Challenge of Electronic Waste (e-waste) Management in Developing Countries", stated that in Nigeria, information on the implications of improper and indiscriminate dumping of e-waste at various dump sites, including the impact on soil, as it affects the soil biota and their biodiversity and other soil resources is very scanty. However, Labunska et al. (2013) noted that PBDEs and PBDD/Fs contaminate the surrounding soil, air and water, causing a depletion of fertility and water quality and acting as neuro-toxicants and endocrine disruptors in infants and children. These toxic chemical compounds and Persistent Organic Pollutants (POP) affect the environment through the ecological food chain and adversely affect human health and ecosystems. Bioaccumulation (i.e., PBCs, BFRs and several chemical elements) in the food chain affects human health, especially in pregnant and breastfeeding women. (Khan, Lodhi, Akthar and Khokar, 2014).

Islam, *et al.,* (2020), opined that the inappropriate handling of WEEE is unsafe for both human health and the environment. The study further stated that overall 70% of reported toxic and hazardous chemicals in the atmosphere today come from e-waste. Plastics are often burned at low temperatures to either dispose of computer casings or retrieve metals from electronic chips and other components. Incineration releases heavy metals such as Lead, Cadmium, and Mercury, which are heavy metals, capable to cause harm to human health and the environment (Chan and Wong, 2012). E-waste poses tremendous risks to the environment, including groundwater pollution, air pollution, acidified rivers and banks, and toxic soil (Terada, 2012). Environmental risks from e-waste affect entire ecosystems and can pose major health risks to wildlife and humans (Terada ,2012).

2.3: Strategies for Managing E-Waste

E-waste has been described as one of the most difficult classes of waste to manage due to a constant change in its features and specificities (Borthakur, 2020). Many strategies and methods have been adopted by many countries and many other methods of managing e-waste are in trial. Landfilling is one of the most widely used methods for the disposal of e-waste (Pramila, Fulekar and Bhawana, 2012). According to Rao (2014), e-wastes is a particular problem faced in many regions across the globe and computer wastes that are landfilled produce contaminated leachates which eventually pollute the groundwater. Acids and sludge obtained from melting computer chips, if disposed off on the ground cause acidification of soil. For example, Guiyu, Hong Kong, a thriving area of illegal ewaste recycling is facing acute water shortages due to the contamination of water resources. (Rao, 2014).

Pramila, Fulekar and Bhawana (2012), in an article titled "E-waste a challenge for Tomorrow" defined incineration as a controlled and complete combustion process in which the waste material is burned in a specially designed incinerator at a high temperature (900-1000 ^{0}C). Stewart and Lemieux (2003), conducted experiments on the incineration of a mixture of personal computer motherboards, keyboards and cases using a pilot-scale rotary kiln incinerator. The flue gas was analysed for metals, halogens, and volatile and semi-volatile organic products of incomplete combustion, including PCDDs/Fs. Measured metal emissions were significant, and consisted primarily of copper, lead, and antimony, while emissions of PCDDs/Fs were well below regulatory limits. Based on the results, the study suggested that incineration may be a viable option for electronics waste disposal, provided an appropriate particulate control device is used to control metal emissions. (Stewart and Lemieux, 2003).

The advantage of incineration of e-waste is the reduction of waste volume and the utilisation of the energy content of combustible materials. By incineration, some environmentally hazardous organic substances are converted into less hazardous compounds (Pramila, Fulekar and Bhawana, 2012). Disadvantages of incineration are the emission to air of substances escaping flue gas cleaning and the large amounts of residues from gas cleaning and combustion. E-waste incineration plants contribute significantly to the annual emissions of cadmium and mercury (Pramila, Fulekar and Bhawana, 2012). Kristina *et al*, (2002), stated that the recovery and reuse technique could reduce waste disposal costs, reduce raw material costs and provide income from saleable waste. Waste can be recovered on-site, at an off-site recovery facility, or through an inter-industry exchange, (Kristina *et al* ,2002).

Sustainable e-waste recycling is critical in achieving a progressive circular economy. Recycling practices in developed countries are dominated by formal activities under controlled conditions that

protect the environment and human health. In developing countries, on the other hand, the majority of recycling practices are informal. According to Adediran and Abdulkarim, (2012) Reuse, in contrary to recycling, extends the lifespan of a device before eventual recycling. There are four main steps involved in the recycling of e-waste, viz: collection, transportation, treatment, and disposal. Developing countries (Nigeria inclusive) lack well-established systems for the separation, collection, storage, transportation and disposal of e-waste as well as adequate enforcement and monitoring of regulations for hazardous e-waste (Agunwamba, Emenike, and Tenebe, 2013). The National Environmental Standards and Regulations Enforcement Agency (NESREA), an Agency of the Federal Ministry of Environment, is responsible for the enforcement of all environmental laws in Nigeria (Amachree, 2013). While NESREA's work is commendable, there is still much room for more work towards an effective solution to the e-waste scenario in Nigeria today.

3.0: METHODOLOGY

This study adopted the experimental research design, and data were derived from primary and secondary sources. Secondary data were obtained from materials that are relevant to the study, which have been previously documented. Such materials include; related research reports, Documents from the Anambra State Ministry of Environment and Ministry of Agriculture, relevant Journal articles, Textbooks, Encyclopedias, online materials,USEPA, World Health Organization (WHO) documents on soil quality standards, NESREA Environmental Chart Sheet, among others. Primary data were obtained through the collection of four soil samples from different locations in the study Area.

Clean new polyethene bags were used to collect the soil samples. For easy identification, the bags were labeled with the names of the location where the samples were collected and the date of collection. The collected soil samples were analyzed in the Biotechnology Research Laboratory,NAU,Awka.The following heavy metals were tested and analyzed; Lead, Cadmium , Hexavalent chromium, copper, Aluminium and Nickel.

3.1: Experimental Procedure

The samples were dried in an oven at 105^0C to a constant weight and sieved through a 2mm mesh to remove large debris, gravel-sized materials and other unwanted materials. A portion (0.5g) of the sieved samples were measured after homogenization and ground with a laboratory mortar and pestle. The ground samples were transferred into a 250ml beaker. A portion (10ml) of 1:1 nitric acid was measured into the beaker and covered with a water glass. The beaker was placed in a steam bath at 99^0C left for 1 hour. The samples were removed from the steam bath and allowed to cool for 10mins after which 2ml of distilled water and 3ml of 30% hydrogen peroxide were added to the sample, the beaker was covered with a watch glass and placed in a steam bath and allowed to digest until the

sample appearance remained unchanged. The samples were filtered through a Whitman filter paper and the solution made up to 50ml mark with distilled water. The samples were subsequently analyzed for Lead, Cadmium, Chromium,Aluminium, Copper and Nickel using Atomic absorption spectrophotometer (AAS) machine and the result of the various heavy metals determined and data recorded.

4.0: RESULT and DISCUSSION

The data presented in this section are the result of laboratory analysis of four soil samples collected within Ochanja dumpsite at some varying distances of 5cm away from the dumpsite within the study area. The collected and analyzed samples assisted in the establishment of the impact of e-waste on soil quality in the study area. The accepted permissible standard of heavy metals as recommended by the National Environmental Standard and Regulatory Enforcement Agency (NESREA) and USEPA are also presented in this section.

Table 1: Heavy Metal Contamination in Soil in the Study Area {Ochanja} (Mg/Kg)

Study Location	Pb	Cd	Cr	Al	Cu	Ni
0	111.42	12.84	164.80	1119.80	110.17	6.66
5	110.40	11.78	164.20	1032.40	102.51	6.63
10	110.26	11.20	161.60	965.43	96.38	6.20
15	110.23	11.31	159.80	168.93	100.35	6.33
Average	111.40	11.79	161.70	393.65	102.37	6.43

Source: Author's Laboratory Analysis (2022).

Table1 showed the average value of the concentration of Lead,Cadmium,Chromium,Aluminium,Copper and Nickel to be 111.40Mg/Kg,11.79Mg/Kg,161.70Mg/Kg,393.65Mg/Kg,102.37Mg/Kg and 6.43Mg/Kg respectively.The heavy metal concentration of the soil was generally above 100mg/kg for all the six heavy metals with the exception of Cadmium and Nickel with average values of 11.79mg/kg and 6.43mg/kg.The values of heavy metal concentrations in this study are lower,when compared to a similar study of e-waste dumpsite in China which reported average concentrations of Cu (513mg/kg),Pb (198mg/kg) and Cd(0.52mg/kg),however the value for Cd(0.52mg/kg)was lower compared to the average concentration of 11.79mg/kg observed in Ochanja ,Onitsha(Wu *et al*.,2015) .Based on USEPA Standard, the concentrations of Pb,Cr and Ni in the soil samples are within the allowable limits 300mg/kg,400mg/kg and 50mg/kg respectively; the concentrations of Cu,Al and Cd are above the allowable limit 50mg/kg,300mg/kg and 3.0mg/kg respectively. This is an indicator that the negative health impacts of these heavy metals should be further investigated in the study area to avert any health and environmental consequences.

The findings of this study are in agreement with the findings of similar experimental research conducted by Khan *et al.* (2011), titled "The Effects of E-Waste on Heavy Metal Composition of Soil at Nathiagali Abbottbad Dumpsite" in Pakistan. The experiment concluded that the e-waste materials produced tangible impacts on soil in Nathagali. The dumping of e-waste resulted in a marked increase in the concentration of heavy metals, such as Manganese (Mn), Iron (Fe), Copper (Cu), Lead (Pb), and Nickel (Ni). The metals were found higher on the site of e-waste accumulation and decreased with the increasing distance from the e-waste dumpsite. The implication of these findings is that wastes are not properly disposed off and as such constitutes a serious environmental hazard.

Table 2: National Standards and Regulatory Enforcement Agency (NESREA) Threshold Limit of Heavy Metal in the Soil.

Heavy Metal	Limit Mg/Kg
Lead (Pb)	40.00
Cadmium (Cd)	3.00
Copper (Cu)	100.00
Iron (Fe)	0.30
Manganese (Mn)	0.00
Nickel (Ni)	0.05

Source: NESREA (2022).

Table 3: USEPA Standard

Heavy Metal	Limit Mg/Kg
Lead (Pb)	300 .00
Cadmium (Cd)	3.00
Copper (Cu)	100.00
Iron (Fe)	_
Aluminium(Al)	300.00
Nickel (Ni)	0.05

Source: Tsafe *et al* (2012).

6.0: CONCLUSION

The significant heavy metals Pb(111.40Mg/Kg), Cd(11.79Mg/Kg), Cu(161.70Mg/Kg), Al(393.65Mg/Kg), Cr(102.37Mg/Kg) and Ni(6.43Mg/Kg) respectively found in soil samples in and around the e-waste dumpsite in Ochanja are as a result of the poor management and dumping of e-waste in the study area.

These heavy metals are carcinogenic and can cause renal impairment, brain disorder and possibly death. Certainly, future studies should determine the health impact of heavy metals on the human population living in Onitsha, including the scavengers in the e-waste dumpsite areas, taking into consideration the probability that such heavy metals can accumulate in plants, making their way to the human body, through the food chain.

The heavy metals concentration reduces as distance increases from e-waste dumpsite and find their way into the soil and underground aquifer through a leaching process and rainfall act as a catalyst that speeds up this action(Citiamba, 2007). Rotich *et al* ,2006 revealed that leachate can contaminate both ground and surface water. During floods, water mixed with leachate may flow out of the dumpsite and set into nearby ponds, streams, and rivers. This of course poses health risks to the communities near the dumpsites, and those downstream who may be using the water for various purposes.

REFERENCES

Adaramodu, A. A., Osuntogun, A. O., & Ehi-Eromosele, C. O. (2012). Heavy Metal Concentration of Surface Dust Present in E-Waste Components: the Westminister Electronic Market, Lagos Case Study. *Resources and Environment*, 2(2), 9-13.

Adediran, Y. A., & Abdulkarim, A. (2012). Challenges of Electronic Waste Management in Nigeria. *International Journal of Advances in Engineering & Technology*, 4(1), 640.

Akuru, U. B., & Okoro, O. I. (2010). Electronic Wastes and the Nigerian Experience. *In Proc. 18th International Conference on Domestic Use of Energy, Cape Town/South Africa* (pp. 17-21).

Amachree, M. (2013). Update on E-Waste Management in Nigeria. In *3rd Annual Meeting of the Global E-Waste Management Network, San Francisco.[Online]. Available: https://www.epa.gov/sites/production/files/2014-05/documents/nigeria.pdf*

Benedicta, A. I. (2012). E-waste Management: A Case Study of Lagos State, Nigeria. Social and Public Policy Master's Programme in Development and International Cooperation. *Department of Social Sciences and Philosophy University of Jyvaskyla, Finland.*

Benebo, N. S. (2009). Status of E-Waste Control in Nigeria. *In NESREA Presentation at the Workshop on E-Waste in West Africa, Accra, Ghana* (Vol. 24).

Borthakur, A. (2020). Policy Approaches on E-Waste in the Emerging Economies: A Review of the Existing Governance with Special Reference to India and South Africa. *Journal of Cleaner Production, 252, 119885.*

Chan, J. K. Y., & Wong, M. H. (2013). A Review of Environmental Fate, Body Burdens, and Human Health Risk Assessment of PCDD/Fs at Two Typical Electronic Waste Recycling Sites in China. *Science of the Total Environment*, 463, 1111-1123.

Citiamba, P. (2007). Trace Metal Contamination of Water at an E-waste Disposal Site at Kariba, Zimbabwe.*African Journal of Aquatic Science*, 32(1), 71-78.

Cucchiella, F., D'Adamo, I., Koh, S. L., & Rosa, P. (2015). Recycling of WEEEs: An Economic Assessment of Present and Future E-waste Streams. *Renewable and Sustainable Energy Reviews*, *51*, 263-272.

Gupta, M. (2014). Environmental Effects of Growing E-waste. *International Journal of Science and Research*, 3(11), 204-206.

Hossain, M. S., Al-Hamadani, S. M., & Rahman, M. T. (2015). E-waste: A Challenge for Sustainable Development. *Journal of Health and Pollution*, 5(9), 3-11.

Islam, A., Swaraz, A. M., Teo, S. H., Taufiq-Yap, Y. H., Vo, D. V. N., Ibrahim, M. L., ... & Awual, M. R. (2021). Advances in Physiochemical and Biotechnological Approaches for Sustainable Metal Recovery from E-Waste: A Critical Review. *Journal of Cleaner Production*, 323, 129015.

Khan, S. S., Lodhi, S. A., Akhtar, F., & Khokar, I. (2014). Challenges of Waste of Electric and Electronic Equipment (WEEE): Toward a Better Management in a Global Scenario. *Management of Environmental Quality:An International Journal*, 25(2), 166-185.

Kiddee, P., Naidu, R., & Wong, M. H., (2013). Electronic Waste Management Approaches: An Overview. *Waste Management,* 33(5), 1237-1250.

Labunska, I., Harrad, S., Santillo, D., Johnston, P., & Brigden, K. (2013). Levels and Distribution of Polybrominated Diphenyl Ethers in Soil, Sediment and Dust Samples Collected from Various Electronic Waste Recycling Sites Within Guiyu Town, Southern China. *Environmental Science: Processes & Impacts*, 15(2), 503-511.

Leung, A.O.W., Duzgoren-Aydin, N.S., Cheung, K.C., & Wong, M.H. (2008). Heavy Metals Concentrations of Surface Dust from E-waste Recycling and its Human Health Implications in Southeast China. *Environ. Sci. Technol*. 42(5), 2674–2680.

Li, J., Duan, H., & Shi, P. (2011). Heavy Metal Contamination of Surface Soil in Electronic Waste Dismantling Area: Site Investigation and Source-Apportionment Analysis. *Waste Management & Research*, 29(7), 727-738.

Nnorom, I. C., and Osibanjo, O. (2008). Electronic waste (e-waste): Material Flows and Management Practices in Nigeria. *E-Waste Management.* 28(4), 1472–1479.

Ofudje, E. A., Akiode, O. K., Oladipo, G. O., Adedapo, A. E., & Adebayo, L. O. (2015). Evaluation of the Chemical Composition of Soil at E-waste Sites in Computer Village, Ikeja, Lagos, Nigeria. *American Chemical Science Journal*, 7(1), 60-70.

Ogbomo, M. O., Obuh, A. O., & Ibolo, E. (2012). Managing ICT Waste: the Case of Delta State University Abraka, Nigeria. *Library Philosophy and Practice*, 12(4), 1-9.

Olafisoye, O. B., Adefioye, T., & Osibote, O. A. (2013). Heavy Metals Contamination of Water, Soil, and Plants Around an Electronic Waste Dumpsite. *Polish Journal of Environmental Studies*, 22(5).

Okorhi O. J., Omotor D. A., Aderemi H. O., & Abang S. I. (2017). Wastes from Industrialized Countries: A Socio-economic Inquiry on Sustainable Management of E-waste for the Recycling Sector in Nigeria. Proceedings of the 3rd AfricaLics International Conference:

Okoye, A., & Odoh, C.C. (2014). Assessment of the Level of Awareness of E-Waste Management and Concern for the Environment amongst the Populace in Onitsha, Southeastern Nigeria. *Journal of Environmental Protection*. 5(2), 120–134.

Osibanjo, O. & Nnorom, I.C. (2007). The Challenge of Electronic Waste (E-Waste) Management in Developing Countries. *Waste Management Research*, 25(6), 489-501. http://dx.doi.org/10.1177/0734242X07082028

Pramila, S., Fulekar, M., & Bhawana, P. (2012). E-waste: A Challenge for Tomorrow. *Research Journal of Recent Sciences*, ISSN, 2277, 2502.

Puckett, J., Westervelt, S., Gutierrez, R., & Takamiya, Y. (2005). The Digital Dump. Exporting ReUse and Abuse to Africa. Report from the Basel Action Network.

Rao, L. N. (2014). Environmental Impact of Uncontrolled Disposal of E-Wastes. *International Journal of ChemTech Research*, 6(2), 1343-1353.

Schmidt, C. W. (2006). Unfair Trade E-Waste in Africa. *Environmental Health Perspectives*, 114(4), 232-235.

Sivathanu, B. (2016). User's Perspective: Knowledge and Attitude Towards E-waste. *International Journal of Applied Environmental Sciences*, 11(2), 413-423.

Stewart, E. S., & Lemieux, P. M. (2003). Emissions from the Incineration of Electronics Industry Waste. *In IEEE International Symposium on Electronics and the Environment,* 2003, 271275. IEEE.

Terada, C. (2011). Recycling Electronic Wastes in Nigeria: Putting Environmental and Human Rights at Risk. *Nw. UJ Int'l Hum. Rts.*, 10, 154.

United State Environmental Protection Agency (2006) Soil Sourcebooks Fact Sheets. www.epa.gov/soilquality/kids/web/pdfs/facts. (accessed May 2023)

Vijarania, M., Gupta, S., & Gambhir, A. (2017). Challenges and strategies for E-waste management in developing countries. *IJ Sci Eng*, 2, 64-8.

Wang, Z., Zhang, B., & Guan, D. (2016). Take Responsibility for Electronic-Waste Disposal. *Nature*, 536(7614), 23-25.