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Electronic waste and environmental toxicology: Assessing health and ecological risks in Nigeria and Sub-Saharan Africa

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Abstract

In the twenty-first century, electronic waste has become one of the most pressing environmental issues in Sub-Saharan Africa and Nigeria. The sources, composition, and environmental fate of electronic trash over the region are investigated in this comprehensive study using thirty-nine (39) previous studies, with a special focus on toxic substance exposure routes and related health dangers. Research shows that Nigeria and the neighbouring countries have an abundance of e-waste, both imported and domestically manufactured, which contains harmful materials like lead, mercury, cadmium, and flame retardants. These substances enter environmental systems and influence soil, water, and air quality via complex exposure paths caused by improper disposal practices, illegal recycling initiatives, and open burning. Neural disorders, respiratory issues, developmental abnormalities, and reproductive health problems are among the serious health repercussions, which disproportionately affect children and workers in the informal sector. Case studies from large e-waste processing facilities demonstrate the high level of contamination, while regulatory analysis reveals significant shortcomings in legislative frameworks and enforcement procedures. The study concludes that fighting e-waste needs all-around answers to protect people's health and the environment in the area. Better laws, new technologies, public awareness campaigns, and working together across borders should all be part of these answers.

Keywords: E-waste; Health Implications; Contamination; Environmental fate; Regulatory analysis

1. Introduction

There is an unheard-of increase in electronic waste in Sub-Saharan Africa and Nigeria because more people are using electronics. This puts public health and the environment at serious risk and needs to be fixed right away. Cell phones, laptops, home gadgets, and industrial electronics are all types of electronic waste (Baldé et al., 2017; Forti et al., 2020). People moving into cities, the growth of the digital economy, and how easy it is to get technology have all sped up the use and dumping of electronics. Rich countries are also throwing their electronic garbage into Sub-Saharan Africa at the same time (Amankwaa, 2013; Mereki et al., 2016).

Nigeria has more than 200 million people, making it the most populous country in Africa. Because of this, the rest of the continent looks to Nigeria's e-waste plan. The country imports used electronics quite often, in addition to having a thriving black market and a manufacturing sector that is rising quickly. These things make it hard to properly handle and create e-waste, say Ogungbuyi et al. (2012) and Nnorom and Osibanjo (2008). Different Sub-Saharan African

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countries have different levels of legal power and technological infrastructure to deal with the rising problem of e-waste, but all of them share some of the same worries (Schluep et al., 2009; Manhart et al., 2011).

The environmental toxicology of e-waste is a big problem because electronic equipment has many parts that could be dangerous. These gadgets contain heavy metals like mercury, lead, and cadmium, as well as persistent organic poisons like polychlorinated biphenyls and brominated flame retardants, according to Robinson (2009) and Widmer et al. (2005). Researchers Grant et al. (2013) and Tsydenova and Bengtsson (2011) say that when electronics are no longer needed, they could release harmful chemicals into the environment if they are thrown away improperly or recycled illegally. This puts people and natural groups in danger in different ways. People who work in the informal recycling industry, children, and women who are pregnant are most likely to be affected by the health risks that build up over time. To get a full picture of these health risks, there is need to look at the demographics of Sub-Saharan Africa, how doses affect people, and how they are exposed (Caravanos et al., 2013; Feldt et al., 2014).

There are now very inadequate procedures in place to handle electronic garbage in the region. There are very few official recycling facilities, regulations are not strictly enforced, and the informal sector is heavily relied upon. The disproportionate impact of e-waste on low-income and marginalised populations, who frequently lack access to protective resources and healthcare, raises questions about environmental justice (Oteng-Ababio, 2012; Blacksmith Institute, 2013; Adelusi et al., 2025). Hence, this current study dived deep into electronic waste and environmental toxicology alongside its health and ecological Risks in Nigeria and Sub-Saharan Africa which has been failed to be addressed in previous studies.

2. Methodology

This systematic review examines Nigeria and Sub-Saharan Africa's electronic waste and environmental toxicity challenges. The methodology uses different research methods to analyse current knowledge and identify key gaps that need further study. Peer-reviewed scientific papers, government reports, international organisation research, and grey literature from 2008 to 2024 were reviewed. Electronic waste, environmental toxicity, heavy metals, health consequences, and Nigeria and Sub-Saharan African geographical terms were searched in PubMed, Web of Science, Scopus, and regional academic databases (Liberati et al., 2009). Studies containing original data on e-waste composition, environmental pollution, or health impacts were prioritised over theoretical or policy-only evaluations.

The amounts of harmful chemicals found in soil, water, and air samples from places that process electronic waste, and nearby towns were very important to this study. The health effects of e-waste exposure were looked at in this study using epidemiology, biomonitoring, and exposure assessment reports from people who lived in the area and worked in the e-waste processing business. The link was also looked into by Hill et al. (2005) and Schulz and Grimes (2002).

E-waste processing facilities in Ghana (Agbogbloshie), Nigeria (Alababa International Market in Lagos), and Ibadan (smaller illegal recycling sites) were examined using case study analysis. This study used environmental monitoring data, occupational exposure evaluations, and community health surveys during site characterisation to demonstrate the real-world effects of e-waste mishandling (Caravanos et al., 2011; Akortia, 2017). All relevant national, regional, and international statutes, policies, and enforcement strategies were examined to evaluate the regulatory framework (Lundgren, 2012; Ogungbuyi et al., 2012).

Data synthesis combined quantitative and qualitative evidence to understand e-waste toxicology. Meta-analysis was employed where comparable studies were available, while narrative synthesis was used to incorporate varied study types and conclusions.

3. Results

3.1. E-Waste Generation and Sources

Analysis of the nature and creation of electronic trash shows that Sub-Saharan Africa and Nigeria are burdened with considerable amounts of e-waste from various sources. The informal sector in Nigeria uses rudimentary dismantling procedures to handle E-waste because the country does not have the proper recycling infrastructure (Nnorom and Osibanjo, 2008). According to import data, Nigeria receives 500,000–700,000 tonnes of used electronics annually, with major amounts travelling to South Africa, Kenya, and Ghana. Nigeria produces 400,000 tonnes of indigenous e-waste annually, and Sub-Saharan Africa produces about 2.9 million tonnes and this in turn lead to domestic e-waste rapid rise (Baldé et al., 2017).

3.2. Contamination Levels at Major Sites

3.2.1. Electronic trash dumps in Agbogbloshie, Ghana

Environmental contamination studies reveal widespread pollution at e-waste processing sites across the region. Samples taken around the perimeter of Agbogbloshie, for instance, found a presence of lead levels as high as 18,125 ppm in soil. The US EPA standard for lead in soil is 400 ppm (Blacksmith Institute, 2013). Mean concentrations at the burning sites were As: 218 mg/kg; Cd: 65 mg/kg; Cr: 182 mg/kg; Cu: 15,841 mg/kg; Ni: 145 mg/kg; Pb: 6,106 mg/kg; Sb: 552 mg/kg; and Zn: 16,065 mg/kg while the dismantling sites had mean concentrations of As: 23 mg/kg; Cd: 38 mg/kg; Cr: 342 mg/kg; Cu: 3239 mg/kg; Ni: 96 mg/kg; Pb: 681 mg/kg; Sb: 104 mg/kg; and Zn: 1658 mg/kg (Akortia et al., 2017).

The organic contaminants tested from Agbogbloshie are semi-volatile compounds that volatilise at ambient temperatures and post-combustion. Potential sources are majorly located at the landfill and in adjacent urban areas along agricultural sites. This kind of site was chosen because only onsite or adjacent evaporation sources could provide significant geographical variations in pollutant concentrations. In comparison to PBDEs and CPs, the variation in concentration within Agbogbloshie samples was minimal, and PCAs containing PAHs exhibited no correlation with pyrogenic PAHs. Consequently, most lighter PCBs that volatilised into the soil originated from e-waste sources rather than the urban environment. Like our samples, soils from several e-waste locations (Tang et al., 2010; Liu et al., 2013) and urban regions 50 km west of Agbogbloshie exhibit elevated tri-PCB contents. This research suggest that they likely originate from transformers utilising Aroclor 1242 as a dielectric medium as revealed by Bentum et al. (2016). Materials with elevated levels of volatile PBDEs and CPs (t-penta PBDEs and SCCPs) may also release these compounds, which are not associated with combustion.

3.3. E-waste Dumpsites in Lagos and Ibadan, Nigeria

Research showed that soils from e-waste dumps were usually more acidic than soils from control sites. This could be because of garbage burning at the dump and parent material. The TOM and acidity of soils from a Lagos dumpsite are higher than those from Ibadan (Adeyi and Oyeleke, 2017). Different dumpsites have very different amounts of metal. Copper levels ranged from 50.5 to 5,390 mg/kg and 79.3 to 1,150 mg/kg in topsoil; Zn levels ranged from 220 to 1930 mg/kg and 27.5 to 3420 mg/kg; and Cd levels ranged from 0.43-5.85 mg/kg and not detectable at 6.50 mg/kg. In Lagos and Ibadan, Ni ranged from 11.0 to 51.5 mg/kg and 27.7 to 128 mg/kg, while Cr ranged from 108 to 118 mg/kg and 94.0 to 325 mg/kg. The fact that metal levels in the control sample were over 100 times lower than those in e-waste dumpsite soils may be because of burning of e-waste at dumpsites (Adeyi and Oyeleke, 2017).

Table 1 Heavy metal concentrations and soil features of e-waste dumps in Lagos and Ibadan (Adeyi and Oyeleke, 2017)

Sampling Location	Depth (cm)	Cu	Zn	Cd	Pb	Ni	Cr	pH	TOM (%)
Lagos LLS_1	15	5,390	1,820	5.63	2,840	51.5	113	5.77	8.85
	30	3,830	1,550	5.85	1,630	36.1	110	5.77	8.63
	45	2,780	1,480	2.63	260	25.1	108	5.76	6.73
Lagos LLS_2	15	50.5	220	0.45	193	17.5	114	5.80	8.32
	30	57.5	1,930	0.58	114	12.0	118	5.77	6.88
	45	50.0	1,750	0.43	142	11.0	111	5.77	3.48
Ibadan ISS_1	15	1,150	3,420	4.53	2,090	48.7	114	5.93	8.65
	30	440	161	2.38	768	27.7	107	5.88	6.79
	45	310	1,430	1.98	302	40.5	104	5.89	3.09
Ibadan ISS_2	15	101	1,840	6.30	1,030	46.4	103	5.84	7.95
	30	356	571	2.88	365	27.7	111	5.88	6.54
	45	1,210	815	6.50	840	41.1	105	5.89	3.06

Ibadan ISS_3	15	79.3	105	0.03	246	128	325	6.30	3.27
	30	51.8	77.8	0.03	253	104	117	6.17	0.88
	45	42.8	27.5	ND	178	47.5	94.0	6.10	0.36
CSS	15	3.98	47.4	0.35	6.25	0.33	3.95	6.89	1.56
	30	7.55	26.2	0.45	6.75	2.35	3.58	7.21	0.29
	45	4.75	19.8	0.50	13.8	2.23	5.08	7.07	0.24

Values presented as mg/kg; Abbreviations: ND = not detected; TOM = Total Organic Matter

Table 2 shows how the US Environmental Protection Agency ranks sixteen PAHs by their molecular weight. Low molecular weight (LMW) PAHs like acenaphthylene, naphthalene, fluorene, phenanthrene, and anthracene are created when organic matter that doesn't come from burning is released, like in oil spills. There are between 128.2 and 178.2 g/mol of molecular mass. It is possible for benzo(a)fluoranthene and pyrolytic PAH molecules to have molecular weights between 202.3 and 278.4 g/mol. Some examples are fluoranthene, benzo(k)pyrene, benzo(a)fluoranthene, benzo(g,h,i)perylene, and indeno(1,2,3-cd)pyrene. Pyrogenic PAHs are made when coal, oil, gas, wood, and trash are burned partially. At both depths, 278 µg/kg of total PAHs were found in the control soil. Total PAHs were much higher in the grounds around the dump than in the control sample, which suggests that they were burned. The Lagos and Ibadan dumpsites had the most phenanthrene, pyrene, and fluoranthene of all the PAHs. Anthracene and 2-methyl naphthalene were not present. The five- and six-membered ring PAHs may be the most common because they don't break down easily in the environment.

Table 2 Polycyclic Aromatic Hydrocarbon Concentrations in Dumpsite and Control Soil Samples, 0–15 cm Depth (Adeyi and Oyeleke, 2017)

Target Analytes	**LLS_1**	**LLS_2**	**ISS_1**	**ISS_2**	**CSS**
Naphthalene (Nap)	10.0	ND	ND	ND	ND
2-methyl Naphthalene (mNap)	ND	ND	ND	ND	ND
Acenaphthylene (Acy)	37.0	38.0	38.0	38.0	ND
Acenaphthene (Ace)	9.00	9.00	9.00	9.00	ND
Fluorene (Flu)	140	137	141	143	ND
Phenanthrene (Phe)	323	593	345	392	50.0
Anthracene (Ant)	ND	ND	ND	ND	ND
Fluoranthene (Fla)	251	293	240	260	41.0
Pyrene (Pyr)	255	384	245	271	37.0
Benz(a)anthracene (BaA)	227	247	235	227	45.0
Chrysene (Chr)	213	199	190	267	33.0
Benzo(k)fluoranthene (BkF)	215	211	204	224	40.0
Benzo(b)fluoranthene (BbF)	109	113	109	111	ND
Perylene (Per)	ND	ND	ND	51.0	6.00
Benzo(g,h,i)perylene (BghiP)	ND	ND	ND	ND	ND
Dibenz(a,h)anthracene (DahA)	ND	ND	ND	ND	26.0
Indeno(1,2,3-cd)pyrene (IcdP)	ND	ND	ND	119	ND
Total PAH	1,789	2,224	1,756	2,112	278
%LMW PAH	29.0	34.9	30.4	27.6	18.0
%HMW PAH	52.9	50.5	51.8	48.5	65.5
%C PAH	36.6	29.5	35.8	39.6	51.8

3.4. Health Impacts and Biomonitoring

Biomonitoring studies have shown that people in damaged areas are exposed to a lot of the harmful chemicals in e-waste. Eighty percent of children who live in areas that process electronic waste and have similar demographics and environmental traits to Agbogbloshie have dangerously high amounts of lead in their blood considering 6,106 mg/kg from Agbogbloshie burning site and 681 mg/kg its dismantling site (Feldt et al., 2014). According to the Blacksmith Institute (2013), many people have migraines, chest pain, nausea, and breathing problems all the time. According to Feldt et al. (2014), people who throw away electronics often get headaches, coughs, chest pains, stomach problems, miscarriages, changes in thyroid and reproductive functions, lower amounts of gonadal hormones, and even cancer.

3.4.1. Public Health Implications of E-Waste

The increasing volume of electronic waste (e-waste) in Africa presents significant environmental and public health challenges. The rapid obsolescence of electronic gadgets, driven by technological advancements, results in large quantities of e-waste being discarded, often in low-income regions. In countries such as Nigeria and Ghana, where informal recycling methods dominate, workers and local populations are exposed to a range of harmful toxicants. These include heavy metals like lead (Pb), cadmium (Cd), and mercury (Hg), as well as persistent organic pollutants (POPs) such as polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) (Orisakwe et al., 2019). Exposure to these toxicants poses substantial risks to human health, including endocrine disruption, neurotoxicity, reproductive harm, and an increased risk of cancer. Vulnerable groups, particularly children and pregnant women, face higher risks due to the bioaccumulation of these toxicants in the environment and the food chain (Orisakwe et al., 2019). Furthermore, the widespread contamination of air, water, soil, and food sources exacerbates the problem, extending the health burden beyond the immediate workers to surrounding communities.

Studies have demonstrated elevated blood lead levels (BLLs), respiratory issues, gastrointestinal discomfort, and reproductive health disturbances among e-waste workers and nearby residents (Orisakwe et al., 2019). Neurodevelopmental delays, thyroid function disruptions, and developmental challenges in children have also been linked to e-waste exposure (Orisakwe et al., 2019). As such, there is a need for a robust regulatory framework, effective e-waste recycling infrastructure, and targeted public health interventions to mitigate the adverse effects of e-waste on African populations. Comprehensive monitoring and continued research are critical to addressing the long-term health impacts and ensuring a sustainable approach to e-waste management in the region.

3.5. Occupational Health Assessment

Issah et al. (2022) reviewed 17 research and identified a link between informal e-waste collection and MSD, back discomfort, cuts, eye problems, skin burns, and noise-induced hearing loss. According to Kyere et al. (2016), e-waste workers experienced an average of 9.9 ± 9.6 injuries and 78.8 ± 5.9 dBA of noise. A time-weighted average of 15% of workers' exposure exceeded safety.

3.6. Environmental Contamination Patterns

Documented occurrences of higher levels of hazardous elements, persistent organic pollutants, and heavy metals have been observed in dust, soils, and flora, including edible plants, at e-waste sites in Africa. Those who manage and dispose of electronic waste encounter these pollutants via many channels (Amankwaa et al., 2017; Daum et al., 2017).

3.7. Regulatory Framework Analysis

Even though the unorganised sector recycles a lot, the ways they do it are not sustainable and are harmful to both people and the environment. Abgynrin-Olafisoye and Adeyi (2025) say that Nigeria's private sector is to blame for damage to the environment, health risks, and falling incomes. People in developing countries like Ghana and Nigeria are putting their health at great risk by not being careful or thinking about how they throw away electrical waste. According to Njoku et al. (2023), treating the issue of unchecked e-waste disposal and the health issues that come with it needs a complete plan and answer.

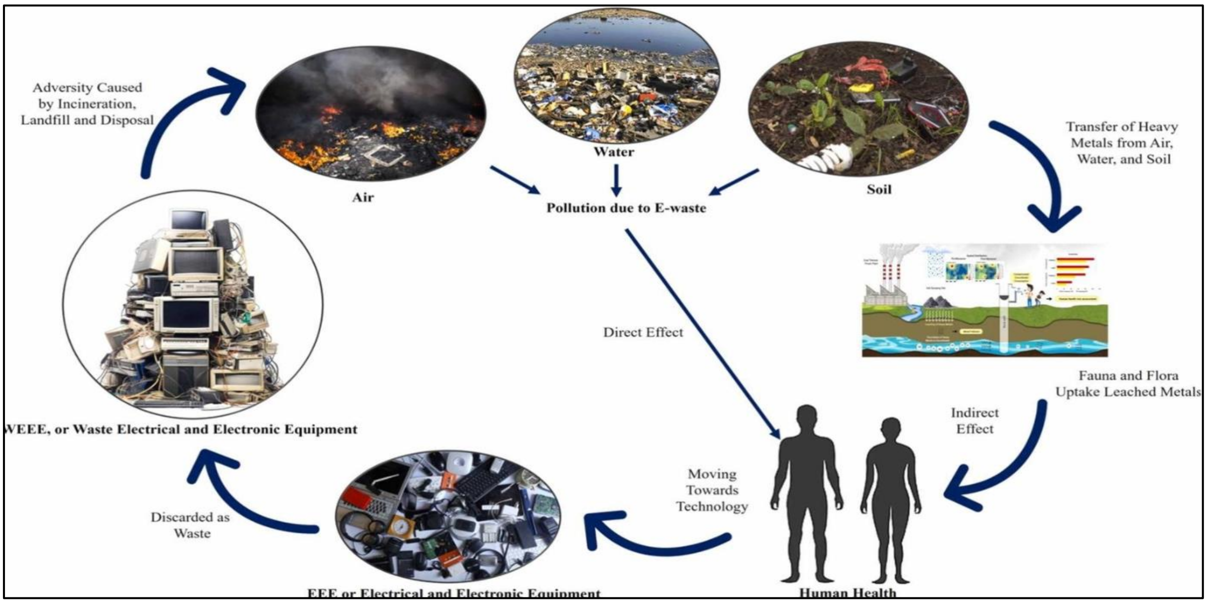

Figure 1 E-Waste Contamination Pathways in Sub-Saharan Africa (Kumar et al., 2024)

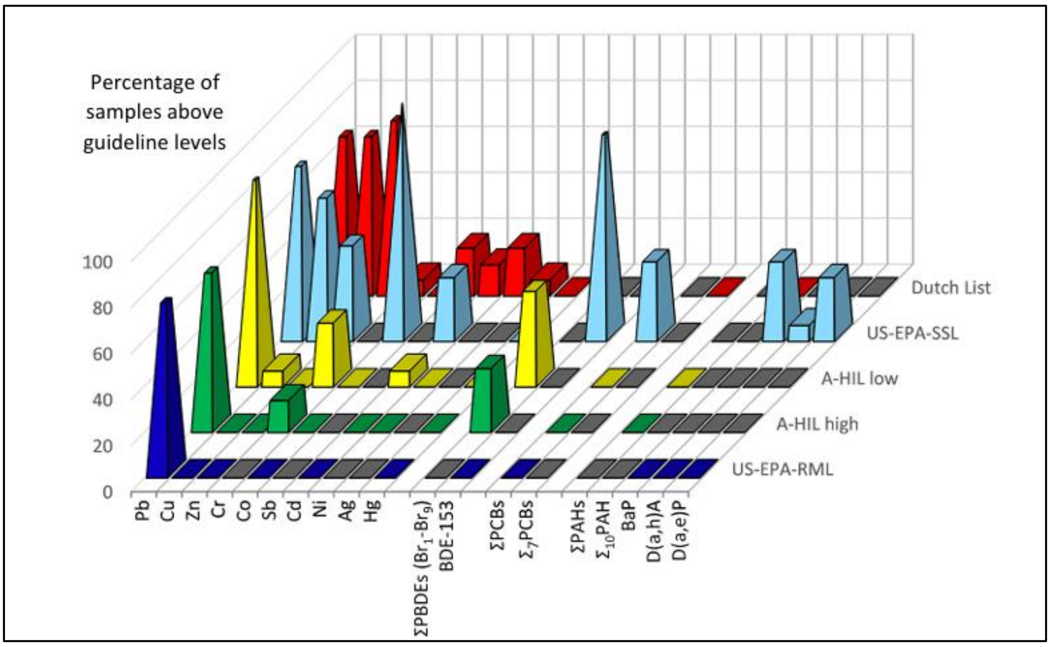

Figure 2 Heavy Metal Contamination Levels at Agbogbloshie (Moeckel et al., 2020)

4. Discussion

The findings of this research indicate that electronic trash poses a significant environmental and public health hazard in Nigeria and Sub-Saharan Africa, with implications that extend far beyond mere disposal issues. The level of pollution at prominent e-waste processing facilities, coupled with extensive human exposure to toxic substances, indicates a fundamental deficiency in existing management techniques aimed at safeguarding environmental and human health (Caravanos et al., 2013; Akortia et al., 2017).

In terms of comparison, both Agbogbloshie, Ghana, and e-waste dumpsites in Lagos and Ibadan, Nigeria, experience significant environmental contamination due to the informal recycling of electronic waste. However, there are notable differences in the extent and type of contamination across these locations.

In Agbogbloshie, lead levels in the soil reached alarming concentrations of 18,125 ppm, far exceeding the US EPA standard of 400 ppm, with other metals such as copper (Cu) at 15,841 mg/kg and zinc (Zn) at 16,065 mg/kg (Akortia et al., 2017). The region also exhibits contamination from organic pollutants like PBDEs, PCBs, and polycyclic aromatic hydrocarbons (PAHs), with sources primarily linked to the combustion of e-waste and nearby urban areas. The consistency of organic contaminant levels across the site suggests that e-waste, particularly from transformers, is a significant source of pollution, with minimal variation in concentration within the samples tested.

On the other hand, Lagos and Ibadan dumpsites show relatively lower concentrations of metals compared to Agbogbloshie. For instance, copper levels ranged from 50.5 to 5,390 mg/kg, while zinc levels varied from 220 to 1,930 mg/kg in Lagos, and from 27.5 to 3,420 mg/kg in Ibadan (Adeyi and Oyeleke, 2017). This research highlights that e-waste dumpsites in these Nigerian cities tend to have more acidic soils, likely due to the burning of e-waste and organic matter. Additionally, while lead and cadmium concentrations are significantly lower than those in Agbogbloshie, the metals present in the soil in Lagos and Ibadan were still over 100 times higher than in control samples, indicating significant pollution from local e-waste processing.

In summary, while both locations suffer from severe e-waste contamination, Agbogbloshie has much higher concentrations of toxic metals and organic pollutants, likely due to more intensive and uncontrolled recycling practices. Lagos and Ibadan, though also heavily polluted, exhibit a different contamination profile, with lower overall metal concentrations and greater soil acidity, possibly because of localized burning practices. The observed trends of environmental pollution in the region illustrate the intricate relationship between insufficient infrastructure, informal sector operations, and difficulties in regulatory enforcement. Despite enhanced management techniques, heavy metal concentrations in soil and water at e-waste sites often above international safety standards by significant margins, resulting in a persistent pollution legacy that may endure for decades (Blacksmith Institute, 2013; Akortia et al., 2017). The mobility of these poisons in environmental systems indicates that their effects on pollution extend well beyond their immediate processing areas, hence influencing larger ecosystems and communities.

Biomonitoring studies have indicated elevated heavy metal concentrations in blood and urine samples from affected communities, suggesting widespread exposure to hazardous agents associated with e-waste (Ajayi et al., 2024). Studies indicate that the chemical compounds released during e-waste processing pose risks to human health (Frazzoli et al., 2010). Research indicates that such levels of exposure are detrimental to the brain, lungs, and developmental processes, thereby posing risks to children and pregnant women (Feldt et al., 2014; Kyere et al., 2016). Informal recycling workers encounter significant health risks due to increased exposure to hazardous substances and limited access to protective equipment, medical care, or alternative employment opportunities. This constitutes a significant issue in environmental justice. Economically managing e-waste presents challenges due to the numerous trade-offs that must be considered among individuals, the environment, and societal factors. Many local workers generate significant income from informal recycling initiatives. The external costs associated with pollution and health impacts significantly exceed the financial advantages (Manhart et al., 2011). Implementing environmentally sustainable methods for e-waste disposal can enhance livelihoods while safeguarding public health and the environment. The regulatory framework requires improvement to enable effective management of e-waste in the region. Numerous governments have enacted pertinent legislation; however, the effectiveness of implementation and enforcement is hindered by constrained resources, insufficient technical expertise, and conflicting policy objectives (Lundgren, 2012; Ogungbuyi et al., 2012). Due to the transboundary nature of e-waste, enhanced regional coordination and collaboration are necessary. Current organisations lack the authority and resources necessary to effectively address global issues.

The case studies studied in this research underscore the gravity of existing issues and possible avenues for enhanced management. Significant contamination levels at sites such as Agbogbloshie have garnered global attention; nevertheless, analogous conditions prevail at other smaller places in the region where monitoring and intervention efforts are scarce (Oteng-Ababio, 2012). The dispersed nature and insufficient regulation of these smaller locations may exacerbate environmental and health problems. Technological factors underscore opportunities for enhanced e-waste management with problems. Even though there are advanced recycling technologies that can safely take valuable materials from electronics, they are hard to use in Sub-Saharan Africa because they require a lot of money, specialised technical knowledge, and problems with economies of scale (Schluep et al., 2009). The advancement of more sophisticated approaches, alongside the enhancement of intermediary technologies and informal sector practices, could yield substantial environmental and health advantages.

In discussing the global aspects of e-waste management, it is essential to recognise that trade dynamics and international consumption patterns influence e-waste challenges in Sub-Saharan Africa. While occasionally providing access to affordable technology, the export of used electronics from rich nations to the region poses environmental and health risks for communities with insufficient resources to mitigate these issues (Amankwaa, 2013). Addressing these difficulties necessitates international collaboration and perhaps innovative concepts on producer liability and accountability. In addition to immediate exposure effects, public health concerns encompass enduring pressures on healthcare systems and intergenerational consequences. Previous research reveals the public health concern in children indicating that existing pollution trends may have enduring consequences on human capital development and economic productivity across the region (Feldt et al., 2014).

The disposal of electronic trash poses significant obstacles, which are further exacerbated by climate change. Extreme weather events jeopardise e-waste storage and processing facilities, potentially leading to significant contamination incidents. Alterations in precipitation patterns and increasing temperatures may influence contamination pathways and exposure levels. Consequently, e-waste management must be integrated into environmental resilience planning within climate adaptation initiatives. Due to familial obligations, occupational segregation, and physiological vulnerabilities, women and children frequently endure disproportionate effects from e-waste exposure, necessitating focused emphasis on the gender dimensions of this issue. Although women's responsibilities in household waste management may heighten exposure to domestic e-waste, pregnant women involved in or residing in e-waste processing areas encounter risks associated with potential developmental impacts on foetuses (Feldt et al., 2014).

5. Conclusion

Currently, electronic trash represents a considerable public health and environmental hazard for Nigeria and Sub-Saharan Africa. This extensive study indicates significant environmental pollution due to harmful substances from mismanaged e-waste, widespread human exposure to toxic materials, and severe health repercussions affecting vulnerable communities throughout the region, as current ways are fundamentally insufficient to ensure environmental integrity and safeguard human health. This indicates that the breadth and intricacy of e-waste issues necessitate comprehensive solutions that simultaneously address multiple interconnected concerns. While enhancing regulatory systems is essential, its implementation necessitates improved enforcement capabilities, the cultivation of technical expertise, and adequate financial resources. Regional cooperation mechanisms must be enhanced to tackle transboundary dimensions of e-waste flows and synchronise national initiatives.

Recommendations

- Technologies tailored to local conditions and capacities can enhance e-waste management. Emerging technologies in Sub-Saharan Africa have the potential to revolutionise human society. Raising consciousness and educating the public are crucial steps towards modifying consumption habits, boosting disposal rates, and winning over political opponents to new policies. Electronic waste from homes and businesses must be managed in a culturally sensitive manner. Hierarchical communication may not be enough if affected groups find cures. Achieving a balance between environmental and market goals could be facilitated by deposit systems, recycling incentives, and extended producer responsibility. Such systems need to be well-designed to avoid unintended outcomes and fairly distribute resources across various demographics and interests.
- Given the global breadth of electronics manufacture and trade, effective e-waste disposal requires cooperation on a global scale. This encompasses capacity-building, technological transfer, and new international agreements for e-waste trading and management. The industrialised world should limit the export of electronic waste to Sub-Saharan Africa and advocate for more eco-friendly methods of disposing of this waste. Improving the health system is necessary to lessen the current and future health risks associated with e-waste. Improving diagnostic and treatment options for toxicant-related disorders, addressing environmental health concerns in primary care, and developing better monitoring systems to determine exposure levels and health implications are all part of this. To prevent economically disadvantaged communities from being unfairly harmed by environmental dangers and excluded from decision-making and financial benefits, we must take environmental justice into account while dealing with electronic trash. Achieving fair outcomes requires the use of participatory tactics that include impacted populations in problem-solving.
- Prioritise future research to address understanding gaps in exposure pathways, health impacts, and intervention effectiveness. Long-term longitudinal research are needed to understand chronic health and intergenerational implications. Policy and practice development could benefit from research on Sub-Saharan African technology and management methods. E-waste issues must be addressed immediately. Current pollution patterns and health implications threaten millions of people in the region, while poor management continues to leave environmental legacies for future generations. However, growing awareness of these difficulties and expanding technology and financial resources offer revolutionary change prospects if seized quickly.

Compliance with ethical standards

Conflict of Interest Disclosure

The authors declare no conflicts of interest related to this work.

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