The Nigerian E-Waste Problem: Way Forward

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Abstract. Technology has constantly evolved, leading to the invention and manufacturing of enhanced electronic and ICT devices. This has fueled the desire for people, companies and organizations to continuously upgrade their electronic and ICT infrastructure. Basically the circulation of these devices is on the increase. However, if new devices continuously replace existing ones, what happens to the ones replaced? Where do they go? How are they managed today? Unfortunately, these old devices end up in under developed and developing countries as "Tokumbos" (second hand, handed down), cheap alternatives. Such countries clearly lack the technology and technical know-how to appropriately recycle or dispose of them when they break down and become irreparable. They then end up as electronic waste (e-waste) not properly managed. Local disposal techniques employed by scavengers in such countries lead to consequences detrimental to the environment, the economy, ecology and lives of their people. This paper looks into the lingering problem of e-waste in Nigeria. It traces its source, reviews its negative impacts and via a comparatives study on countries that have good waste management practices, vis-à-vis efforts so far by the Nigerian government, seeks to suggest how to improve on the countries e-waste management strategies.

Keywords: Assessing · E-Waste · Problem · Way-forward

1 Introduction

Electronic waste also known as e-waste can be defined from different perspectives. The Basel Convention defined e-waste as "substance or objects, which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law" [1, 2]. The United Nations Statistics Division defined e-waste as "materials that are produced for the market for which the generator and the user has no further use in terms of its purposes of production, transformation or consumption, and of which they want to dispose" [3]. Thus, e-waste can simply be viewed as any electronic device that is either of the following; damaged beyond repair, whose life cycle has expired, has become obsolete, can still be used, but consequently rejected by the user. All definitions of e-waste have a key point in common, which is that that the device is no longer needed or useful to the owner. The Organization for Economic Cooperation and Development (OECD) categorize waste into three categories namely,

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nuclear or radioactive waste, toxic waste and municipal waste [4]. E-waste was categorized as toxic waste [4]. The European Union directive on Waste Electrical and Electronic Equipment (WEEE) and African E-Waste Solution Group based in South Africa presents a more detailed category of e-waste shown in Tables 1 and 2, respectively.

Table 1. E-waste categories pursuant to the EU Directive 2002/96//EC [5]

SN	Category	Label
1	Large household appliances	Large HH
2	Small household appliances	Small HH
3	IT and telecommunications equipment	ICT
4	Consumer equipment	CE
5	Lighting equipment	Lighting
6	Electrical and electronic tools (with the exception of large-scale stationary industrial tools)	E&E tools
7	Toys, leisure and sports equipment	Toys
8	Medical devices (with the exception of all implanted and infected products)	Medical devices
9	Monitoring & control instruments	M&C
10	Automatic dispensers	Dispensers

As at 2013, E-waste was reported as the world's leading waste stream in terms of growth. It was also revealed e-waste's growth index was triple that of overall municipal solid waste [7]. According to Professor Ming Wong in 2013, about 50 million tons (Mt) of hazardous e-waste of various electronics is generated each year [7]. According to Statista.com in 2018, the amounts of e-waste generated worldwide from 2010 to 2014 in million metric tons were 33.8, 35.8, 37.8, 39.8 and 41.8, respectively [8]. The same source projection for 2015 to 2018 was 43.8, 44.7, 47.8 and 49.8 million metric tons respectively [8]. This is attributed to the decrease in lifespan of the devices [9]. Table 3 shows different devices and their respective approximate life spans.

Problem at Hand. In Nigeria, most of the growth in the ICT sector is via the inflow of second hand electronic products and devices from developed countries. They seem like cheap alternatives, but when examined extensively are best classified as e-waste. Before reaching the shores of Nigeria, a large percentage of them are obsolete, expired or broken down beyond repair. These e-wastes have flooded Nigeria, making her emerge as one of the topmost electronic waste dumping grounds in the world [14] as at 2012. In 2018, an article by Kid Krunk on E-Terra Technologies placed Nigeria 3rd in the top 20 Countries that have become e-waste dumping grounds in the world [15]. As a large percentage of the devices are either broken, unrepairable or pack up in a while, they end up in dump sites, landfills and worse of all burnt openly under precarious conditions by scavengers for valuable components. Sadly, e-waste contains hazardous materials detrimental to the environment, the economy, ecology and lives of those

Table 2. Categories of E-Waste [6].

Category	Examples
Large House hold Appliances	Washing machines, Dryers Refrigerators, Air conditioners, etc.
Small House hold Appliances	Vacuum cleaners, Coffee Machines, Irons, Toasters, etc.
Office, Information & Communication Equipment	Telephones, Fax Machines, Computers, Copiers, Printers etc.
Entertainment, Consumer, Electronics, Toys, Leisure, Sports Recreational Equipment, and Automatic Issuing Machines	Televisions, VCR/DVD/DC players, Hi-Fi sets, Radios, Electric train sets, coin slot machines, treadmills, Vending machines, parking ticket equipment etc.
Lighting Equipment	Fluorescent tubes and lamps, sodium lamps etc. (Except Incandescent Bulbs, Halogen Bulbs) etc.
Electric and Electronic Tools	Drills, electric saws, Sewing Machines, Lawn Mowers etc.
Security & health care equipment	Surveillance and Control Equipment (e.g. CCTV cameras, scanning equipment), and Medical Instruments and Equipment (e.g. x-ray and heart lung machines) etc.

staying around such areas, yet Nigeria is yet to effectively address this problem. A few hazardous and yet valuable metals contained in e-waste are listed in Table 4.

2 Reviewed Literatures

Nigeria, one of the most populous countries in Africa, is home to one-sixth of African's population. The increase in population translates to an increase in demand for better technology. Unfortunately the weak financial strength and poverty level creates the market to import these cheap and affordable alternatives. A research work in 2013 stated that Nigeria was at risk of becoming a dumping ground for obsolete electronics [16]. Virtually every electronic device consumed in Nigeria (home appliances, computers, accessories, electronics etc.) are imported. It was assumed from statistics that the share between used electronic devices and the new at a point was about 70/30% going by an e-waste assessment report in 2012 [1]. Approximately 30% of second-hand products were deemed non-functional and best classified as e-waste going by the report. About 100 Mt of e-waste flooded their way into Nigeria illegally in 2010 [1]. Around 6.4 Mt of that were personal household appliances and ICT devices, while institutional and corporate consumer devices were estimated at 400 thousand tons (Tt) [1]. About 440 Tt ends up as e-waste in landfills, repair and refurbishment shops, or just about anywhere [1]. According to the Nigerian Communication Commission (NCC), Nigeria's tele-density grew from 91.1% in 2013 to 99.4% in 2014. In 2015 and 2016, it rose to about 107.9 and 110.4% respectively [17]. By the end of 2018, E-Terra

Table 3. E-waste types and their estimated life cycle. Extracted from [10–13].

Item mass of	Category	Label
Personal Computer (PC)	25	3
Fax machine	3	5
High-fidelity system	10	10
Cell phone	0.1	2
Electronic games	3	5
Photocopier	60	8
Radio	2	10
Television (TV)	30	5
Video recorder/DVD Player	5	5
Air-conditioner	55	12
Dish washer	50	10
Food mixer	1	5
Freezer	35	10
Hair-dryer	1	10
Iron	1	10
Kettle	1	3
Microwave	15	7
Refrigerator	35	10
Telephone	1	5
Toaster	1	5
Tumble dryer	35	10
Vacuum cleaner	10	10
Washing machine	65	8

Table 4. Contents of selected valuable metals in the printed circuit boards of seven types of electronic products [1].

Products	Valuable metals contained in products
TV (CRT monitor)	Gold, silver, copper, platinum, antimony, nickel, yttrium, neodymium, iron, and aluminum
Washing machine, Air conditioner, Refrigerator	Gold, silver, copper, platinum, antimony, iron, and aluminum
TV (LCD, plasma)	Gold, silver, platinum, antimony, indium, yttrium, iron, aluminum

Technologies estimated that Nigeria generates around 1.1 million tons of e-waste yearly [18]. E-Terra Technologies also placed Nigeria 3rd in the top 20 Countries according to an article by Kid Krunk [15]. The overall resulting effect is the huge pile of e-waste accumulating around the country, as all available repair outlets lack the capacity and appropriate technology to safely repair, recycle or get rid of them. The

following researches have in the past discussed the Nigeria's e-waste problem from different perspectives:

1. "Variation In Some Haematological Parameters, Iron And Lead Levels In Workers Exposed To Electronic Waste In Benin City, Nigeria" 2018 [19].
2. "Environmental and Health Impacts Of Informal Electronic Waste Recycling" 2018 [20].
3. "Impact of informal electronic waste recycling on metal concentrations in soils and dusts" 2018 [21].
4. "Health Risks Awareness Of Electronic Waste Workers In The Informal Sector In Nigeria" 2017 [22].
5. "Material And Substance Flow Analysis Of Mobile Phones In Nigeria: A Step For Progressing E-Waste Management Strategy" 2017 [23]
6. "Electronic Waste Scenario in Nigeria: Issues, Problems and Solutions" 2013 [24].
7. "E-Waste Country Assessment Nigeria" 2012 [1].
8. "An Overview of ICT Waste Management: Suggestions of Best Practices from Developed Countries to Developing Nations (Nigeria)" 2011 [25].

Research recommendations so far center on the following points:

1. The need to enforce existing laws by developing effective strategies.
2. The need for Nigeria to immediately ratify the Bamako Convention by enforcing local regulations, intensifying prohibition on importation of hazardous wastes, enforce proof of test and categorization on trans-boundary movement of electronic products.
3. Producer companies should be compelled to use raw materials that are more environmentally friendly in the manufacturing of electronic products.
4. Developing countries should intensify the ban and prohibition on importation of used products marked for repair or refurbishing.
5. Encourage the development of local capacity for the safe extraction of valuable metals from e-waste.
6. Enforcement across producing countries the "Extended Producer Responsibility Programme"; which states that manufactures should buy back the products they produced at the end of their life span.

Despite research recommendations over the years, the implementation of these recommendations have either not been established or intensified. Nigeria is still flooded with e-waste and more flow in by the day. It is therefore important at this time to revisit the Nigeria e-waste problem, trace its source, review its negative impacts then identify and suggest based on efforts so far, ways to practically resolve and effectively manage the countries e-waste problem.

Approach Employed. This paper looked into the Nigerian electronic waste problem, traced its source, reviewed its negative impacts, identified and suggested based on efforts made so far by the Nigerian Government ways to improve the countries e-waste management strategies. It explored for lessons that can be learnt from other countries with good waste management, thus then strike a balance with the reality on ground and suggests ways forward.

3 Tracing the Source of the Electronic Waste Problem in Nigeria

The Basel Convention, European Union directives on WEEE established it is unlawful to export e-waste from developed nations to developing nations [2]. Stakeholders and several researches have over the years advised same. Yet, e-waste is still exported to developing countries [26–28]. According to a survey conducted at Lagos in 2013, the volume of imported electronics was 15 tons at Computer village, 100 tons at Alaba International Market, 15 tons at 30 tons at Oshodi Market, Lawanson Market and 40 tons at West Minister [29]. These figures as reported in 2016 increased annually because the collection of e-waste was not organized [30]. Going by an article in 2018 by Green Compass Recycling, it was discovered that 90% of illegally shipped in e-waste to Africa ended up in Nigeria [27]. The article was a based on report titled, "e-Waste Recycling's Contribution to a Circular Economy". The report was presented at the Nigerian Economic Summit Group stakeholders' workshop in Lagos. It identified Nigeria as the third largest generator of e-waste in Africa, contributing 12% to the total volume, with 288,000 metric tons in 2017.

Another report in 2018 revealed over 66,000 tons of used electronics and electrical equipment flooded Nigeria between 2015 and 2016 [28]. Around 16,900 were toxic illegal e-waste because they were nonfunctional. The study was led by the Basel Convention Coordinating Centre for Africa and United Nations University. More than 200 shipping containers with 2,100 vehicles heading to Nigeria were inspected. About 70% (41,500 tons) of the UEEE reaching Lagos each year arrived in vehicles exported to Nigeria's used car markets, and about 18,300 tons arrived in shipping containers. About 77% of the used electronics were shipped from the European Union and 7% were sent from the US. According to the article no one was prosecuted and held responsible upon investigations and findings, neither the exporters nor the importers. This simply means the countries e-waste problem is worsening. Figure 1 shows the flow of electronic products as they come into a country.

Quite a number of issues have militated against the successful actualization of these directives. The Osun State House of Assembly member and Chairman House Committee on Industry, Commerce, and Cooperative Empowerment, 'Tunde Olatunji', pointed out the need for state parliaments to domesticate national laws, review existing laws, and issue legally binding targets and deadlines towards waste reduction [27]. A research in 2015 also stated that "most African countries have ratified the convention directives, but they have not domesticated it into national laws" [1]. As earlier pointed out, an article in 2018 with respect to illegally shipped in e-waste observed no one was prosecuted and held responsible upon investigations and findings, neither the exporters nor the importers. Thus, Governments of most developing nations are the major challenge to the Basel Convention directives. This is why the dumping has continued. Results cannot be achieved if these directives are not embedded as part of national laws and enforced, as there will be no grounds for prosecuting any offender.

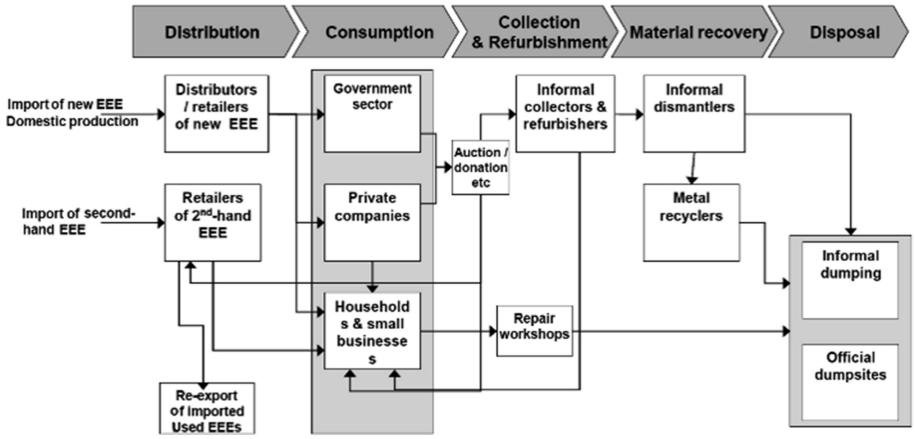

Fig. 1. A flow of products from importation to disposal [1].

4 Reviewing the Negative Impacts of E-Waste in Nigeria

E-waste procession of toxic substances was recognized only two decades ago, however it has been established that a large variety of such substances are contained in them [31]. These toxic substances pose health hazards to humans and are capable of contaminating the surrounding environment. It is thus paramount for this issue to be appropriately managed. One of the ways in which they are dangerous to humans involves the contamination of food. These toxic substances find their way into farmlands close to where e-waste are disposed or primitively recycled, consequently the farm produce affect human health when eaten. Another way is the direct impact on those involved or around primitive recycling sites. The result is being exposed through the air they breathe.

There also exists the risk of significant water contamination. On the long run these practices result in the poisoning of many locals within and around such sites. Over the years, incidences of excessive e-waste pollution were reportedly emitted from the e-waste recycling processes in Delta State, Nigeria [32], similarly in Accra, Ghana [33]. Puckett and Smith in 2002 revealed more than 1000 toxic substances that have been identified with improper e-waste recycling and disposal [34]. Some reported substances include: Manganese (Mn), Silver (Ag), Nickel (Ni), Molybdenum (Mo), Mercury (Hg), Lanthanum (La), Lithium (Li), Lead (Pb), Iron (Fe), Copper (Cu), Barium (Ba), Chromium (Cr), Cobalt (Co), Cadmium (Cd), Beryllium (Be), Hexavalent chromium Cr(VI). Also persistent organic pollutants (POPs) such as: Polychlorinated dibenzo-p-dioxins and Dibenzofurans (PCDD/Fs), DioxinPolyvinyl chloride (PVC), Polychlorinated biphenyls (PCBs), Brominated flame retardants (BFRs), Polycyclic aromatic hydrocarbons (PAHs), Polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/Fs). Table 5 shows common toxic substances associated with e-waste and their health impacts.

Table 5. Effects of chemicals in e-waste on human health [1].

E-toxin	Source of e-toxin	Health effects
Arsenic	Found in computer chips and light emitting diodes	Arsenic is a known cancer-causing substance (carcinogen). It is known to cause skin and lung cancer
Brominated flame retardants	Added to plastic to prevent fires	Brominated flame retardants act as hormone disrupters. Children exposed to these substances show increased risk to thyroid disease and neurobehavioral disease
Cadmium	Cadmium coating of contacts and switches in the CPU and monitors is used to prevent corrosion. It is found in NiCd batteries	Breathing high levels of Cd can cause lung damage and death. Long term exposure to low levels of Cd can cause elevated blood pressure and kidney damage. Cadmium is a known carcinogen
Chromium	It is used as a hardener in plastics and a dye in pigments. It may be present in the coatings on some metal parts	Chromium has a variety of effects depending how it en-ters the body. Chromium is a carcinogen if inhaled. Chromium may also cause DNA damage
Halogens	Plastics and insulation	These substances are of concern because of the possibility that toxins such as dioxins and furans may be created and released burning
Lead	Cathode-ray tubes (about 5 lbs.) and solders	Initial symptoms of exposure are anorexia, muscle pain, malaise, and headache. Long-term exposure to lead de-creases the overall performance of the nervous system. High level exposure causes brain damage and death
Mercury	Cathode-ray tubes (about 5 lbs.) and solders	Initial symptoms of exposure are anorexia, muscle pain, malaise, and headache. Long-term exposure to lead de-creases the overall performance of the nervous system. High level exposure causes brain damage and death
Polyvinyl chloride (PVC)	PVC plastic is used in the insulation f some cables used in ICT equipment	When burnt it produces highly toxic dioxins; research is finding if PCV is a hormone disruptor

Various e-waste disposal methods exist detrimental to soil, water and air of those living around areas such is practiced. Table 6 identifies toxic substances related with e-waste recycling and the respective environmental mediums they could be disseminated through.

Table 6. Extracted from: Toxic substances associated with recycling e-waste and their presence in the surrounding environment [7].

Environment	Toxic substances
Soil	PBDEs, PAHs, PCDD/Fs, As, Cu, Cr, Cd, Hg, Pb, Ag, Bi, Cd, Co, Cr, Cu, In, Hg, Mn, Mo, Pb, Sb, Sn, Tl, V and Zn
Water	As, Cd, Cr, Cu, F, Fe, Hg, Mn, Ni, Pb, Zn, Ag, Al, As, Be, Ca, Cd, Co, Cr, Cu, Fe, Li, Mg, Mn, Mo, Ni, Pb, Sb, Se, Sr, Ti, V and Zn
Air	PAHs, As, Cd, Cr, Cu, Mn, Ni, Pb, Zn, Ag, Bi, Cd, Co, Cr, Cu, In, Hg, Mn, Mo, Pb, Sb, Sn, Tl, and V

4.1 Landfills

Landfill sites also commonly referred to as tip, dump, rubbish dump or dumping ground, in this context are land sites allocated to disposal of e-waste materials and e-waste management processing (sorting, treatment, or recycling). Regardless of the global efforts put in place towards zero waste in recent times, more landfills can be observed across developing and under developed countries. Although owners of modern landfills are of the view that modern landfills are able to safeguarding the environment from e-waste pollutants [35], it has on the other hand been established they still cause groundwater contamination [36, 37]. Also it is certain that pollution tend to migrate via the soil and groundwater around and within landfill sites [38]. A decomposition of organic and putrescible material in landfills occurs via the soil through landfill leaching. Heavy metals, High concentrations of inorganic compounds and suspended/dissolved organic substances could be contained in leachates. The concentrations of the various toxic substances from leachates depend on the stages of waste decomposition and waste characteristics in a particular landfill [39]. Electronic devices are considered to be Toxicity Characteristic (TC) hazardous if they contain specific elements higher than TC regulated concentrations stipulated by the Resource Conservation and Recovery Act (RCRA). By this Act, they are considered TC hazardous if they contain specific elements higher, which are 1 mg/l of Se, 5 mg/l of Ag, 0.2 mg/l of Hg, 5 mg/l of Pb, 5 mg/l of Cr, 1 mg/l of Cd, 100 mg/l of Ba, 5 mg/l of As etc. [40]. Figure 2 shows leaching from electronic devices under laboratory-based TCLP conditions.

A study in 2018 at an e-waste site in Nigeria revealed the concentrations of 6 heavy metals [41]. Indigenous soil microbial communities were dominated by Planctomycetes, Acidobacteria, Firmicutes, Proteobacteria. Another study in 2018 investigated haematological indices, lead and serum iron levels in workers occupationally exposed to electronic wastes in South-South, Nigeria. The study enrolled participants from Benin City. Results obtained from this study show a significantly low serum iron (11.5 ± 2.14 μg/dL) in the EW compared with Control (168.9 ± 2.39 μg/dL); while blood lead level in EW (1.07 ± 0.02 μg/dL) was significantly elevated compared with Control (0.72 ± 0.12). The study concluded that chronic occupational e-waste exposure may increase blood lead level, lower serum iron status and may have adversely altered some important haematological parameters in the studied population.

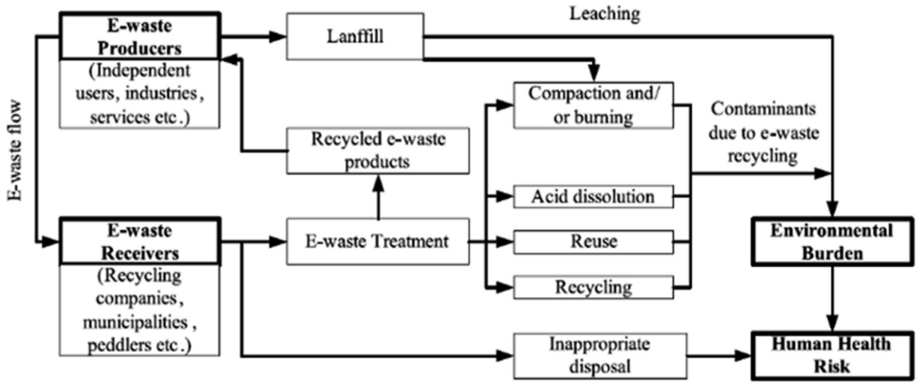

Fig. 2. Leaching process under TCLP [5].

4.2 Incineration and Local Recycling

There is an absence of the right set of recycling tools, technology and technical know-how in developing countries to properly perform incineration and recycling, Nigeria included. This leads to what is known as "backyard recycling" or "primitive recycling". This set of unsafe techniques end up having major impacts such as severe contamination of air from chlorinated compounds and brominated. Also from, heavy metals as detected at local recycling sites in developing countries. High concentrations of heavy metals such as Cu (483), Cr (1161) and Zn (1038) were detected in China via studies. These figures as revealed were between 4 and 33 times higher than those established across other Asian Countries. In Guiyu, China high pollution levels of PBDEs were 58–691 times higher than at other urban sites [42]. PCDD/Fs were detected at 64.9–2365 pg/m3, making them the highest concentrations in ambient air worldwide [43]. Environmental and human contamination at the e-waste recycling areas was also of great concern in Bangalore [44]. There, high levels of Ti, Sn, Mn, In, Cu, Cr, Co, Sb, Pb and Bi were detected in air around recycling areas as well as in India recycling sites [33]. Likewise the level of PPBDEs (BDE-17, 28, 47, 49, 66, 85, 99, 100, 153 and 154) in the indoor air of an e-waste storage facility were found at 46–350 pg/m3 in Thailand, on the other hand air pollution in outdoor locations, were estimated to be at about at 8 to 150 pg/m3 [45].

A Nigerian based study in 2017 assessed the practices, attitude and knowledge of e-waste workers association with the occupational health risk awareness via a control group in the informal sector [22]. The study sought establish the health risk awareness level across 279 e-waste dismantlers and repairers, 221 butchers from the informal sector in three locations. Results revealed a positive correlation existed between the workers' practice, attitude and knowledge. It was concluded that to decrease risky practices, there is a need to increasing workers' knowledge. Another study in 2018 sought establish the impact of various informal e-waste recycling activities (repairing, dismantling and burning) on metal concentrations in top soils and various dust samples [21]. In this study, comparative cross-sectional study design approach was employed to assess metal concentrations on samples from multiple e-waste recycling sites. Metal

concentrations from a control were compared with that of Lagos, Ibadan, and Aba e-waste recycling sites. Results revealed that the Mean metal concentrations of the three study sites exceeded the concentrations at the control sites and the Nigerian standard guideline values by 100 s to 1000 s times. Burning sites showed the highest pollution level, followed by dismantling sites, lastly repair sites. Findings revealed serious environmental and public health concerns. The metal concentrations were also higher than levels reported in other studies at the same locations in Nigeria, indicating that the situation is worsening. Based on the results obtained, the study recommended the urgent development and implementation of effective support existing e-waste regulations in Nigeria. These findings and much more over the years have confirmed the significant levels of toxic substances that result from e-waste primitive recycling processes and their potential risk levels to the ecosystem and human health.

5 Suggestions on How to Improve the E-Waste Problem in Nigeria

In the comparative study of Switzerland, Japan and Greece, it was observed that one of the first country worldwide to establish an official e-waste management system was Switzerland [46]. They also as far back as 1998 introduced legislation for e-waste management via ordinance on "The Return, the Taking Back and the Disposal of Electrical and Electronic Appliances", ORDEA Law [47]. Consumers could either drop their e-waste at strategically located collection points, or take them directly to the recycling point where they are disassembled, shredded, sorted and disinfected to get rid of toxic substances. Manufacturers were fully made responsible for taking back their products from customers at no cost, and ensuring that they pose no threat to the environment [48].

In the case of Japan, the e-waste recycling system is based on social responsibility, environmental sensitivity and general discipline of Japanese people along with proper regulations put in place [5]. Their laws stipulate target rates and also penalties for violators [47]. Manufacturers in Japan are meant to be responsible for receiving products on return by last owners. Producers there have facilities and there exists collaborative partnerships between them and customers. They also have implemented in their business strategic e-waste management plans. Consumers return products to collection points where they proceeded to recycle facilities through distribution systems [12]. There also exists a withdrawal fees paid by consumers. Up till 2004 they had 41 e-waste recycling facilities partly funded by companies and ministries. It is also known that Japanese companies were the first to evolve welding without insulation and the electrical panel board connections without bromide compounds in accordance to the European guidelines on electronic products.

For a while Greece practiced an e-waste management system known as "grey recycling". This involved mixing e-waste with other materials such as metal waste for recycling. Approximately 170 kilotons (Kt), representing 3.8% of the total amount of domestic solid waste were processed using this method between 2003–2006. About 90% of Greece e-waste within that period were recycled or mixed with other materials. An alternative e-waste management system kicked off in 2004, with the responsibilities

of collecting, transposing and processing e-waste in special facilities in other to effectively handle the developing problem increase in amounts of e-waste generated. The new approach recorded the collection of about 0.1 Kt of e-waste in 2005, also 31.5 Kt in 2007, 47 Kt in 2008 and 25 Kt during the first five months of 2009 [5]. This was achieved through the separate collection of at least 4 kg per resident per year of e-waste of domestic origin that is 44 Kt/year for Greece in total [5].

The first thing the Nigerian government should focus on now is raising proper awareness at all levels nationally. The National Environmental Standards and Regulations Enforcement Agency (NESREA) should also consider working with other stakeholders (both private and public) to create awareness on the e-waste problem, because efforts so far have grossly been insufficient. It can be recalled that NESREA in 2009, organized an International Conference titled "The Abuja Platform on E-Waste", the Environment Division of the Nigerian Society of Engineers also organized a Conference titled "Environmental Impact of Telecommunication Projects in Nigeria" in Abuja in 2010. Similarly in 2011, Nigeria held its 1st Eko International Summit on E-Waste at Lagos. These conferences aimed at e-waste control and to draw the attention of the Federal government to encourage, enforce collection, recovery, recycling and re-use of e-waste in Nigeria [49]. A research by Obaje in 2018 reported that while NESREA's efforts were commendable, country wide survey research revealed gross lack of awareness on the e-waste menace both within the literate and illiterate Nigerians [24]. As concluded by [22] in 2018, an increasing e-waste workers' knowledge may decrease risky practices.

It is believed when every stakeholder including the common man on the street down to school children are well aware and properly educated of the down sides associated with e-waste, no one would be interested in opting for products that neither may work let alone last nor keep them safe from the impending danger as a result of the toxic composition of its components. This would go a long way making it difficult for unscrupulous exporters making money from shipping in these junks to be patronized. It will thus be only a question of time before they begin considering channeling their investments into more environmentally friendly ventures.

The Federal Government of Nigeria in 2011 made efforts through agencies such as NESREA, to establish sound e-waste regulation starting with banning the importation of e-waste in Nigeria but allowing secondhand working devices to still scale through as cheap alternatives to those who cannot afford to buy new ones. Unfortunately smuggling of e-waste amongst second hand shipments started again. Today we are back to square one. Thus to address this lingering problem further steps have to be taken by the Federal Government and all agencies responsible, beyond efforts made so far to counter all improvised techniques developed over time in smuggling e-waste into the country.

5.1 How Can the Nigerian Government Counter All Improvised Techniques Developed Over Time in Smuggling E-Waste into the Country?

There exists a challenge as how to effectively classify each used electrical electronics shipped from outside Nigeria as second-hand or e-waste. The lack of clarity with regards to this issue makes it difficult for enforcement officers to distinguish between

second-hand sound working devices and e-waste when screening shipments documents and during visual inspections. In most cases, exporters of these products deliberately do not declare these goods as waste to be able to smuggle them into developing countries and make money. In consideration to the fact that not every Nigerian citizen can afford new product couple with the goal of bridging the digital divide, the Federal government can place a total ban on the direct importation of second hand products by setting up another agency saddled with the responsibility of liaising directly with manufacturers in major countries and others across the world through whom cheap working alternatives can pass through. In other words this will narrow down the inflow of second hand products to just one source; a government agency that will ensure what it is shipping in are deemed sound and still in good working condition. With this, any further inflow of e-waste can then be blamed on that single established gateway. Once the inflow of e-waste has been taken care of properly, the country will then be faced with the next stage of getting rid of tons of e-waste already within Nigeria. According to [50], an encouraging success story was recorded of NESREA for successfully detecting and impounding two containers at TinCan Island, Lagos, Nigeria from France, flooded with electronic products that did not have exporter's test certification. Quite a laudable efforts and action it was from NESREA, however another set of questions still springs up. Has that effort been sustained since then? How do we deal with the excessive tons of e-waste that has already found its way and are currently within Nigeria?

5.2 How Can Efforts so Far Be Sustained? How Do We Deal with the Excessive Tons of E-Waste Already in Nigeria?

Agencies such as NESREA need to intensify efforts and actions to ensure the sustenance of such success stories. To successfully accomplish this task they continually have to strive to be steps ahead of smugglers in other to catch them. With regards to handling the excessive ton of e-waste already in the country; some measures are in place but does not cut across the entire nation. For example, e-waste collection exercises exist in Lagos handled by the Lagos Waste Management Authority (LAWMA). After gathering e-wastes, they are transferred to the available municipal dumpsites. It is there informal collectors sort out fractions valuable to them. Likewise, the Lagos State Environmental Protection Agency (LASEPA) is also saddled with e-waste collection focusing on e-waste from businesses. However this formal arrangement is not obtainable across the entire country. The only activities on ground elsewhere in Nigeria is the gathering and local recycling of e-waste by scavengers who lack the technical know-how for safe recycling let alone the right technology, using crude methodologies to recycle. They randomly go house to house, gathering metallic wastes steel, aluminum and copper, a times paying some money for each item. This is a good approach but must be restructured. Nigeria is blessed with land mass and collection centers can be strategically set up across all 36 states of the federation to facilitate collection. The government can provide incentive to these scavengers and engage them in gathering these e-waste to the nearest established collection site. When these pile up over time, measures can then be taken for proper scavenging of useful materials and recycling. The Nigerian Government could also provide incentive to Nigerians to encourage them let go of such e-waste to collectors for a token amount. All these will boost the rate at

which the nation will be purged of e-waste lying around every home. On successful compilation of e-waste across the nation through strategically located collections centers, the next huddle to cross would be how to get them properly recycled or disposed of.

5.3 After the Successful Gathering of E-Waste Across Collection Centers, What Next?

An International Summit organized by Lagos State LASEPA in conjunction with NGOs, took place at Lagos in 2011. One major outcome of this event was the idea to form an alliance on African e-waste. Prominent companies such as Phillips, HP, Dell and Nokia were involved and part of the achievements so far was a pilot recycling program in Kenya. Nigeria can also get started on establishing a pilot recycling program as such to help when accumulated e-wastes pile up, to have it successfully moved from collection sites. If after due consideration this pilot program is not feasible, an alternative would be to saddle the earlier suggested agency (to handle the coordination of shipping in certified second hand working products), with an additional responsibility of establishing contacts with prospective interested recycling companies closest to Nigeria such as Kenya. Thus, as the agency helped coordinate the inflow of usable product, they should as well coordinate the exporting of now e-waste products to appropriate recycling plants, through the appropriate channels. Thus, if going the extra mile of dismantling, removing plastic, circuit board, smelting with the right technology to get the gold and silver is not feasible, they can simply be shipped to where it can be properly done. The cost of flushing out this toxic waste should be considered an investment and a sacrifice in comparison to the possible adverse effect they are capable of posing.

6 Recommendations

This paper makes the following recommendations that will ensure an effective management of the Nigerian e-waste problem:

1. There is need for an immediate exponential increase in every effort made so far in creating awareness. With social media and other advanced information dissemination mediums, the awareness campaigns can be overhauled with very little effort. It is suggested that no stone be left unturned, citizens from all works of life including children nationwide be carried along as this would drastically help establish the right mind set and attitude needed to facilitate the solution to our e-waste problem.
2. It is also recommended that collection centers across the nation be strategically established nationwide for the effective collection and accumulation of these e-wastes from the junk collectors where they can be properly sorted and stored as they await further processing.
3. Measures should be put in place to intensify the existing house-to-house collection of e-waste techniques by junk collectors alongside the voluntary take-back

technique practiced in Europe, but restricting them to collection and gathering only. They should be prevented from making any attempts to recycle or extract any materials as they lack the technology and technical know-how. The junk collectors should be encouraged with some form of incentives to help gather these e-wastes to designated collection sites as it is believed that that this house-to-house collection technique achieves significantly higher and rapid collection rates compared to other methods and is more convenient for consumers.

4. Agencies responsible for health and occupational safety issues, environmental sanitation and national security must at this point come in and ensure effective enforcement of laws and regulations preventing junk collectors, scavengers from using crude methodologies to extract materials and recycle e-waste, thus rather ensuring they deliver all gathered waste at appropriate collection sites.
5. Having achieved proper general public awareness and the right set of measures in place to ensure effective e-waste gathering, some form of incentive to citizens will also go a long way in boosting their willingness to trade off as much e-waste in their possessions as possible.
6. An immediate ban should be placed on the importation of all used electronic products and devices, after which the government can take advantage of the situation, stream line and narrow down their importation to one single source; a government established agency saddled with the responsibility of liaising with foreign governments, organizations, manufacturers and companies. This will help properly scrutinize each and every used device to be shipped into the country as cheap alternative to those who cannot afford new ones, making sure they are still in good working condition.
7. Lastly, notable exporting countries of used electronic products should be urged to enforce existing laws, such as the proof of testing and categorization, and other directives of the Basel Convention.

It is therefore hopeful, if Nigeria puts all suggestions in this paper in place. There would barely be any avenue for inflow of e-waste into the country. It is time Nigeria and other developing nations realize they are capable of solving the e-waste problem on their own.

7 Conclusion

E-waste is clearly a growing problem especially amongst developing countries and possesses the potential of adversely affecting the water, air and lives of people who find themselves around such areas. Thus, as a matter of urgency the Nigerian government must swing into action and take extra measures aside depending on International Laws. This will ensure the situation is properly managed. This paper establishes a need to consistently ensure that every measure put in place is sustained to yield results, back up plans and strategies be continuously put in place in event of failed plans until the problem of e-waste is managed across the country.

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