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Generation and Management of Electrical and Electronic Wastes (E-waste) in Abakaliki Capital Territory, Ebonyi State, Nigeria. Implications for Human Health Risk.

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Abstract: *The management of e-waste is a challenge especially in the developing countries. E-waste comprises of a multitude of components, some containing potentially toxic elements that can have an adverse impact on human health and the environment if not handled properly. This work examined existing e-waste management protocol in Ebonyi State, Nigeria. The investigation revealed poor practices including; indiscriminate waste dumping, the use of obsolete waste disposal equipment, handling all waste as one, the use of open burning and landfill as the treatment option and lack of adequate legislation covering e-waste management in the State. Obviously, such practices would release significant toxic contaminants which could negatively affect human health and the environment.*

Keywords: *E-waste, Abakaliki Capital Territory (ACT), open burning, health risk*

I. Introduction

The global production of electrical, electronic, and particularly of information and communication technology (ICT) equipment is one of the fastest growing global manufacturing activities. This is because their use has proliferated significantly in recent decades, and proportionately, the quantity of these devices that are disposed of, are growing rapidly throughout the world. Electrical electronic waste (e-waste) refers to any appliance using an electric power supply that has reached its end-of-life. The European Waste from Electrical and Electronic Equipment recognises ten categories of e-waste [1]. These include: large household appliances (refrigerators, washing machines, stoves); small household appliances (vacuum cleaners, toasters, hair dryers); information and telecommunications equipment (computers and peripherals, cell phones, calculators); consumer equipment (radios, TVs, stereos); lighting (fluorescent lamps, sodium lamps); electrical and electronic tools (drills, saws, sewing machines); toys, leisure, and sports equipment (electric trains, video games); medical devices (ventilators, cardiology and radiology equipment); monitoring instruments (smoke detectors, thermostats, control panels) and automatic dispensers (appliances that deliver hot drinks). It can be seen that the composition of e-waste is very diverse and differs in products across different categories. It has been reported [2] that while e-waste contains materials that can be processed into useful products, the presence of elements like arsenic (As), cadmium (Cd), Chromium, (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni) and selenium (Se) and flame retardants represent a potential threat to man and his environment.

The increasing volumes of e-waste, in combination with the complex composition of these items and the resulting difficulties in treating them properly, are causes of concern. The hazardousness of e-waste is well recognized, but the knowledge on these hazards and the resulting environmental and the human health risks associated with different treatment options is currently fragmented [3]. The 21st century is witnessing a scenario where second-hand electrical and electronic equipment are continuously been shipped to developing countries, including Nigeria. Developing countries patronise these products because of their reduced prices not considering that most of them are either obsolete or not in good condition and as a result have short life span. Obviously, such already used electrical and electronic waste products will end up in the environment as waste. Due to the absence of appropriate mechanisms for and standards of disposal, these toxin-laden high-tech products often end their lives in the ‘normal’ waste stream, subject to either burning or landfilling. Apparently such poor management of e-waste could contaminate soil, groundwater and air, as well as affecting all those involved in their end-of-life processing and the nearby communities. It has been observed that if the trend continues, many developing countries will have large amounts of hazardous e-waste, resulting in serious consequences for the environment and public health. [4]. It is to be noted that while most developed countries have standard method of handling waste accompanied with strict regulation on generation and management, many developing countries including Nigeria are yet to attain this height [5-7].

1.1 Existing framework for waste management in Ebonyi State.

Deliberations on environmental, health and social problems associated with the uncontrolled dumping and inappropriate management of e-waste has already reached the mainstream of policy-makers in developed as well as developing countries. However, most of the developing countries including Nigeria have not yet been able to enforce national policies and legislations for managing e-waste. The federal government of Nigeria (FGN) only realised the need to protect human health and the environment in 1987 when to brought about the promulgation of the Harmful Waste Decree 42 of 1988, which facilitated the establishment of the Federal Environmental Protection Agency (FEPA) through Decree 58 of 1988 and 59 (amended) of 1992. The federal government of Nigeria mandated FEPA to oversee environmental management and protection in Nigeria. In 1999, in order to further enhance the management of environmental pollution, the FGN merged FEPA and other relevant departments in other Ministries to form the Federal Ministry of Environment but without an appropriate enabling law on enforcement issues. This scenario paralysed the effective enforcement of environmental laws, standards and regulations in the country. To be able to bridge this gap, the FGN in line with section 20 of the 1999 Constitution of the Federal Republic of Nigeria, established the National Environmental Standards and Regulations Enforcement Agency (NESREA) as an agency of the Federal Ministry of Environment, Housing and Urban Development. This parastatal (NESREA) was charged with the responsibility of enforcing environmental Laws, regulations and standard in deterring people, industries and organization from polluting and degrading the environment. The NESREA Act was signed into law on 31st July, 2007 [8]. In addition to NESREA, the FGN also empowered state governments to establish environmental bodies to oversee environmental issues in their respective states.

In line with this, the Ebonyi State House of Assembly (Governmental arm responsible for enacting State laws) enacted law called Ebonyi State Environmental Protection Agency, law 2009. Thus, Ebonyi State Environmental Protection Agency (EBSEPA) was established. The law charged the EBSEPA to monitor and maintain the environment in terms of pollution and control. Since then, the EBSEPA is the body responsible for environmental management and protection in Ebonyi State.

Literature survey shows that no study has investigated the generation, disposal and management of e-waste in Abakaliki Capital Territory (ACT), Ebonyi State, Nigeria. This work is therefore designed to x-ray existing protocols and the environmental and human health implications.

II. Experimental (materials and method).

2.1 Study area.

Abakaliki Capital Territory is the capital of Ebonyi state. It is predominantly urban covering a total area of 5533 km^2. As of 2006 census conducted by National Population Commission (NPC), Ebonyi State had a population of 2, 176, 947, out of which the capital territory comprising of 271, 833 [9]. It is to be noted that this population must have increased by at least 40 % after nine years considering the rate of birth and urbanization in developing countries. The capital territory (longitude $6^o25^/$N and latitude $8^o08^/$E) is located basically in the North senatorial zone of Ebonyi State. Figure 1 shows the map of ACT. Urban activities in the ACT include; commercial, education and industrial development as well as rapidly expanding residential areas. Improved living standards of people in ACT due to its socio-economic development have led to the generation of enormous quantity of e-waste. Abakaliki Capital Territory is facing a crisis in e-waste management with no designated site for either its dumping or an integrated scheme for its sustainable management.

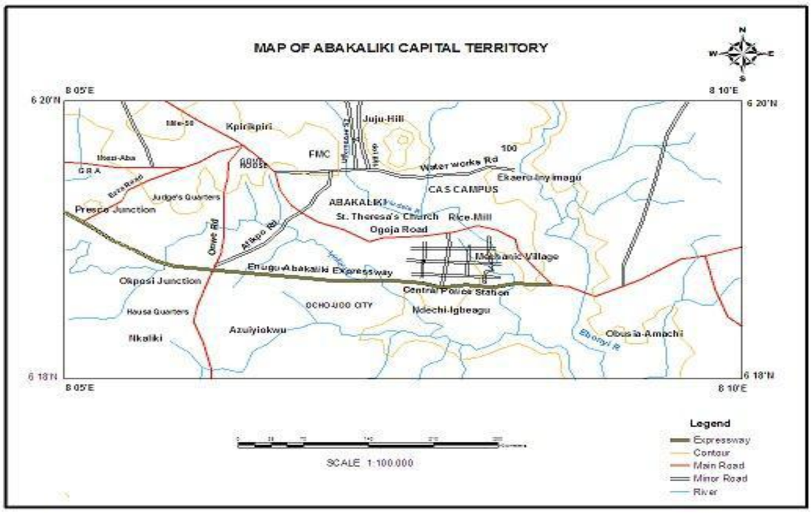

Figure 1: **Showing the map of Abakaliki Capital Territory (ACT).**

2.2 Data collection Protocol

In order to collect representative samples, the study covered the following electrical and electronics equipment (EEE) handlers: commercial (marketers, repairs and maintenance) (group 1), industrial (group 2), institutional (group 3) and residential (group 4). Questionnaires were specifically designed to cover e-waste generation and end-of-life disposal approach. Questionnaires were randomly distributed in the following order: group 1 (100 questionnaires); group 2 (100 questionnaires); group 3 (100 questionnaires) and group 4 (100 questionnaires). Thus, a total of 400 questionnaires were administered, together with interviews with officials and staff of the EBSEPA on e-waste management practice in place. Data collection was conducted for a period of three months (June 1 to August 31, 2015).

III. Results and discussions

In terms of e-waste generation, the study showed that group 1 generated the highest amount of e-waste (43 %). It is to be noted that this group include second-hand marketers as well as engineers, technicians and artisans who are involved in dismantling, repairs and maintenance. It was discovered that most of the imported second-hand electrical and electronics equipment are mostly dismantled inappropriately and used to refurbish new electrical and electronics equipment parts which are believed to be fake or not durable. Thus, more people prefer second-hand ones or refurbish ones to new ones. This practice has resulted in the generation of enormous amount of e-waste in ACT. In addition, the other groups also patronise this group, hence the highest amount is justifiable. Although, dismantling of EEE has become a source of income to many, it is to be noted that inappropriate dismantling techniques to recover metals such as copper, aluminium and iron, also represent enormous risks to the workers. For example, breaking of cathode ray tube (CRT)-monitors using stones, hammers, heavy metal rods and chisels, to recover copper, steel and plastic casings, could result in the inhalation of hazardous cadmium dust and other pollutants by the workers. Group 1 was closely followed by group 2 (industrial) (30%). It was discovered that most of the waste resulting from this group was as a result of poor quality of EEE being used. Group 3 (institutional) generated 17 % while group 4 (residential) generated 10 %. This distribution of e-waste generation in ACT is shown in Figure 2.

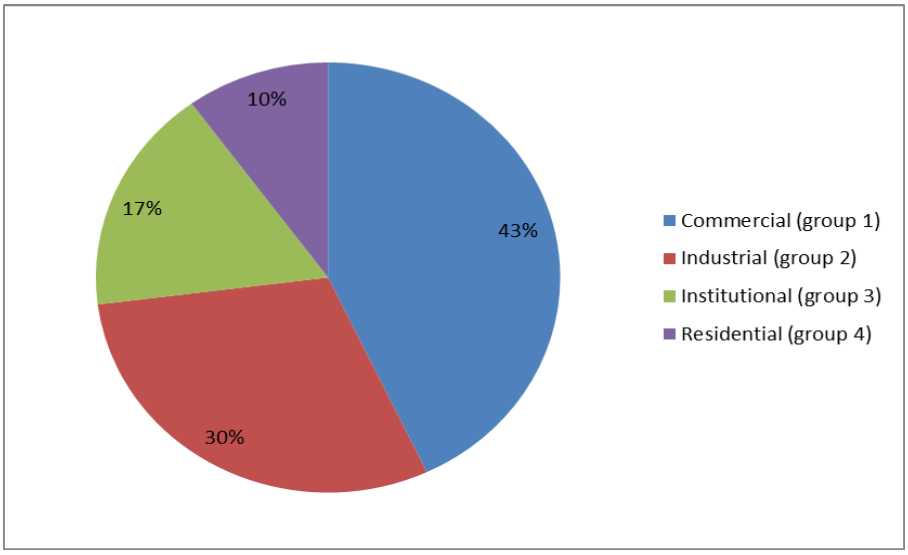

Figure 2: Distribution of e-waste generation in Abakaliki Capital territory.

The result from the e-waste disposal is the same for all the groups. It was observed that people are not aware that e-waste should be disposed separately and as a result e- wastes are normally combined with any other waste which are either taken to government designated dump sites, be burnt, thrown to any nearby river, farmland or gutters. Figure 3 shows a blocked water ways due to indiscriminate dumping of waste. The act of blocking water ways with waste has contributed immensely to the flooding occurrences in ACT which has caused loss of lives and property. In addition, this scenario could lead to road accident.

Figure 3: Blocked water ways due to indiscriminating dumping of waste at Nnorom Street ACT.

3.1 Waste management protocol in Abakaliki Capital Territory

The management staff of EBSEPA who were interviewed on e-waste policy and management in Ebonyi State revealed that there is no policy on e-waste and as a result no management protocol exist currently. The absence of strict legislation on the management of e-waste creates a scenario where e-waste will be treated as a biodegradable waste even when most of them are non-biodegradable. It was gathered from EBSEPA management team that the only government approved protocol is landfill. However, prior to this, people were asked to either keep their waste on designated roads (Streets) for onward collection by EBSEPA staff or take such waste to designated dumpsites. Obviously, e-waste is stream of municipal solid waste (MSW) in ACT. It was also gathered from EBSEPA management team that whilst burning is not the recommended practice, it has become an easy way through which people do away with their waste. It can be seen that each of these approach represents avenues through which contaminants could be released into the environment. Visitation to the so-called government designated dumpsites showed that waste decompose while awaiting evacuation. Figure 4 shows one of such sites located at water-works road Abakalki. The figure shows uncovered container provided by EBSEPA for dumping of refuse with the obligation of regular evacuation but due to negligence on the part of the workers and lack of strict monitoring by the concerned authority, wastes overflow its content. A worst case scenario is observed in most residential homes where children (< 10 years) are commonly found carrying MSW from their respective homes to various dumpsites within their neighbourhood. This ugly situation prevalent in most ACT exposes children to health risk from waste. Moreover it is a form of child abuse that should not be allowed to continue

Figure 4: Waste dump at Water-works ACT showing decomposing waste calling for attention,

Apparently, figure 4 shows a poor practice because the facility provided is not enough and also obsolete (no cover) and as such collect water when rain falls which not only increase the weight of the waste but increases the rate of decomposition prior to evacuation. When wastes are allowed to decompose before evacuation, it poses risk to the people within the vicinity, in such scenarios dumpsites act as reservoirs for infectious diseases. This was proven by the analysis of decomposed municipal solid waste (MSW) in Kano metropolis [10]. The result of the analysis showed the presence of bacteria flora (six bacterial isolates) which have been directly implicated in food borne infectious disease including typhoid, diarrhoea and gastroenteritis within the zones were the dumpsites were situated. The study further revealed that waste were dumped on any available open spaces along the road, street, near rivers and in some zones directly into the rivers. It is obvious that each of these scenarios is a potential pathway through which disease causing micro-organisms could enter the human body. Children living near dumpsites or those who play near dumpsites are likely going to have their hands contaminated and since they have the habit of sucking their hands, they could easily introduce disease into their bodies. In addition, drinking of untreated water is another pathways through which disease from decayed wastes enter the human bodies.

3.1.1 Waste treatment in Abakaliki Capital territory (ACT)

The study gathered from EBSEPA management team that the approved method of handling MSW of which e-waste is a significant stream is by burying. When waste are buried, the biodegradable components will surely decompose with time while the non- biodegradable becomes potential environmental and human health threat. When waste is allowed to decompose, the constituents leach into the environment [11]. Leachate such as toxic metals and synthetic organic compounds enter the soil and water. Methane (CH_4), carbon dioxide (CO_2), odour and noise characterises the air. The presence of these substances in the environment could lead to the contamination of these natural resources which would significantly affect the general public directly or indirectly. With the rate of population increase, urbanization, industrialisation and economic growth in Ebonyi State, the burial sites will soon be converted to schools, recreation sites, residential or commercial which could cause health risk.

In addition to burial, open burning is a popular method of waste disposal in ACT, though not recognised by EBSEPA. Investigation as to way many people prefer to burn their waste instead of taking it to waste dump revealed that many people who do this claim to be busy or do not have children to do it and moreover, it is faster. Whilst this approach might be a faster means of waste disposal, the environmental and health risk must be considered. Figure 5 shows open waste burning in ACT.

Figure 5: Open burning of waste in Abakaliki Capital Territory (ACT)

Open burning of MSW releases toxic substances into the environment. Studies [12-14] have shown that ashes released from open burning of MSW contain potentially harmful elements such as metals, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenils (PCBs), chlorobenzenes, chlorophenols and chlorinated dioxins and benzofurans. The use of open burning as waste treatment option pose both environmental and health risks.

3.2 Environmental and health risk associated with poor management of e-waste.

Electrical and electronics equipment (EEE) contain potentially toxic elements (PTEs) of concern and since they all end up as e-waste, they could be a threat to the environment and the inhabitants. Table 1 summarises key components of e-waste and the PTEs found in them.

Table 1: Potentially toxic elements (PTEs) present in e-waste components.

Potential toxic elements (PTEs)	Components of e-waste containing PTEs
Barium (Ba)	Barium and barium compounds are used in electron gun getter (a component of cathode ray tubes (CRT) [15].
Cadmium (Cd)	Cadmium is used in nickel–cadmium (Ni-Cd) batteries, printed circuit boards, surface mount devices, chip resistors, infrared detectors, and semiconductor chips. Cadmium is also present in phosphors of CRT [16].
Chromium (Cr)	Hexavalent chromium. Cr(VI) is used in metal coatings of some electronic devices for corrosion protection [17]
Copper (Cu)	Copper is used for its conductive properties, is either plated or etched onto surfaces of fiberglass epoxy resin boards; Copper is used in cables. Printed circuit boards (PCBs) are known to contain a substantial quantity of cu and the main value carrier of CRTs is copper, which makes up more than 60% of the total intrinsic value [18]
Lead (Pb)	Lead is used in many components including; solder in printed circuit boards, CRT computer monitor, Pb-acid batteries, cone glass and solder [19 – 20]
Mercury (Hg)	Mercury is used in laptop monitors, cold cathode fluorescent lamps, cell phones, and printed circuit boards. Mercury is also used in relays (used in telecommunication circuit boards, commercial/industrial electric ranges, and other equipment) and switches (used in a variety of consumer, commercial, and industrial products, including appliances, space heaters, ovens, air handling units, security systems, levelling devices, and pumps), batteries, and gas discharge lamps [21]
Nickel (Ni)	Nickel has magnetic and structural applications, so it is widely used in CRT [22]
Zinc (Zn)	The inside of CRT panel is coated with fluorescent phosphors composed of Zn with physical characteristics, such as weight, size, shape, density, and electrical and magnetic properties [23].

Table 1: Potentially toxic elements (PTEs) present in e-waste components.

Presence of PTEs in electrical and electronic equipment inevitably links its end-of-life disposal with the potential risks to human health and the environment particularly if, improperly managed. This is the situation in ACT where landfills and open burning are in use. The implications is that PTEs can either leach or be released into the environment. In addition, research has shown that Large quantities of organic compounds generated during e-waste treatment are released into the surrounding environment resulting in high levels of persistent organic pollutants (POPs) such as; sixteen (16) United States Environmental Protection Agency (US EPA) priority polycyclic aromatic hydrocarbons (PAHs)[24]; Seventeen (17) polychlorinated dibenzo-p-dioxins (PCDDs) [25]; 2,3,7,8-substituted polychlorinated dibenzofurans (PCDFs) [26]; polychlorinated biphenyls (PCBs) [27]. More so, Polybrominated diphenyl ethers (PBDEs) are flame retardants, which are extensively used in EEE and PBDEs have been reported [28-29] to be persistent and ubiquitous in environmental matrices resulting in increased human exposure.

The presence of these contaminants in the environment raises health concern because they can be toxic and may not be degraded to non-toxic forms by any known method and as a result remain in the environment for decades. Humans are exposed to these contaminants via oral ingestion, inhalation or dermal absorption [30]. The presence of contaminants in environmental matrices might have irreversible adverse effects on humans particularly children due to their pica behaviour, physiology unique exposures and special vulnerabilities [31], which put them at a higher risk because immature organs tend to be more susceptible to contaminants than adult [32]. In ACT children and adults are unavoidably exposed to e-waste contaminants. Gastro-intestinal infections, respiratory and skin diseases as well as muscular-skeletal problems and cutting injuries are some of the adverse health effects prevalent in areas where there is poor e-waste management as obtained in ACT. It has been observed that PTEs including Cd, Cu, Ni, Pb, and Zn except Cr measured in soil samples from open burning sites in Guiyu (China) exceeded the action values of Dutch List [33]. The study further revealed that high concentrations of these PTEs were found in human placentas collected from Guiyu. This is justifiable because PTEs could enter the local residents through inhalation, dermal exposure, and even oral intake of contaminated food. Another study [34] investigated PTEs concentrations in dust from within EEE dismantling workshops with that from roads and public places, and the result revealed that Cd, Cu, Ni, Pb, and Zn were significantly higher in the EEE dismantling workshops than non e-waste sites. Risk assessment of the study predicted that PTEs from circuit board recycling have the potential to pose serious health risks to workers and local residents especially children. The determination of dioxin-like compounds in agricultural soils near e-waste recycling sites from Taizhou area (China) showed high concentrations of PCDD/Fs, PCBs, PAHs (16 USEPA priority PAHs, including 7 USEPA carcinogenic PAHs) and traced the source to open burning of plastic in e-waste [35]. The characterization and determination of diurnal variation of PBDEs in the atmosphere of an e-waste dismantling region revealed very high concentration of PBDEs generated by different burning processes [36].

Environmental and health risk associated with e-waste management through burial (landfills) are widely reported. The leachability of thirty-six colour CRTs were assessed and 58.3 % CRTs exceeded the 5 mg/l of Pb regulatory limit for characterization as a hazardous waste [37]. It was also reported [37] that 12 different EEE were tested for Pb levels in leachates and the result revealed that Pb concentrations in the leachates exceeded the regulatory limit of 5 mg/L. Based on these findings, the authors concluded that there is sufficient evidence that discarded EEE containing a colour CRT or printer wiring boards with lead-bearing solder have a potential to be hazardous wastes for Pb. Furthermore, the determination of PBDEs levels in the landfills that had crushed e-waste showed high concentrations of PBDEs [38]. Adverse health effects resulting from exposure to these contaminants include: abdominal pain, vomiting, diarrhoea, respiratory malfunctioning, renal disorder, skin lesions, melanosis (change of pigmentation), cough, chest pain, hypertension and cardiovascular complications [39].

IV. Recommendations

E-waste management in ACT can only be properly managed if there is strict and robust legislation. The Ebonyi State government should enact legislation and good practice guidelines to define, classify, segregate and treat e-waste with measures in place to ensure full implementation and incorporating the principle of 'Polluter Pays'. In developed countries of the world, e- wastes are managed with less risk due to functional legislation.

Such a law if enacted will define e-waste and make the necessary provisions for sorting of waste into different categories. In addition, the Federal Government of Nigeria (FGN) should restrict the importation of second-hand EEE. A regulated recycling method is preferred to burning and landfills. In addition to adequate legislation, the authors strongly suggests that;

- Ebonyi State government should provide appropriate fund for the management of e-waste and actively monitor its utilization.
- Obsolete waste management protocols that emit toxic substances into the environment should be avoided and embrace modern techniques such as recycling and supercritical fluid carbon dioxide sterilization techniques.
- Ebonyi State Environmental Protection Agency should regularly train all staff in order to acquire all the necessary skills and up-to-date knowledge and information on waste management protocols.
- Ebonyi State Environmental Protection Agency should have a database to account for day-to-day waste generation and disposal.
- Nigeria higher institutions and research centres should be restructured to focus on research aimed at converting waste-to-wealth.

V. Conclusion

The study has revealed that e-waste contains a number of hazardous substances. Potentially toxic elements and organic contaminants are of particular concern. Thus, improper handling and management of e-waste and other end-of-life treatment options may pose potentially significant risks to both human health and the environment. E-waste management in ACT is obsolete, poor and without adequate legislation, hence the way forward has been proposed. It is to be noted that while this study is only literature based, studies are on the way to determine the concentrations of these contaminants.

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