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Research Article

E-Waste Recycling: A Sustainable Approach to Technology Consumption

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Abstract:

This paper focused primarily on e-waste recycling, its conceptual framework, meaning, types, the processes involved, the need and the adverse effect of e-waste on public health, aesthetics and environment. The inherent benefits of e-waste recycling were highlighted as EEE helps to improve living standards worldwide by providing information and means of communication, in addition to business and educational as well as income opportunities. In addition, the problems or difficulties facing e-waste recycling in Nigeria were discussed and ways to overcome these challenges were recommended. It was concluded that while recycling is crucial for mitigating the environmental and public health impact of WEEE, it is clear that the process is not without its challenges. The problems of recycling e-waste highlight the need for more funding, education and awareness campaign in addition to formulation and implementations of strict national and international standards and regulations. The drawbacks of e-waste recycling do not negate its benefits. Recycling of e-waste is still a vital part of sustainable waste management. By improving e-waste recycling habits in Nigeria, it can help not only in preserving natural resources or in safeguarding public health and environment, but also promote a sustainable approach to technology consumptions hence paving the way for a cleaner, greener and more sustainable future. This will also avoid environmental degradation and seepage into the food chain causing public health concerns. Government should ensure the adequate assembly of used e-waste gadgets for recycling to avoid exposure to man in secluded environments.

Keywords: Electrical and Electronic Equipment (EEE), Used Electrical and Electronic Equipment (UEEE), Waste of Electrical and Electronic Equipment (WEEE or E-waste), temperature exchange equipment.

Introduction

In this era of rapid science and technology advancement, electrical and electronic equipment (EEE) plays a crucial role in our daily lives. Cell phones, laptops, televisions and other EEE have become integral parts of our existence. The United Nations (UN) divided EEE into 54 different product-centre categories. These were further grouped into six general categories based on their waste management needs [1]. They are;

a) Temperature Exchange Equipment, examples are air conditioner, freezers, refrigerator e.t.c
b) Screens and Monitors, these include computer, television, tablet
c) Lamps: examples are fluorescent, high intensity discharge, LED
d) Large Equipment, such as household appliances like copiers, washing machine,
e) Small equipment such as electric cookers, heaters, fans, microwaves, pressing iron.
f) Small information technology and Telecommunication equipment, mobile phones, radio sets, home printers [2].

The EEE can also be defined as any device or gadget that uses electricity either from a power outlet or a battery. EEE helps to improve living standards worldwide by providing information and means of communication, in addition to business and educational as well as income opportunities [1]. With constant introduction of new and improved EEE, consumers are enticed by the latest models and tend to upgrade their gadgets and devices more frequently. This has led to a staggering increase in demand of FEE globally. This increase is attributable to the growing number of people using EEE worldwide, as well as constant innovation, shorter innovation cycle and the phasing out of 'old' technologies. This is in addition to shorter life cycle of modern EEE and designs that do not support repair or reuse. This increase in consumption of EEE has led to millions of EEE and devices being discarded as product breakdown or become obsolete and thrown away every year [3]. The result is generation of a unique stream of Waste of Electrical and Electronic Equipment (WEEE).

i) E-waste

The WEEE or simply E-waste refers to discarded EEE. The Basel convention defined e-waste as any EEE that is waste, which

means has stop functioning, including all components, sub-assemblies and consumables that are part of the equipment at the time the equipment becomes waste [2] . This includes obsolete and faulty devices.

E-waste is one of the fastest-growing waste streams. Globally, e-waste constitutes more than 5 percent of all municipal solid waste [4]. It is a growing global problem with an estimated 41.8 million metric tons generated globally in 2014 [5]. The rapid increase in e-waste globally has resulted in the "Global E-waste Crisis."

The concept of e-waste is relatively new in Nigeria. Back in the 1970s, that is about 50 years ago, very few people used EEE. The devices and gadgets they did use, like radios, were used and kept for many years, before discarding. These items were repaired repeatedly rather than being thrown into the garbage once they stop working. However, a lot has changed since then, particularly the exponential increase in the number of EEE being discarded on daily basis nowadays. Most of today's EEE cannot be repaired - they get thrown away once they stop working or functioning. Manufacturers, its known, intentionally build devices to eventually become obsolete, that is produce sub-standards devices that would not last long. The result is a shorter product life cycle.

This is because Nigeria is a major destination of used EEE (UEEE) generated in developed countries. Nigeria is the second highest importer in Africa with about 100,000 informal workers operating in the sector [6]. The importation of huge quantities of UEEE into Nigeria has aggravated the country's e-waste problem, since UEEE have reduced life-span, and many are nonfunctional [7]. E-waste is the fastest growing solid waste stream in the world, increasing three times faster than the world's population [3].

ii) E-Waste Recycling: Definition

E-waste is unique as it contains both hazardous and valuable resources [7]. The recycling of e-waste has become a significant issue because of the exponential growth in the generation of e-waste, shorter life cycle of modern EEE and increased awareness among people regarding environmental and health impact of e-waste.

E-waste recycling is the process of collecting and processing or treatment of materials that would otherwise be thrown away as trash (waste) and turning them into new products [8]. It can also be defined as the collection and treatment of used objects and materials that are ready to be thrown away, in order to produce materials that can be used again by Plastic for change in 2021. E-waste represents a significant potential source of valuable materials and this make its recycling economically fascinating.

iii) Benefits of E-Waste Recycling

E-waste recycling has all sorts of benefits to public health, the economy and environment.

a) Environmental benefits: Recycling provides many benefits to the environment. By recycling e-waste, we create a healthier environment for present and future generations. Recycling e-waste helps to conserve natural resources. This is because recycling e-waste reduces the need to extract resources such as silver, mercury for new products. Most of the materials that make up e-waste are derived from non-renewable minerals. Recycling these materials can prevent the supply of consumer goods that becomes inevitable in human lives from being suspended until substitutes are discovered. Recycling impact the climate change positively. According to USEPA [8], the recycling of solid waste saved over 193 million metric tons of CO_2 equivalent in 2018.

b) Recycling conserves energy: USEPA [8] reported that recycling just 10 plastics bottles saves enough energy to power a laptop for more than 25 hours.

c) Reduction of waste and pollution: Recycling diverts waste away from landfills and incinerators which reduces the harmful effect of pollution and emissions.

d) Environmental Justice: Waste management facilities are concentrated or located in undeserved areas, and these dumpsites have negative impacts on property values, aesthetic and recreational values as well as land productivity. Recycling provides these areas with a healthier and more sustainable alternative.

Economic benefits of e-waste recycling are many for example, recycling of valuable elements contained in e-waste such as copper, aluminum, gold, silver *etc* has become a source of income mostly in the informal sector of developing countries like Nigeria [9]. In addition, according to USEPA [8] report, in a single year, recycling and reuse activities account for 681,000 jobs, $37.8 billion in wages and $5.5 billion in tax revenues.

e) Towards achieving Sustainable Development Goals (SDGs)

E-waste recycling has a critical role to play in the global shift to a circular economy and efforts to achieve the SDGs. It offers a practical solution to minimize waste and in promoting sustainability [10]. Recycling e-waste directly contributes to a number of the SDGs including SDG 3 (Good health and Wellbeing), SDG 6 (clean water and Sanitation), and SDG 8 (Decent work and Economic Growth). Others are SDG 12 (responsible consumption and production) and SDG 14 (life below water).

iv) Types of Waste Recycling

There are three types of waste recycling known as primary, secondary and tertiary recycling.

a) Primary recycling means that the recyclable materials are recovered and reused without being changed in any way and usually for the same purpose. Primary recycled products can be simply referred to as "second hand" gadgets or 'OK" devices.

b) Secondary recycling means that the materials are reused in some other ways, without reprocessing i.e. some sort of modification of the materials without the use of chemical processes.

c) Tertiary recycling refers to a process that involves chemicals or heat altering of the materials in order to make it reusable according to Recycling Consortium in 2024. These three types of waste recycling can also be referred to as mechanical energy and chemical recycling [11].

v) Recycling Process Overview

The recycling process is made up of several steps that are repeated over and over again. The various stages involved are:

Step 1: Collection: Businesses and consumers generate wastes that are then collected by either a private hauler or government entity. There are several methods for collecting recyclables, including curbside collection, drop-off centres and deposit or refund programs.

Step 2: Transportation: Once e-waste is collected; it is transported to the recycling facilities to be sorted into different categories according to their types and models.

Step 3: The sorted parts that are still functional will be separated, cleaned to be reused. They can be sold as individual parts or processed into new materials or combine to form new products. Recyclables are bought and sold just like raw materials would be.

Step 4: The e-waste left behind, mainly obsolete and non-functional parts, are sent to recycling processing plants. In the processing plant they are passed through a process called de-manufacturing which refers to the action of disassembling a product into the individual components. This step helps to remove all the potentially hazardous materials in e-waste that will destroy the machine or contaminate the environment once disposed into landfills.

Step 5: Then, the remaining components are thrown into an enormous machine where it is shredded or crushed into tiny pieces. The individual steps must be performed by skillful workers [12] .

vi) Effects of E-waste on Environment

Although EEE offer numerous benefits during their operational lives, however their resultant e-waste poses significant environmental and health hazards, if not disposed of properly. The major concern regarding e-waste is environmental and seepage into the food chain [13]. E-waste devices are typically not biodegradable and will not break down naturally or safely when discarded in landfills [3]. Discarded e-waste often piles up in the environment, contaminating habitats and leaching chemicals that are harmful to people, animals and plants. Furthermore, when e-waste is exposed to extreme heat, harmful chemicals are released into the air. Burning or heating is considered one of the most hazardous activities due to the toxic fumes created [2] .

E-waste contain many different toxic substances, these toxicants can be released into the environment if the devices are managed using environmentally unsound practices and activities [3] . Several unsound practices that take place at e-waste sites include:

a) Scavenging
b) Dumping on land or in water
c) Landfilling along with regular waste
d) open burning or heating
e) Stripping and shredding plastic coatings
f) Manual disassembly of equipment
g) Acid baths or acid leaching

These activities are considered hazardous to the environment and human health as they release toxic pollutants contaminating the air, soil, dust and water. Once in the environment, toxic pollutants from e-waste produced through unsound activities can travel significant distances from the point of pollution exposing people in faraway areas to health-damaging substances.

vii) Effect on Health

Again, e-waste is considered hazardous waste as it contains toxic materials or can produce toxic chemicals when treated inappropriately. Many of these toxic materials are known or suspected to cause harm to human health, and several are included in the 10 chemicals of public health concern, including dioxins, lead and mercury Long-term exposure to the hazardous substances found in e-waste can lead to various health problems especially during pregnancy, as well as in infants and children who are particularly vulnerable due to their unique pathways of exposure and their developmental status. E-waste exposure may be linked to the following health effects according to WHO [3] in their earlier exertions;

a) Adverse neonatal outcomes, including increased rate of stillbirth and premature babies.
b) Neuro-development, learning and behaviour outcomes especially associated with lead released through e-waste unsound practices.
c) Reduced lung and respiratory function and increased asthma incidence
d) Neurological damage, kidney diseases, cancer.

In summary, the consequences of improper e-waste disposal in landfills or other non-dumping sites pose serious threat to public health and can pollute ecosystems for generations to come [14] .

viii) Challenges Facing E-waste Recycling is Nigeria

While recycling e-waste has its benefits, it is important to understand that like any other system, it has its set of drawbacks or unique

challenges. A number of these challenges are preventing the e-waste industries from scaling up. These challenges are multifaceted involving technical, economics, regulatory and social aspects.

a) Complex and Costly Recycling Process. E-waste recycling presents a unique challenge due to the complex composition of EEE. One of the primary challenges of recycling e-waste is the complexity of the process. EEE and devices are composed of various types of materials, including metals, plastics and glasses. These materials need to be separated and processed separately, which is a complex and costly process. The recycling process often involves manual disassembly, shredding, magnetic separation and even water separation. Each step requires specialized equipment and skill as well as well-trained workers, adding to the overall expense of recycling operation. The cost factor is a significant deterrent for many municipalities, organizations and individuals considering establishing recycling programs or facilities. In many cases, it is far cheaper to dispose of e-waste in landfills than to recycle it [15] . The high cost or expense of recycling has made e-waste an expensive venture for industrialized countries. As a result, the burden of recycling has been transferred to the developing world, where environmental protection is lax and the necessary technologies to safely extract material do not exist. Stockpiles of e-wastes are open to the public for scavenging by low-income families and their children. The result is environmental contamination and negative health effects [13].

b) Risk of Contamination and inefficiency. The recycling process can also lead to contamination. Contamination occurs when non-recyclables items are mistakenly included in the recycling process. The presence of non-recyclable materials during recycling process can compromise the quality of the recycled materials. Contaminants such as food waste, chemicals or plastics can contaminate recyclables and render them unsuitable for reuse [15].

c) The biggest limit to e-waste recycling is that not all components of EEE can be recycled. For example, plastics are challenging to recycle efficiently, thus limiting the overall recycling potentials. This result in significant portion of e-waste still ending up in landfills or incinerators. In addition, even the recyclables can only be recycled a limited number of times due to degradation [16].

d) Non-existence of recycling infrastructure**:** In Nigeria, development of e-waste recycling infrastructure has not kept pace with generation of e-waste stream. Nigeria lacks the necessary infrastructure for e-waste recycling. This lack of infrastructure can make it inconvenient for people to recycle, leading to a lower participation rates and increased reliance on landfill disposal. Again, this lack of infrastructure allows the participants to rely on environmentally unsound practices, backyard recycling techniques, for example, uncontrolled open burning of cables to recover copper wire and disposal at dumpsites.

e) Lack of standardized regulations**:** The lack of standard regulations of e-waste recycling is another key challenge. Different countries of the world have different rules, regarding what can and cannot be recycled, leading to confusion and inefficiency. In Nigeria, e-waste is usually considered as part of general domestic waste, the consequence is that it ends up in landfill and very insignificant percentage are recycled using local and environmentally unsound practices.

f) Lack of proper education and awareness**:** Many people in Nigeria are unaware of the idea of recycling, hence unsure of what goes into the recycling bin. This often leads to recyclables going into the trash and trash going into the recycling bin.

g) Limited market for recycled products and materials: This specifically refers to limited market demand for recycled or fairly used or OK products.

h) Health Risks for Workers: The recycling of e-waste can pose health risks for workers involved in the process. E-waste often contains hazardous substances such as lead (Pb), mercury (Hg) and cadmium (Cd). Workers who are exposed to these substances without protective measures can face serious risks, since these hazardous substances can lead to various health problems. Therefore, ensuring the safety of workers in e-waste recycling facilities is a significant challenge.

i) Environmental Impact: While recycling e-waste reduces the need for landfill space and the extraction of new raw materials, it is not without its environmental impacts. The recycling process itself requires energy and can generate pollutants. For example, shredding e-waste can produce dust particles that contribute to air pollution. Similarly, the use of water in the recycling process can lead to generation of waste-water that needs to be treated before it is released into the environment.

ix) Ways to Overcome Challenges of E-waste in Nigeria

Proper handling and recycling of e-waste are essential to mitigate its adverse effects on the planet and public health, and consequently promote a sustainable approach to technology consumption[17]. To address the challenges of e-waste recycling in Nigeria and thus pave the way for a cleaner and greener future, the following are essential;

a) Domestic markets for recycled materials need to be strengthened in Nigeria. This call for improving communication among the different sectors of the recycling system. This is needed to strengthen the development of existing materials markets and to develop new innovative markets. Again, communication between the manufacturers of new products and devices; and the recycling industry needs to be improved to prepare for and optimally manage the recycling of new products and materials.

b) Investment in infrastructure: The solution to lack of infrastructure requires development of robust infrastructure that encompasses the entire life-cycle of e-waste, from collection to recycling and disposal. This means investment in the development and improvement of e-waste recycling infrastructure is crucial. Government and organizations need to allocate resources for the establishment of state-of-the art recycling plants that can safely handle and extract valuable components from e-waste.

c) The challenge of lack of awareness can be tackled by increasing consumer education and awareness, Public campaigns can play a crucial role in informing public about the environmental and health risks associated with improper e-waste disposal. Furthermore, raising awareness among the general public about the dangers of informal recycling practices is essential. Educating individuals about the importance of responsible e-waste management and the availability of formal recycling options can encourage them to make informed choices, and dispose of their e-waste devices properly. Educating health workers across all levels on e-waste related child health issues [2].

d) The environmentally-unsound practices as informal recycling practices can be completely eradicated through a collaborative effort involving government, regulatory bodies, recycling industries, and the general public to ensure the sustainable disposal and recycling of e-waste.

e) In addition, it is essential to formalize and regulate the e-waste recycling process. By implementing strict standards and guidelines, authorities can ensure that recycling facilities adhere to proper practices that priorities the health and safety of workers. This would involve providing training and guidance to recyclers as well as promoting the use of safer methods.

f) The following are recommendations adapted from Obaje [18] in previous research studies.

i) The National Environmental Standards and Regulations Enforcement Agency (NESREA) Regulations 2011 is a laudable legislative document which is in line and complements the Basel Convention. The Basel Convention controls the trans-boundary movement of hazardous waste and their disposal.

ii) Nigeria should develop national e-waste collection centres and e-waste recycling infrastructure.

iii) Nigeria through NESREA should monitor e-waste sites and communities.

iv) There is urgent need for development of local capacity for the recovery of copper, steel, lead, gold, platinum, silver, plastics *etc* from e-waste [19].

v) The concerned federal agency should create incentives to encourage citizens to shun e-waste and willingness to release all e-waste in their possession.

vi) Initiate awareness campaigns in local and indigenous languages on the dangers of e-waste to human and environmental health.

vii) Nigerian government should ban all import of EEE labeled products for repair or refurbishing from entering the country.

viii) Development of national database infrastructure on e-waste recycling in Nigeria.

Conclusion

From the foregoing, it is obvious that recycling e-waste is crucial for mitigating the environmental and health impacts of WEEE. It is however clear that the process is not without its challenges. The challenges of recycling e-wastes do not negate its benefits. The recycling of e-waste is still a vital part of sustainable waste management. It is important to recognize the urgency of addressing this issue, by proffering viable solutions to the challenges. To address this issue, it is essential to formalize and regulate the e-waste recycling process. This can be achieved by implementing strict national and inter- national standards and guidelines. Authorities can ensure development of state-of-the-art recycling infrastructure and that the recycling facilities adhere to proper practices that prioritize the health and safety of workers. This would involve improving consumer education and awareness, providing training and guidance to recyclers as well as promoting the use of safer methods.

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