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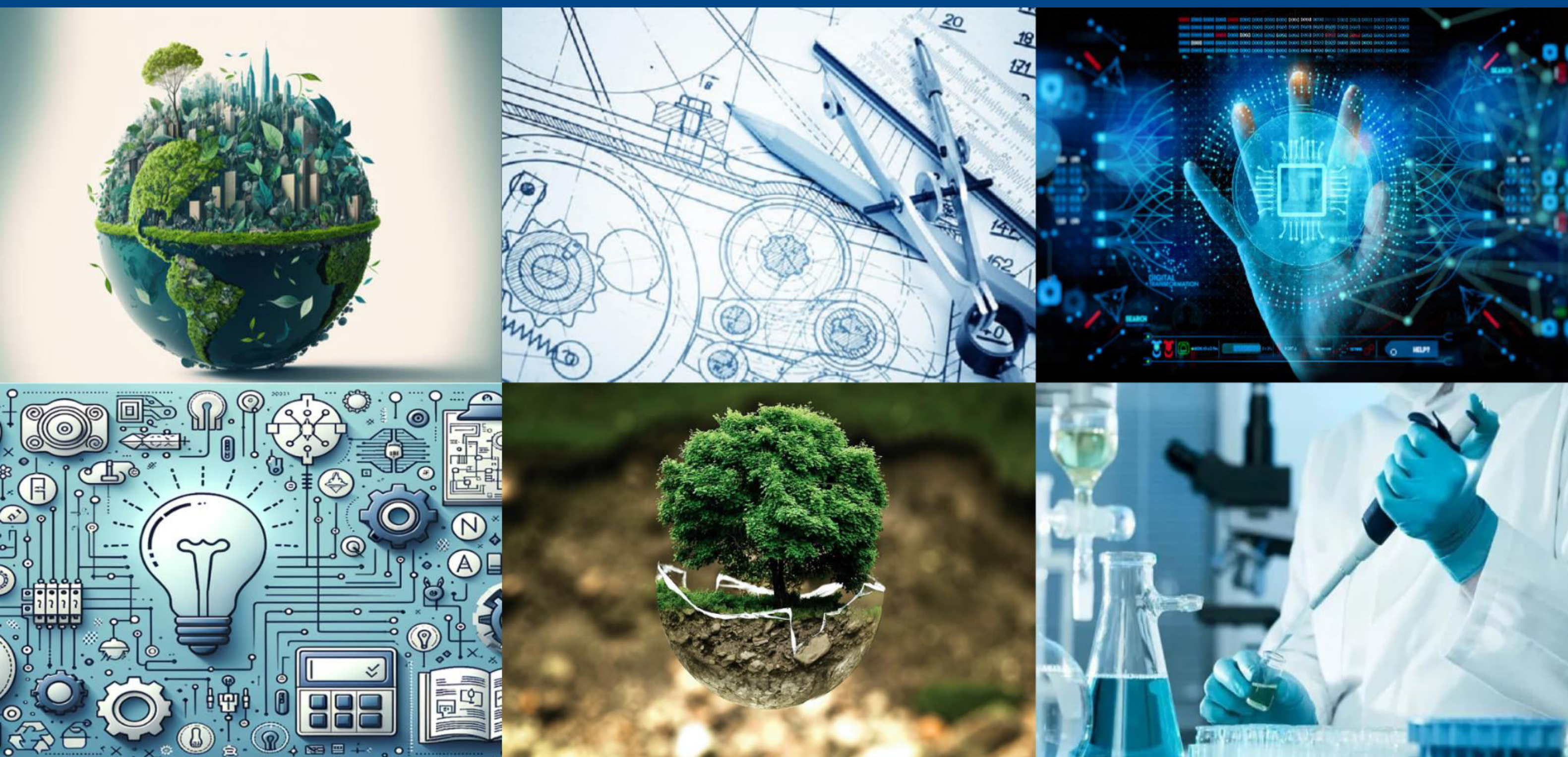

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A Systematic Review of the Human Burden of E-Waste Exposure in Nigeria

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ABSTRACT: Electronic waste, commonly known as e-waste, has emerged as a major environmental and public health concern globally. Its swift increase presents considerable dangers, especially in nations such as Nigeria. This systematic review seeks to thoroughly investigate the impact of e-waste exposure on humans in Nigeria by evaluating current research on health consequences and associated elements. We analyzed five key studies that focus on e-waste and its effects on health in various environments, including electronic marketplaces, informal recycling areas, and neighboring communities. The studies included in our review reveal several alarming patterns. Both work-related and home exposure to e-waste in prominent electronic markets has been linked to negative health outcomes, such as respiratory problems and other chronic diseases. Environmental evaluations indicate significant noncancer health risks due to contact with hazardous metals like lead and chromium in indoor dust, which primarily impact children. Additional research highlights a rise in lipid levels and atherogenic indices among workers in the e-waste sector, suggesting an elevated risk for cardiovascular illnesses. Moreover, there is evidence indicating that exposure to e-waste may cause genotoxic effects, oxidative stress, and a potential increase in cancer risk. This review emphasizes the difficulties surrounding e-waste management, such as the widespread existence of informal recycling methods, complex characteristics of the waste, and an absence of strong regulatory systems. These issues lead to environmental contamination and direct health threats, particularly within low-income communities. To tackle these challenges, it is essential to implement comprehensive policies, raise awareness, and enhance waste management strategies that prioritize both health and safety.

KEYWORDS: E-waste, Human burden, Exposure, Human health, Nigeria

I. INTRODUCTION

As stated by the OCED (Organization for Economic Cooperation and Development), any device powered by electricity that has reached the end of its usefulness falls under WEEE. WEEE, which stands for waste from electrical and electronic equipment, is a distinct type of waste that has garnered significant focus over the last 15 years. This type of waste is varied and intricate, involving different materials and components and relating to the original process of manufacturing the equipment (Reena & Sangita, 2011).

With advancements in technology, the duration that electrical and electronic equipment (EEE) can be used is getting shorter. From 1992 to 2005, the lifespan of computers reduced from 4. 5 years to just 2 years, leading to the production of vast amounts of e-waste, estimated at 20 to 50 million tons per year globally (Davis & Heart, 2008). In Nigeria, the increasing generation and management of e-waste present considerable challenges to environmental health and sustainability. Nigeria, which has a population exceeding 200 million and a quickly growing market for consumer electronics, is facing rising levels of e-waste, worsened by poor waste management systems and informal recycling methods (Awodele & Ogbudu, 2019). The practice of discarding e-waste in open landfills and informal recycling operations contributes to the pollution of the air, soil, and water. It also poses risks to individuals, particularly those

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working in waste management and residents of nearby areas, due to exposure to harmful chemicals and pollutants (Grant et al. , 2013).

Research conducted in Nigeria aims to shed light on the health impacts of e-waste exposure on humans. Alabi (2015) explored how the public perceives health risks from working in and living near e-waste sites in Lagos, Nigeria, discovering a notable rise in serious health issues for those near electronic markets and dump sites. Likewise, Igharo et al. (2020) studied how exposure to e-waste affects the lipid profile and cardiovascular health of waste electronic workers in SouthSouth Nigeria, noting the potential health threats connected with handling e-waste.

The e-waste issue in Nigeria is complex and has serious consequences for both the environment and public health. When e-waste is improperly disposed of, particularly in open dumps or through informal recycling, it can release toxic substances and pollutants, contaminating air, soil, and water. These pollutants, which include heavy metals, brominated flame retardants, and persistent organic pollutants (POPs), represent significant health hazards, especially for those living or working near e-waste sites or involved in informal recycling.

Despite these observations, there is still a notable lack of comprehensive studies on the human impacts of e-waste exposure in Nigeria. Most research tends to concentrate on specific locations or job categories, providing incomplete views of the wider health impacts and environmental dangers related to e-waste pollution. Additionally, there is insufficient integration of existing data to guide effective interventions and policy measures aimed at tackling the e-waste crisis in Nigeria.

This thorough review aims to fill these gaps by carrying out an extensive analysis of the current literature regarding the health risks of e-waste exposure in Nigeria. By combining results from various studies conducted in Nigeria, the review intends to clarify the health impacts and policy consequences of e-waste pollution. Through a systematic review and integration of information from different sources, such as peer-reviewed articles, reports, and gray literature, this study seeks to offer a complete understanding of the relationship between e-waste and human health in Nigeria. Consequently, this research examined the available literature on the human impact of electronic waste (e-waste) exposure in Nigeria.

II. ELECTRONIC WASTE

Electronic waste, often called e-waste, refers to a wide array of discarded electronic devices and electrical appliances that are no longer useful or functional (Balde et al. , 2020). Examples of e-waste include items such as computers, laptops, smartphones, tablets, televisions, refrigerators, washing machines, and other home devices with electronic parts. These items frequently have harmful substances, such as heavy metals, brominated flame retardants, and persistent organic pollutants (POPs), which can create serious health and environmental dangers if they are not handled correctly.

Several elements contribute to the creation of e-waste, such as rapid technological progress, growing consumer interest in electronic goods, and shorter life spans of products (Robinson, 2009). Quick technological changes and obsolescence lead to frequent upgrades and replacements of devices, resulting in a steady flow of unwanted electronics. Moreover, practices like planned obsolescence, where companies deliberately make products that do not last long to drive consumers towards newer models, further increase the e-waste problem (Baldé et al. , 2017).

E-waste comes from many sources, including homes, businesses, industries, and government sectors, with each area adding to the total e-waste amount. The growing issue of e-waste has caused significant environmental pollution, especially in developing countries where informal recycling methods are widely used (Grant et al. , 2013). The Global E-waste Monitor reported that around 53. 6 million metric tons of e-waste were produced globally in 2019, with merely 17. 4% being recycled through official systems (Baldé et al. , 2020). Mishandling and discarding e-waste improperly leads to the release of toxic materials into the surroundings, affecting air, soil, and water and creating health hazards for people.

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2.1. Historical Background and Evolution of E-Waste Management

The handling of electronic waste, or e-waste, has undergone significant transformation in recent decades, mainly due to the increasing production and disposal of electronic devices. The roots of e-waste management can be found after World War II, a period characterized by a notable rise in the creation and consumption of electronic goods. In the aftermath of the war, advancements in technology combined with economic growth led to the widespread manufacturing and use of gadgets such as televisions, radios, and home appliances. During this period, however, there was little attention given to the harmful environmental impacts associated with the disposal of electronic waste.

As the 20th century approached its end, growing concerns regarding pollution and risks to human health prompted a more detailed evaluation of e-waste management practices. Issues arose about the disposal of electronic devices containing dangerous materials in landfills and incineration, which could result in soil and water contamination, air quality problems, and exposure to hazardous substances. In response, governments and international organizations began to implement regulations and policies aimed at enhancing e-waste management on a global scale. A significant agreement in this regard was the Basel Convention, which was ratified in 1989, marking one of the earliest international efforts to address the importance of coordinated e-waste management. This convention concentrated on controlling the transboundary movement of hazardous waste, including e-waste, and promoted environmentally sound disposal practices. It laid the groundwork for future initiatives aimed at mitigating the environmental and health hazards linked to e-waste disposal.

Over the years, there has been a gradual yet consistent shift toward more environmentally friendly e-waste management strategies, spurred by technological innovations, changes in consumer behavior, and heightened awareness of environmental concerns. Numerous regions have implemented recycling programs and set up e-waste collection points to ensure responsible disposal and recycling of electronic devices, facilitating the recovery of valuable materials and reducing the ecological impact of e-waste. However, several challenges remain, such as the prevalence of informal recycling methods, insufficient collection and recycling systems in certain areas, and the lack of comprehensive regulatory frameworks.

2.2. Types of E-Waste Devices

Ewaste includes a wide range of electronic items that are found in various environments like homes, businesses, industries, and government use. Some typical types of e-waste are:

Consumer Electronics: These are devices that people commonly use at home or in offices. Examples are televisions, computers, laptops, tablets, smartphones, digital cameras, and gaming consoles.

Home Appliances: Appliances used in the home that have electronic parts, such as refrigerators, washing machines, dryers, microwaves, air conditioners, and vacuum cleaners, greatly add to the amount of e-waste produced.

Office Equipment: Many electronic devices used in offices, such as printers, copiers, fax machines, scanners, and telephones, are often replaced because of new technology or changes in how businesses operate.

Industrial Equipment: Machinery and tools used in industries, including control systems, manufacturing equipment, lab instruments, and medical devices, also add to e-waste when they are outdated or stop working.

Entertainment Devices: Devices used for entertainment and multimedia, like DVD players, audio systems, speakers, projectors, and video game consoles, are often thrown away as newer versions are released.

2.3. Factors Influencing E-Waste Generation

The production of electronic waste is shaped by a variety of complicated factors, such as advancements in technology, consumer choices, product development, and economic elements. There are several main reasons that lead to the increase in e-waste:

Advancements in Technology: The fast pace of technological progress, highlighted by Moore's Law, suggests that the number of transistors on a microchip is expected to double roughly every two years, causing many electronic devices to become outdated quickly. With the introduction of new and improved products, older gadgets are commonly replaced or upgraded, which leads to a rise in e-waste.

Consumer Choices: The desire for the newest electronic devices fuels a cycle of buying and throwing away. Planned obsolescence is the practice where manufacturers purposely create products that have short lifespans to promote regular upgrades, which speeds up the production of e-waste. Moreover, the growth of throwaway electronics and one-time-use devices worsens the issue of accumulating e-waste.

Product Development: How electronic items are designed greatly affects how long they last, how easily they can be repaired, and how well they can be recycled. Products that are built with modular designs and standard parts are simpler to fix, update, and recycle, extending their duration of use and minimizing their environmental footprint. In contrast, items designed for planned obsolescence with unique components are more challenging and expensive to repair and recycle, contributing to early disposal and increased e-waste.

Economic Elements: Economic aspects, including production costs, labor expenses, and the price of raw materials, impact how manufacturers make choices about product design, pricing, and the management of product lifecycles. Economic incentives, such as financial support for recycling electronic waste and extended producer responsibility programs, can motivate manufacturers to embrace more sustainable methods and lower the creation of e-waste.

2.4. Composition and Materials Present in E-Waste

Electronic waste, often referred to as e-waste, consists of a wide variety of materials and components, many of which have both valuable and harmful characteristics.

Plastics

One of the most commonly found materials in e-waste is plastic, which makes up a large part of its overall structure. Different kinds of plastics are utilized in electronic gadgets because they are light, insulating, and protective. Typical plastic items in e-waste include cases, bezels, connectors, wires, and insulating materials. Nonetheless, the plastics present in e-waste can be mixed with harmful additives such as flame retardants and plasticizers, which can endanger both the environment and health when they are released during recycling or disposal (Schluep et al. , 2009).

Metals

E-waste is also largely made up of metals, including both ferrous and nonferrous types, each with unique properties and uses. Ferrous metals like iron and steel are frequently found in the structural parts, cases, and chassis of electronic equipment. Nonferrous metals such as aluminum, copper, gold, silver, and palladium are included in circuit boards, wiring, connectors, and semiconductor elements because of their good conductivity and resistance to corrosion (Widmer et al. , 2005). Although the metals within e-waste can be valuable for recycling, they may also contain harmful substances like lead, mercury, cadmium, and chromium, which can be detrimental to health and the environment if not handled correctly (Ongondo et al. , 2011).

Printed Circuit Boards (PCBs)

Printed circuit boards, known as PCBs, are essential elements of electronic devices that facilitate connectivity and functionality through parts like integrated circuits, resistors, capacitors, and other electronic elements. Typically, PCBs are made of fiberglass-reinforced epoxy resin bases with thin copper or other conductive metal layers on their surfaces. However, they also hold harmful materials, including brominated flame retardants, lead solder, and precious metals, which can complicate the recycling and disposal processes (Tsydenova & Bengtsson, 2011).

Glass

Glass is another material widely found in electronics, used for display screens, lenses, and protective covers because of its clarity, strength, and scratch resistance. In e-waste, glass components include cathode ray tubes (CRTs) from older televisions and monitors, liquid crystal displays (LCDs), and light-emitting diode (LED) panels. Although glass is generally inert and nontoxic, CRT glass can contain lead oxide as a stabilizing agent, leading to potential environmental and health concerns if not dealt with properly during recycling or disposal (Schluep et al., 2009).

Other Materials

Beyond plastics, metals, PCBs, and glass, e-waste may also include various other materials like ceramics, rubber, adhesives, and composites, which serve different functional and structural roles in electronic devices. Due to their mixed composition and complex recycling requirements, these materials can complicate efforts for recycling and recovery (Yamane et al. , 2009).

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2.5. E-Waste Management Approaches and Challenges in E-Waste Recycling Systems

Electronic waste management includes various methods that aim to lessen the health and environmental effects of thrown-away electronic devices while encouraging sustainable practices and recovering resources. The most effective way to handle e-waste is to minimize its quantity. Next, recycling and reusing materials can help lower e-waste (Ramachandra & Saira, 2004). By recovering metals, plastic, glass, and other elements, the overall amount of e-waste can be diminished. These methods can save energy and keep harmful substances from entering the environment. In Switzerland and other developed nations, Extended Producer Responsibility (EPR) and Advance Recycling Fee (ARF) serve as key components of the e-waste management system (Wath, et al. 2010).

Typically, strategies for managing e-waste involve a mix of recycling, reusing, refurbishing, and disposal techniques designed to cater to the different types and qualities of e-waste materials. The directives from the EU (2003) require all 27 member countries to recycle their ewaste. The Basel Convention is another important move by UNEP to regulate international trade in dangerous waste, and India is also a signatory to this agreement (Williams, et al. , 2008), (Pinto, 2008).

Extended producer responsibility

Extended Producer Responsibility, commonly known as EPR, is being promoted as a new way to handle waste. According to the OECD, EPR is defined as a method of environmental policy where the duties of a producer for a product extend to how that product is dealt with after it has been used, including its ultimate disposal (OECD. Extended producer responsibility 2001). In line with the principle that those who cause pollution should take on the costs, an EPR approach moves the burden from local governments and integrates the expenses of managing and disposing of products into their selling price, which accounts for the environmental effects they cause. More lawmakers are putting EPR policies into action to control different types of waste, like old cars, electronic devices, and batteries, which need special care and handling (OECD. Extended producer responsibility 2001).

2.5.1. Challenges in E-Waste Recycling Systems

Complex Composition: E-waste is made up of a diverse mixture of materials, parts, and harmful substances. This varied makeup creates problems for recycling, as each type of material needs unique handling, processing, and treatment techniques. Issues related to contamination and cross contamination also make recycling more difficult, especially in informal recycling settings.

Informal Recycling Sector: The informal recycling sector includes small-scale operations and unregistered workers, and it has an important role in recycling e-waste, especially in developing nations that lack established recycling systems. Nevertheless, informal recycling methods often do not meet health and environmental standards, resulting in risks from toxic substances, environmental harm, and social inequalities. To tackle the issues linked to informal recycling, it is essential to enforce regulations, build capacity, and connect these efforts to formal recycling networks.

Technological Obsolescence: The fast pace of technological progress and frequent updates to products lead to electronic devices becoming outdated quickly, which increases the amount of e-waste. Planned obsolescence, in which companies create products with short lifespans or limited compatibility, worsens the problem of e-waste production. To combat technological obsolescence, it is important to adopt innovative design methods, promote product durability, and educate consumers on sustainable consumption habits.

2.5.2. Capacity building, training and awareness programmes

The management of electronic waste in the future relies on not just the efficiency of local governments and those who run recycling services, but also on how citizens view the issue. Campaigns that promote teamwork are essential to make users aware, and consumers need to contribute financially towards the recycling of electronic items. It is important to inform consumers about their responsibilities in the system, which can be achieved through labeling requirements for products.

Consumers must be taught to purchase only what they truly need, focusing on products that incorporate new technologies such as lead-free materials, halogen-free components, and recycled plastics. To promote better management practices, initiatives and programs to raise awareness about the safe and environmentally friendly handling of e-waste, along with health and safety issues, should be carried out for various groups.

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2.6 Health Impacts of E-Wastes

E-waste poses a greater danger compared to various other types of waste produced by cities. Electronic devices have countless parts composed of harmful chemicals and metals such as lead, cadmium, chromium, mercury, PVC, brominated flame retardants, beryllium, antimony, and phthalates. Prolonged contact with these materials harms the nervous system, kidneys, and bones, as well as affecting the reproductive and endocrine systems. Moreover, some of these substances can cause cancer and damage the nervous system.

Table.1 Composition of metals for different e-scrap samples (Jha, et al 2011)

S/N	Electronic waste	Weight (%)					Weight (ppm)		
		Fe	Cu	Al	Pb	Ni	Ag	Au	Pd
1.	TV board scrap	28	10	10	1	0.3	280	20	10
2.	PC board scrap	7	20	5	1.5	1	1000	250	110
3.	Mobil phone scrap	5	13	1	0.3	0.1	1380	350	210
4.	Portable audio scrap	23	21	1	0.14	0.03	150	10	44
5.	DVD player scrap	62	5	2	0.1	0.05	115	15	4
6.	Calculator scrap	4	3	5	0.1	0.5	260	50	5
7.	PC main boar scrap	4.5	14.3	2.8	2.2	1.1	639	566	124
8.	Printed circuit board scrap	12	10	7	1.2	0.85	280	110	NR
9.	TV scrap (CRTs removed)	NR	3.4	1.2	0.2	0.038	20	<10	<10
10.	Electronic scrap	8.3	8.5	0.71	3.15	2.0	29	12	NR
11.	PC scrap	20	7	14	6	0.85	189	16	3
12.	Typical electronic scrap	8	20	2	2	2	2000	1000	50
13.	E- scrap sample 1	37.4	18.2	19	1.6	NR	6	12	NR
14.	E- scrap sample 2	27.3	16.4	11.0	1.4	NR	210	150	20
15.	Printed circuit board	5.3	26.8	1.9	NR	0.14	3300	80	NR
16.	E-scrap (1972 sample)	26.2	18.6	NR	NR	NR	1800	220	30
17.	E-waste mixture	36	4.1	4.9	0.29	1.0	NR	NR	NR

Table.2 Effects of E-waste constituent on health (Sastry & Murthy, 2012)

s/n	Source of E-wastes	Constituent	Health effects
1.	Solder in printed circuit boards, glass panels and gaskets in computer monitors	Lead (PB)	Damage to central and peripheral nervous systems blood systems and kidney damage. Affects brain development of children.
2.	Chip resistors and semiconductors	Candmium (CD)	Toxic irreversible effects on human health. Accumulated in kindly and liver. Causes neural damage. Teratogenic
3.	Relays and switches, printed circuit boards	Mercury (Hg)	Chronic damage to the brain. Respiratory and skin disorders due to bioaccumulation in fishes.
4.	Corrosion protection of untreated and galvanized steel plates, decorator or hardener for steel housings	Hexavalent chromium (Cr) VI	Asthmatic bronchitis. DNA damage.
5.	Cabling and computer housing	Plastics including PVC	Burning produces dioxin. It causes Reproductive and developmental problems; Immune systems damage; Interfere with regulatory hormones
6.	Plastic housing of electronic equipment's and circuit boards.	Brominated flame retardants (BFR)	Disrupts endocrine system function

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7.	Front panel of CRTs	Barium (Ba)	Short term exposure causes: Muscle weakness; Damage to heart, liver and spleen.
8.	Motherboard	Beryllium (Be)	Carcinogenic (lung cancer) Inhalation fumes and dust. Causes chronic beryllium disease of beryllicosis. Skin diseases such as warts.

In 2005, Greenpeace carried out research in electronic recycling sites located in Delhi. The findings show that there are significant amounts of dangerous chemicals such as harmful dioxins and furans in the regions where this basic recycling happens. Workers involved in the e-waste disposal industry have insufficient protection against these dangers, according to Saoji, A. (2012).

2.7 Environmental Impacts of E-Wastes

Electronic waste poses a significant threat to the environment because toxic materials are used in the production of electronic devices (Mehra, 2004). E-waste comprises harmful substances, including Lead and Cadmium found in circuit boards; Lead oxide and Cadmium present in monitor Cathode Ray Tubes (CRTs); Mercury used in switches and flat screen displays; Cadmium located in computer batteries; polychlorinated biphenyls (PCBs) which are in older capacitors and transformers; and brominated flame retardants on printed circuit boards, plastics, cables, and polyvinyl chloride (PVC) cable insulation that release dangerous dioxins and furans when burnt to extract Copper from the wires (Devi, et al. , 2004).

Disposing of e-waste in landfills can result in the contamination of groundwater with lead. If a CRT is shattered and set on fire, it releases harmful gases into the environment (Ramachandra & Saira, 2004). The cadmium from just one mobile phone battery can contaminate 600 cubic meters of water (Trick, 2002). Furthermore, uncontrolled landfill fires could occur frequently in numerous countries.

2.8 Conclusion and Recommendations

The results underscore the critical necessity for improved regulations and enforcement related to e-waste management in Nigeria. Strategies should emphasize proper disposal methods, recycling programs, and minimizing harmful substances in electronic goods to lessen risks to health and the environment. Lawmakers must make it a priority to create and uphold health standards for workers involved in the e-waste recycling industry. This involves offering training on safe handling, access to protective gear, and ongoing health assessments to avoid work-related illnesses. Extensive public education campaigns are crucial to inform communities about the health dangers posed by e-waste exposure and to encourage proper disposal methods. Collaboration between government bodies, nonprofit groups, and educational organizations can increase awareness and enable individuals to take steps to lower e-waste pollution. Policies should motivate manufacturers to create products that last longer, are easier to recycle, and contain fewer harmful materials. Establishing extended producer responsibility (EPR) programs can motivate companies to manage the disposal of their products responsibly and to invest in environmentally friendly design and manufacturing practices.
In conclusion, this systematic review on e-waste and its impact on human health in Nigeria highlights the complex and varied nature of this issue. The findings indicate serious health threats linked to both occupational and environmental contact with e-waste, such as heart disease, genetic damage, and cancer risk. Tackling these issues necessitates a united effort from policymakers, public health officials, industry players, and community organizations to enhance regulations, improve waste management strategies, and increase public education. By implementing solutions based on evidence and encouraging cooperation across different sectors, Nigeria can alleviate the negative health impacts of e-waste exposure and support sustainable development for generations to come.

Recommendations

Ongoing funding for research and monitoring programs is crucial to keep track of the health impacts from e-waste exposure, spot new dangers, and guide interventions based on solid evidence. Longterm studies that follow the health of affected groups over time can offer important information about the lasting effects of e-waste contamination.
It is advised that the government enhance the skills of healthcare workers, environmental officials, and waste management specialists to tackle the issues that e-waste brings. Through training sessions, workshops, and platforms

for sharing information, the awareness, technical skills, and cooperation among those working on e-waste management and public health can be improved.

Given that e-waste pollution crosses borders, global teamwork and sharing knowledge are crucial to tackle this worldwide e-waste problem. Nigeria should work together with regional and international organizations to exchange successful strategies, utilize technical knowledge, and gather resources for effective e-waste management programs.

Lastly, empowering communities impacted by e-waste pollution is vital for fostering environmental fairness and strength. Initiatives led by the community, processes that involve everyone in decision-making, and programs that build skills can enable people to stand up for their rights, hold policymakers responsible, and play an active role in efforts to decrease e-waste pollution and its effects on people.

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