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RESEARCH ARTICLE

Human Health and Environmental Impact of Electronic Waste in Hadejia Metropolis, Jigawa State, Nigeria

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ABSTRACT

This study examined the impact of electronic waste (e-waste) disposal on human health and environmental quality in Hadejia. The rapid increase in the use of electrical and electronic equipment has resulted in a corresponding rise in e-waste generation, which poses significant environmental and public health challenges, especially in developing urban areas where waste management systems are inadequate. The study specifically assessed current e-waste disposal practices, evaluated the environmental and health effects of improper disposal, and identified factors influencing e-waste management within the study area. A descriptive survey research design was adopted, and data were collected from 150 respondents using structured questionnaires, interviews, and field observations. Data were analyzed using descriptive statistics such as frequencies and percentages, while inferential analysis was conducted using the Chi-square test to determine the relationship between e-waste disposal practices and socio-economic sustainability. Findings revealed that a majority of respondents engaged in improper e-waste disposal practices such as open dumping and burning. The study further showed that improper e-waste management significantly contributes to environmental pollution, including soil, water, and air contamination, as well as health risks such as respiratory disorders and skin diseases. The Chi-square analysis indicated a statistically significant relationship between e-waste disposal and socio-economic sustainability. The study concludes that inadequate e-waste management practices pose serious threats to environmental quality and human health in the study area. It recommends strengthened environmental regulation enforcement, establishment of recycling facilities, increased public awareness, and promotion of sustainable e-waste management practices to mitigate environmental and health risks associated with electronic waste disposal.

Keywords: *E-waste; Environmental pollution; Human health; Waste management; Sustainability; Hadejia Metropolis*

1. INTRODUCTION

Electronic waste (e-waste) has become one of the fastest-growing waste streams globally due to rapid technological advancement, urbanization, industrialization, and increasing consumer demand for electrical and electronic devices. E-waste comprises discarded electrical and electronic equipment (EEE), including computers, mobile phones, televisions, refrigerators, printers, batteries, electric cables, and other household appliances that have reached the end of their useful life (STEP, 2014). According to the United Nations Environment Programme, e-waste includes both complete electronic devices and their components that are discarded after use.

Globally, e-waste generation has increased dramatically over the past two decades as a result of rapid expansion in information and communication technologies, shorter product life cycles, and changing consumption patterns. The Global E-waste Statistics Partnership reported that more than 62 million metric tonnes of e-waste were generated worldwide in 2022, with the volume expected to continue increasing (UNITAR, 2024). However, only a small proportion is formally collected and recycled, while a substantial amount is disposed of through open dumping, burning, or unsafe recycling practices, particularly in developing countries.

In Africa, electronic waste management remains a major environmental and public health concern because many countries lack adequate recycling facilities, effective regulatory frameworks, and environmental monitoring systems. Nigeria is among the leading importers and users of second-hand electrical and electronic equipment in Africa. Although these products improve access to affordable technology, many rapidly become obsolete and contribute significantly to increasing e-waste volumes (Baldé et al., 2017). Consequently, improper handling and disposal of e-waste expose communities to severe environmental contamination and health risks.

Rapid urbanization and population growth have further intensified waste management challenges in Nigeria. While major cities such as Lagos, Port Harcourt, and Onitsha have received considerable research attention, similar challenges are increasingly evident in emerging urban centres such as Hadejia, where rising ownership of electronic devices has accelerated the generation of electronic waste.

2. LITERATURE REVIEW

Electronic waste contains valuable materials such as copper, aluminium, silver, and gold, alongside hazardous substances including lead, cadmium, mercury, chromium, and brominated flame retardants (Forti et al., 2020). Improper disposal methods such as open burning, indiscriminate dumping, and informal recycling release these toxic substances into the environment, contaminating soil, water, and air. Exposure to these contaminants has been associated with respiratory illnesses, neurological disorders, kidney damage, reproductive complications, skin diseases, and various forms of cancer (WHO, 2021).

In many Nigerian communities, e-waste is commonly disposed of in open spaces, drainage channels, roadsides, and water bodies without adequate environmental safeguards. Informal recyclers frequently burn electronic components to recover valuable metals, releasing hazardous emissions into the atmosphere. Such practices contribute significantly to environmental pollution and threaten ecosystem integrity as well as public health (Awasthi et al., 2019).

One of the major concerns associated with e-waste management is the unsafe handling of electronic materials by informal waste workers who often lack protective equipment and technical expertise. Exposure to toxic substances during dismantling and burning processes increases occupational health risks and environmental contamination (WHO, 2021). Toxic metals such as lead, mercury, cadmium, arsenic, and chromium may leach into soils and groundwater, while open burning generates harmful gases and particulate matter that degrade air quality and contribute to climate-related environmental impacts (Awasthi et al., 2019).

In Hadejia Metropolis, increasing population growth, urban expansion, commercialization, and technological advancement have contributed to rising quantities of electronic waste. Despite this increase, effective systems for collection, recycling, and environmentally sound disposal remain inadequate. Existing waste management infrastructure is insufficient to accommodate the growing volume of discarded electronic materials, resulting in widespread open dumping and environmentally unsafe disposal practices.

Although several studies have investigated e-waste management in major Nigerian cities, relatively little empirical evidence exists for smaller urban centres such as Hadejia. Consequently, there is limited information regarding prevailing disposal practices, environmental contamination, associated human health risks, and public awareness within Jigawa State. This knowledge gap constrains evidence-based planning and policy formulation for sustainable e-waste management. From a geographical perspective, understanding the spatial dimensions, environmental consequences, and socio-economic implications of e-waste disposal is essential for promoting sustainable urban environmental management.

This study aims to assess the impact of electronic waste disposal on human health and environmental quality in Hadejia Metropolis, Jigawa State, Nigeria. The study seeks to examine the current practices of e-waste disposal, evaluate the effects of improper e-waste management on humans and the environment, identify factors influencing electronic waste disposal within the study area, determine whether improper disposal has any significant impact on economic sustainability, and assess how improved sustainable e-waste disposal practices can contribute to the economic development process in the Study Area.

3. MATERIALS AND METHODS

Study Area

The study was conducted in Hadejia, located in Hadejia Local Government Area of Jigawa State, northwestern Nigeria. Hadejia lies within the semi-arid ecological zone of northern Nigeria. The area forms part of the Hadejia-Nguru Wetlands, an internationally recognized wetland ecosystem of ecological, agricultural, and socio-economic importance. The wetlands support irrigation farming, fishing, livestock grazing, and biodiversity conservation, thereby serving as an important source of livelihood for millions of people within the Komadugu-Yobe Basin (UNDP, 2022; Ramsar Convention Secretariat, 2023).

Hadejia experiences a semi-arid tropical climate characterized by distinct wet and dry seasons influenced by the seasonal movement of the Inter-Tropical Convergence Zone (ITCZ). Rainfall generally begins between May and June and ends around September or October, with annual rainfall ranging from 500 mm to 700 mm (Nigerian Meteorological Agency, 2023). The rainfall pattern is highly seasonal and variable, which significantly affects agricultural production, water availability, and environmental conditions within the area. According to Ibrahim *et al.* (2022), climatic variability and irregular rainfall patterns have increased environmental vulnerability and resource pressure in many semi-arid regions of northern Nigeria.

Temperature in the area is generally high throughout the year due to its location within the Sudan Savannah ecological belt. Mean annual temperature ranges between 25°C and 32°C, while temperatures may exceed 40°C during the hot dry season,

particularly between March and May (Nigerian Meteorological Agency, 2023). Relative humidity is higher during the rainy season and significantly lower during the Harmattan season when dry continental winds blow from the Sahara Desert. These climatic conditions contribute to high evapotranspiration rates and environmental stress within the region (Usman & Salisu, 2021).

The relief of the area is generally low, flat, and undulating with extensive floodplains associated with the Hadejia River system. The geology is dominated by unconsolidated sediments of the Chad Formation, consisting mainly of sand, silt, and clay deposits (Muhammad *et al.,* 2020). Soils in the area are predominantly sandy and sandy-loam, supporting both rain-fed and irrigated agriculture. Hydromorphic soils also occur within low-lying wetlands and floodplain environments. These soils are important for crop cultivation but are increasingly vulnerable to pollution resulting from urbanization and improper waste disposal activities.

Vegetation within the area is mainly Sudan Savannah, characterized by scattered drought-resistant trees, shrubs, and grasses. Common plant species include Acacia species, *Balanites aegyptiaca, Tamarindus indica*, and *Adansonia digitata,* while wetland vegetation such as Typha grass and aquatic plant species dominate marshy environments (Abubakar *et al.,* 2022). According to Bello *et al.* (2023), increasing anthropogenic activities such as indiscriminate waste disposal, deforestation, overgrazing, and urban expansion have negatively affected vegetation cover and ecosystem stability within the Hadejia-Nguru wetlands.

Hydrologically, the area is strongly influenced by the Hadejia-Jama'are river system, which contributes significantly to wetland formation and seasonal flooding. The wetlands provide water resources for irrigation farming, fishing, livestock rearing, and domestic activities. Seasonal flooding also supports agricultural productivity and biodiversity conservation within the area (Sobowale *et al.,* 2021). However, increasing human activities, urbanization, climate variability, and poor waste management practices have contributed to environmental degradation, water pollution, and ecological stress in the wetland ecosystem (UNEP, 2023).

The population of Hadejia consists mainly of Hausa, Fulani, Kanuri, and Bade ethnic groups. The major occupations of the inhabitants include farming, fishing, livestock rearing, trading, and small-scale commercial activities. Rapid population growth, urban expansion, and increased use of electrical and electronic devices have contributed to rising volumes of electronic waste within the metropolis. Informal disposal and open dumping of e-waste materials are becoming increasingly common due to inadequate waste management infrastructure and low public awareness regarding environmental hazards (World Bank, 2023). These conditions make Hadejia suitable for investigating the impact of electronic waste disposal on human health and environmental quality.

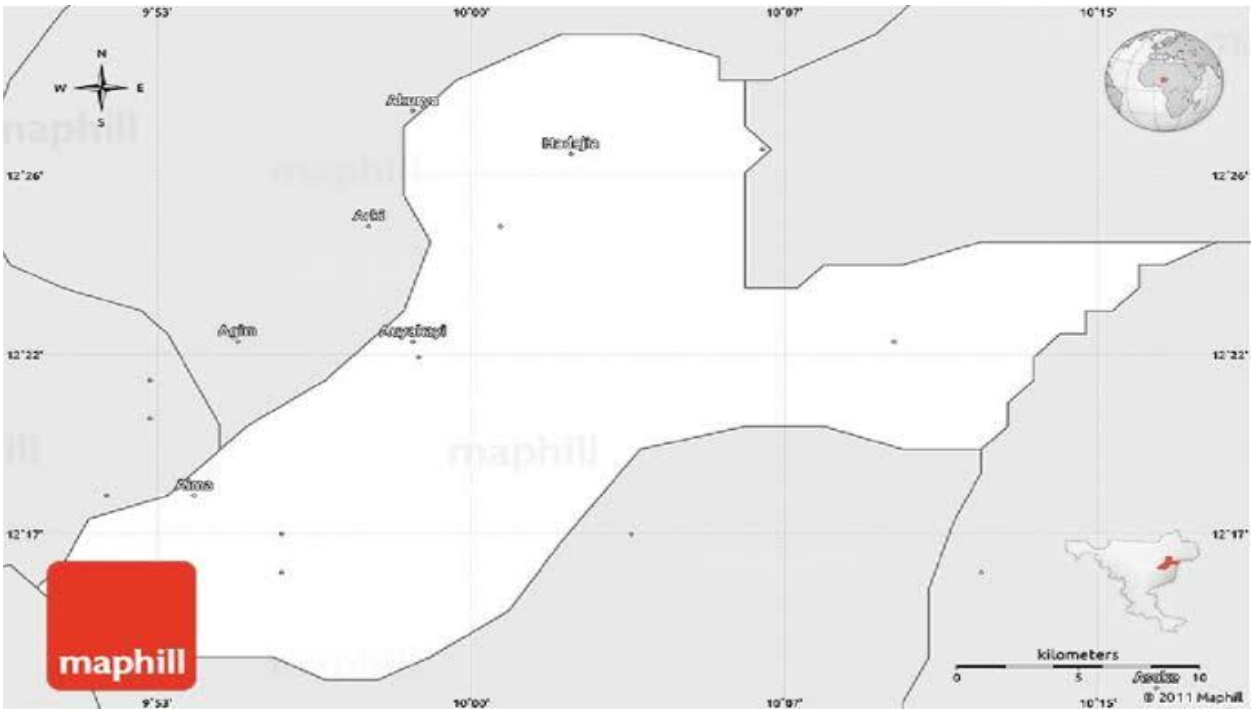

Figure 1. Map of Jigawa State Showing Hadejia Metropolis (Source: Maphill, 2026)

Research Design

This study adopted a descriptive survey research design to assess the impact of electronic waste disposal on human health and environmental quality in Hadejia. The descriptive survey design was considered appropriate because it enables the researcher to obtain detailed information on existing e-waste disposal practices, environmental conditions, and health-related issues within the study area. The design also facilitates the collection of quantitative and qualitative data from respondents regarding the effects of improper e-waste management and factors influencing electronic waste disposal practices. According to John W. Creswell (2014), descriptive survey research is suitable for studies aimed at describing current situations, behaviors, attitudes, and environmental conditions within a population.

Population of the Study

The population of the study comprised residents, traders, electronic repair technicians, waste handlers, scavengers, and users of electrical and electronic devices within Hadejia Metropolis who are directly or indirectly involved in the generation, handling, or disposal of electronic waste. The study also included environmental officials and community leaders with knowledge of waste management practices within the area. A total population of 200 respondents was considered for the study.

Sample Size and Sampling Technique

The sample size for this study was determined using the Taro Yamane (1967) formula, which is widely used for calculating sample sizes from finite populations. The formula provides a scientifically acceptable sample that adequately represents the study population while maintaining a specified level of precision.

Taro Yamane formula, $n = \frac{N}{1+N(e)^2}$ ..... (Eqn. 1)

Where:

n = required sample size

N = total population of the study

e = Level of precision (Sampling error), usually 0.05 (5%) at a 95% confidence level

1 = Constant

This formula was adopted because it is simple, reliable, and suitable for descriptive survey research involving finite populations. It ensures that the selected sample is sufficiently representative of the target population while minimizing sampling error. The calculated sample size for the study was 133 respondents. The study employed simple random sampling and purposive sampling techniques. Simple random sampling was used to select household respondents and residents within the study area to ensure equal chances of participation. Purposive sampling was used to select key informants such as environmental health officers, waste collectors, electronic repair technicians, and community leaders who possess relevant knowledge regarding e-waste disposal practices and environmental challenges in Hadejia Metropolis.

Method of Data Collection

Data for the study were collected from both primary and secondary sources. Primary data were obtained through structured questionnaires, semi-structured interviews, and direct field observations. The questionnaire was designed based on the objectives of the study and consisted of sections covering socio-demographic characteristics of respondents, types and sources of electronic waste, methods of e-waste disposal, awareness of environmental and health effects, and factors influencing e-waste management practices within the study area.

Semi-structured interviews were conducted with environmental officers, waste handlers, electronic repair technicians, and community leaders to obtain additional qualitative information regarding the environmental impacts of electronic waste disposal, existing waste management practices, and challenges associated with e-waste management in the area. Direct observations were also carried out at dumping sites, drainage channels, repair workshops, and other locations where electronic waste materials are commonly disposed of in order to assess the environmental condition of the study area.

Secondary data were obtained from textbooks, journal articles, conference papers, government publications, internet materials, and reports from relevant organizations such as the World Health Organization, United Nations Environment Programme, and National Environmental Standards and Regulations Enforcement Agency. These materials provided relevant literature and empirical information related to e-waste management, environmental pollution, and public health.

Validation of Research Instrument

The questionnaire used for data collection was validated by experts in environmental management and research methodology to ensure clarity, relevance, and reliability of the research instrument. Necessary corrections and modifications suggested during the validation process were incorporated before the final administration of the questionnaire.

Method of Data Analysis

Data collected from the field were coded, classified, and analyzed using descriptive statistical techniques. Frequencies, percentages, tables, and charts were used to present and interpret the data collected in relation to the objectives of the study. The analysis focused on identifying the prevailing methods of e-waste disposal, examining the environmental and health effects associated with improper disposal practices, and assessing factors influencing electronic waste management in Hadejia Metropolis. Statistical analysis was conducted using SPSS version 25 and Microsoft Excel. The use of these software applications improved the accuracy, reliability, and efficiency of data analysis and presentation.

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4. RESULTS AND DISCUSSION

Socio-Demographic Characteristics of Respondents

Table 1 presents the socio-demographic characteristics of the respondents involved in the study. The variables considered include gender, age, marital status, and educational qualification of the respondents within Hadejia.

Table 1. Socio-Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	90	60.00
	Female	60	40.00
Age	21–30 years	86	57.33
	31–40 years	43	28.67
	41–50 years	21	14.00
Marital Status	Single	24	16.00
	Engaged	41	27.33
	Married	76	50.67
	Divorced	9	6.00
Educational Qualification	ND	26	17.33
	Non-Formal Education	31	20.67
	Primary	27	18.00
	Secondary	31	20.67
	Tertiary	23	15.33
	Qur'anic	12	8.00

The socio-demographic results indicate that male respondents constituted the majority with 60.00%, while female respondents accounted for 40.00%. This suggests active participation of both genders in issues relating to environmental management and electronic waste disposal within the study area. The age distribution showed that the majority of respondents (57.33%) were between 21 and 30 years, indicating that young adults constitute the most active population group exposed to electronic device usage and waste generation. Respondents within the age range of 31–40 years accounted for 28.67%, while 14.00% were between 41 and 50 years.

Regarding marital status, 50.67% of respondents were married, 27.33% were engaged, 16.00% were single, and 6.00% were divorced. The educational status of respondents revealed that a substantial proportion possessed tertiary education qualifications. Respondents with non-formal and secondary qualifications each constituted 20.67%, while Primary holders represented 18.00%, tertiary holders represented 15.33%, and Qur'an holders constituted 8.00%. The relatively moderate literacy level among respondents suggests that most participants possess moderate awareness regarding environmental issues and electronic waste management practices. Similar observations were reported by Oteng-Ababio Martin (2012), who noted that educational attainment significantly influences environmental awareness and waste disposal behavior in urban African communities.

Current State of E-Waste Disposal in Hadejia Metropolis

Table 2. Respondents' Perception on the Current State of E-Waste Disposal

Response	Frequency	Percentage (%)
Properly managed	61	40.67
Poorly managed	89	59.33
Total	150	100

The findings in Table 2 revealed that 59.33% of respondents perceived the current state of e-waste disposal in Hadejia Metropolis as poorly managed, while only 40.67% believed that e-waste disposal practices were properly managed. This indicates the existence of inadequate waste collection systems, absence of formal recycling facilities, and indiscriminate dumping of obsolete electronic devices within the metropolis. Improper disposal practices observed during fieldwork

included open dumping, roadside disposal, burning of electronic components, and mixing e-waste with municipal solid waste.

The results support findings by Rolf Widmer *et al.* (2005), who observed that developing countries experience increasing environmental challenges associated with poor e-waste management due to weak institutional frameworks and inadequate recycling infrastructure. Similarly, the World Health Organization (2021) reported that improper disposal of electronic waste contributes significantly to environmental contamination and public health risks in low- and middle-income countries.

Impact of E-Waste Disposal on Human Health and Environmental Quality

Figure 2 revealed that 64.00% of respondents agreed that improper disposal of electronic waste has significant impacts on environmental sustainability in Hadejia Metropolis, while 36.00% disagreed. The findings indicate growing public concern regarding environmental pollution associated with e-waste disposal practices. Respondents identified soil contamination, air pollution, blockage of drainage channels, and water pollution as major environmental problems linked to indiscriminate dumping and burning of electronic waste materials.

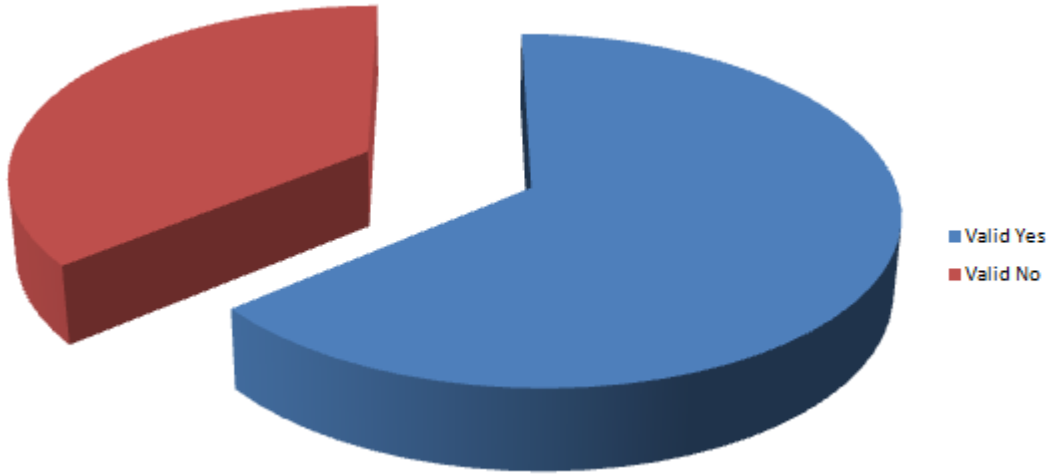

Figure 2. Impact of Improper E-Waste Disposal on Environmental Sustainability

The findings correspond with earlier studies by Richard Robinson (2009), who emphasized that toxic substances such as lead, cadmium, mercury, chromium, and brominated flame retardants released from electronic waste contaminate ecosystems and threaten biodiversity. Exposure to these toxic substances has been associated with respiratory diseases, skin irritation, neurological disorders, kidney damage, and reproductive health complications among populations exposed to polluted environments (Grant *et al.,* 2013).

Field observations further revealed that open burning of cables and electronic components is commonly practiced by informal recyclers to recover valuable metals such as copper and aluminum. This process releases hazardous gases and particulate matter into the atmosphere, thereby contributing to poor air quality and human health risks. According to the United Nations Environment Programme (2023), uncontrolled burning and dismantling of electronic waste represent major environmental hazards in rapidly urbanizing regions of Africa.

Factors Influencing E-Waste Disposal Practices

The findings indicated that several factors influence electronic waste disposal practices in Hadejia Metropolis. These include inadequate awareness regarding safe disposal methods, lack of formal recycling facilities, weak enforcement of environmental

regulations, poverty, urban population growth, and inadequate government intervention in waste management. Respondents also identified lack of designated collection centers and limited environmental education as major barriers to effective e-waste management.

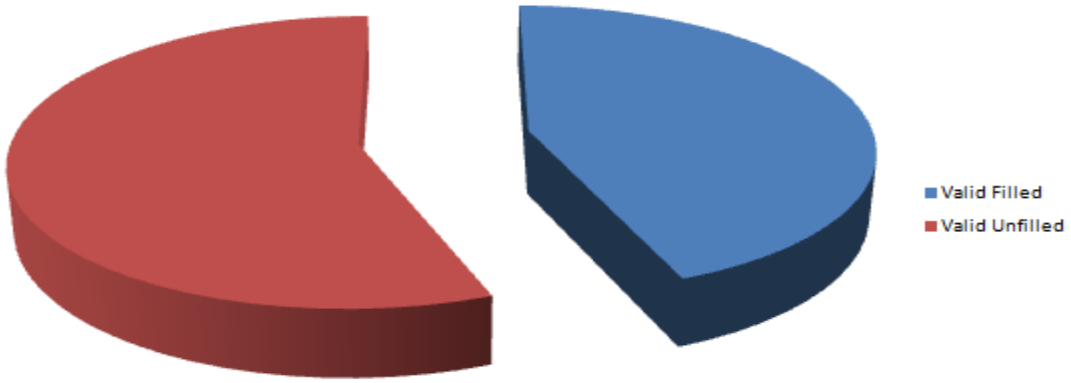

Figure 3. Factors Influencing E-Waste Disposal Practices

Economic conditions were also found to influence disposal behavior, as many individuals resort to selling obsolete electronic components to informal recyclers for income generation. Similar findings were reported by Borthakur Anwesha and Pardeep Singh (2013), who observed that poverty and inadequate waste infrastructure contribute significantly to informal e-waste recycling activities in developing countries.

The study further revealed weak implementation of environmental regulations relating to electronic waste management. Respondents indicated limited government monitoring and inadequate provision of waste management infrastructure within the study area. This finding agrees with Veena Sahajwalla (2020), who emphasized that ineffective policy enforcement remains a major obstacle to sustainable e-waste management in many developing economies.

Contribution of Sustainable E-Waste Disposal Practices to Human Health and Environmental Protection

Figure 4 showed that 60.67% of respondents believed that sustainable e-waste disposal practices could significantly improve environmental quality and human health within Hadejia Metropolis. Respondents emphasized the importance of public awareness campaigns, establishment of recycling centers, enforcement of environmental regulations, and promotion of environmentally friendly waste management systems.

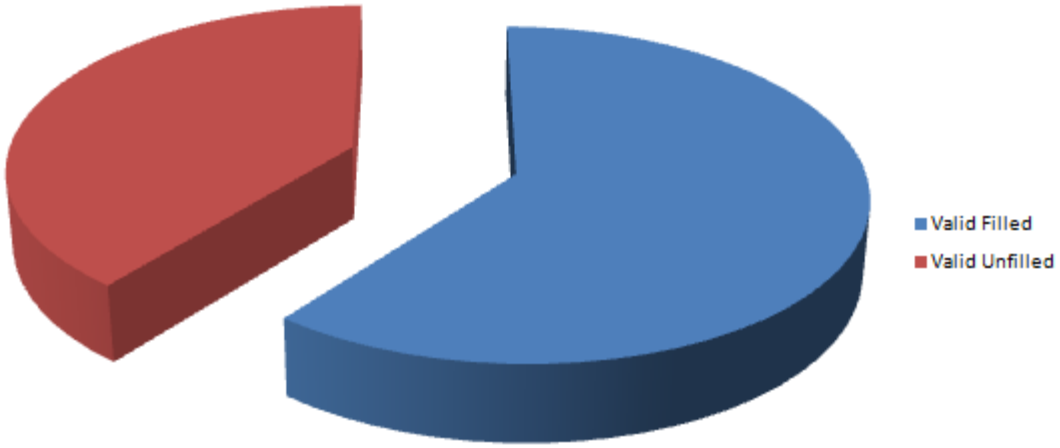

Figure 4. Contribution of Sustainable E-Waste Disposal Practices

Sustainable e-waste management practices such as recycling, reuse, proper segregation, and controlled disposal can reduce environmental pollution and minimize exposure to hazardous substances. According to the World Health Organization (2021), environmentally sound management of electronic waste is essential for protecting vulnerable populations, especially children and informal waste workers exposed to toxic materials.

The findings also revealed that improved e-waste management systems could contribute to economic development through job creation, resource recovery, and environmental sustainability. Formal recycling systems can create employment opportunities while reducing ecological degradation associated with indiscriminate disposal practices. This aligns with findings by Chi *et al.* (2011), who noted that integrated recycling systems contribute to sustainable urban development and environmental protection.

Test of Hypothesis

- H_0: There is no statistically significant relationship between e-waste disposal and socio-economic sustainability in Hadejia Metropolis.
- H_1: There is a statistically significant relationship between e-waste disposal and socio-economic sustainability in Hadejia Metropolis.

Table 3. Chi-Square Analysis of Relationship between E-Waste Disposal and Socio-Economic Sustainability

Response	Observed Frequency	Expected Frequency	Residual
Yes	83	50	33
No	40	50	-10
Undecided	27	50	-23
Total		150	

Table 4. Chi-Square Test Statistics

Variable	Value	Asymptotic Significance	Degree of Freedom (df)
Chi-Square	28.211	0.000	2

The Chi-square result showed a calculated value of 28.211 with a significance level of 0.000, which is less than the 0.05 level of significance. Therefore, the null hypothesis was rejected and the alternative hypothesis accepted. This indicates that there is a statistically significant relationship between e-waste disposal and socio-economic sustainability in Hadejia Metropolis. The result implies that improper electronic waste disposal negatively affects environmental sustainability, public health, and socio-economic development within the study area.

Discussion of Findings

The findings of this study demonstrate that electronic waste (e-waste) disposal has become an emerging environmental and public health concern in Hadejia Metropolis. The results revealed that a considerable proportion of respondents dispose of obsolete electronic devices through open dumping, open burning, and indiscriminate disposal in refuse dumps and drainage channels. These findings are consistent with those of Forti *et al.* (2020), who reported that developing countries experience poor e-waste management due to inadequate recycling infrastructure and weak regulatory enforcement. Similarly, Awasthi *et al.* (2019) observed that informal disposal methods such as open burning and uncontrolled dumping remain the dominant e-waste management practices in many African countries, exposing communities to hazardous pollutants.

The study further established that improper e-waste disposal has significant adverse effects on environmental quality. Respondents identified soil contamination, water pollution, air pollution, and degradation of surrounding ecosystems as the major environmental consequences of indiscriminate e-waste disposal. These findings corroborate those of Balde *et al.* (2017), who reported that hazardous substances such as lead, mercury, cadmium, and chromium released from discarded electronic equipment contaminate environmental media and threaten ecosystem integrity. Similarly, the United Nations Environment Programme (UNEP, 2023) emphasized that uncontrolled disposal and burning of electronic waste contribute substantially to environmental pollution and biodiversity loss, particularly in rapidly urbanizing areas.

The results also indicate that improper e-waste management poses serious human health risks. Many respondents associated exposure to e-waste with respiratory illnesses, skin irritation, eye problems, headaches, and other health complications. These findings agree with the World Health Organization (WHO, 2021), which reported that exposure to toxic substances released from electronic waste is associated with respiratory diseases, neurological disorders, reproductive problems, kidney damage, and certain cancers. Likewise, Grant *et al.* (2013) found that communities located near informal e-waste recycling sites experience higher levels of exposure to hazardous chemicals than populations living elsewhere.

The study further revealed that inadequate public awareness, poor waste management infrastructure, weak enforcement of environmental regulations, and the absence of functional recycling facilities are major factors responsible for improper e-waste disposal in Hadejia Metropolis. These findings are consistent with the observations of Forti *et al.* (2020), who identified insufficient collection systems, weak policy implementation, and limited public awareness as major barriers to sustainable e-waste management in developing countries. Similarly, Awasthi *et al.* (2019) noted that ineffective institutional capacity and poor environmental governance continue to hinder proper electronic waste management across many low- and middle-income countries.

The Chi-square analysis demonstrated a statistically significant relationship between improper e-waste disposal and socio-economic sustainability, indicating that poor waste management negatively affects environmental quality, public health, and sustainable urban development. This finding supports the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being), SDG 11 (Sustainable Cities and Communities), and SDG 12 (Responsible Consumption and Production), which emphasize environmentally sound waste management as a prerequisite for sustainable development (United Nations, 2023). Overall, the findings confirm that strengthening environmental regulations, expanding recycling infrastructure, improving public awareness, and promoting environmentally responsible disposal practices are essential for reducing the environmental and health impacts of electronic waste in Hadejia Metropolis.

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5. CONCLUSION

This study demonstrates that improper electronic waste disposal has become a significant environmental and public health challenge in Hadejia Metropolis. The findings revealed that open dumping, open burning, and indiscriminate disposal are the predominant e-waste management practices, largely driven by inadequate waste management infrastructure, weak regulatory enforcement, low public awareness, and the absence of formal recycling facilities. These practices contribute to soil, water, and air pollution and increase residents' exposure to hazardous substances associated with respiratory illnesses, skin diseases, and other adverse health outcomes. The significant relationship observed between e-waste disposal practices and socio-economic sustainability further highlights the need for effective intervention. Based on these findings, the study recommends that the Jigawa State Environmental Protection Agency (JISEPA) and the National Environmental Standards and Regulations Enforcement Agency (NESREA) should strengthen the enforcement of e-waste management regulations

and establish designated electronic waste collection and recycling centres within Hadejia Metropolis. The Hadejia Local Government Council, in collaboration with JISEPA and community-based organizations, should implement sustained public awareness campaigns on the environmental and health risks associated with improper e-waste disposal and promote safe disposal practices. The Federal and Jigawa State Ministries of Environment should support private-sector investment in formal e-waste recycling facilities through policy incentives and public-private partnerships to reduce dependence on informal recycling. Furthermore, health authorities, including the Jigawa State Ministry of Health, should conduct regular health surveillance and awareness programmes for communities and informal e-waste handlers exposed to hazardous electronic waste. Finally, future research institutions and universities should undertake laboratory-based assessments of heavy metal contamination in soil, water, and air to quantify the long-term environmental and health impacts of e-waste pollution in Hadejia Metropolis.

6. COMPETING INTEREST

None to declare

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