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Environmental Impacts of the Lemna Dumpsite (Calabar, Nigeria): Surface Water, Air Quality, and Community Health

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ABSTRACT

This study investigates the environmental impact of the Lemna dumpsite located in Calabar, Cross River State, Nigeria, focusing on its effects on water quality, air quality, and public health. The research problem addresses the growing concerns about the contamination of the environment and its associated health risks due to improper waste management at the Lemna dumpsite. The study employs a quantitative method, involving a combination of field measurements, laboratory analyses, and survey data collection from 400 respondents living in proximity to the dumpsite. The study covered a small temporal coverage of 4 weeks (n = 4). Water quality parameters such as Colour, Lead, Dissolved Oxygen (DO), and pH were assessed, with results indicating significant deviations from the World

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Health Organization (WHO) standards, highlighting severe contamination in surrounding water bodies. Air quality measurements revealed hazardous levels of Particulate Matter ($PM_{2.5}$) and Carbon Dioxide (CO_2), with readings far exceeding acceptable thresholds, signaling significant air pollution due to waste burning activities at the dumpsite. A paired samples *t*-test revealed substantial differences in physico-chemical and bacteriological water quality parameters between the Lemna dumpsite and a control site along the Calabar River. The study also examined the health implications for residents, finding a strong correlation between proximity to the dumpsite and the prevalence of respiratory conditions such as frequent coughing, asthma, and breathing difficulties.

Keywords: Environment; Dumpsite; Pollution; Health Challenge; Erosion

1. Introduction

Waste generation is an unavoidable component of our daily lives. Almost all human activities generate waste. The real problem associated with waste generation is its disposal and management [1]. Its magnitude is increasing at an alarming rate. Urban areas are known for high level of industrial activities which generate more pollutants and are therefore subject to the menace of resultant indiscriminate disposal of both domestic and industrial waste. Nearly all human activities generate waste and the way in which this is handled, stored, collected and disposed of can pose risks to the environment and to the public health. The earth is very good at recycling waste, but when the amount of waste generated is far more than the earth can cope with, it poses a big threat to lives, a phenomenon called pollution. Pollution occurs at different levels and affects lives ranging from plants, animals to man [2]. The decay of these solid wastes releases substances that can affect the soil nutrient content, increasing the concentration of heavy metals in the soil, altering the natural balance of nutrients available for plant growth and development thereby affecting species diversity and agricultural production. Indiscriminate disposal of waste has forced us into a polluted environment and energy crisis. It is thus imperative for us to manage the refuse generation, conserve energy and look for alternative source of energy. In fact, there is a need for awareness about adopting efficient scientific and safe methods of treatment and disposal of refuse including conversion of refuse into energy. Waste can be grouped based on its source of origin: (i) domestic, (ii) municipal, (iii) agricultural, and (iv) industrial. Refuse dumping can influence the engineering constituent of the soil, but can still be used for farming provided the risks associated with its usage are continuously assessed and controlled [1]. The introduction of metal contaminants into the soil could result from various sources, a few of which are application of sewage materials and leaching of garbage. Waste handling facilities are lacking in many highly populated areas in most developing and under-developing countries due to cost and lack of proper planning. These results are due to the discharge of household sewage and refuse into the soil untreated. A lot of toxic materials are leached by rain into the soil and water ways from such dumpsite. Waste amended soils have been reported to have high organic matter content [3]. Soil organic matter influences the degree of aggregation and aggregate stability and it can reduce bulk density and increase total porosity and hydraulic conductivity concentrations. Heavy metals have harmful effect on soil.

Statement of the Research Problem

Refuse dumping is becoming a concern in Nigeria due to its effects on soil properties and air quality. Contamination of soil by heavy metals resulting from refuse dumping could affect the PH of the soil. The PH of soil affects all soil properties: strength, compressibility and permeability parameters of soil. In Lemna Junction and its environment, a lot of different materials end up in landfills, which contain toxins that are eventually released and seep into the soil and groundwater. These substances are major hazards to the environment and can last for several years [4,5], for example, electronics such as computers, batteries and television that get thrown out end up in landfills. These products contain substances like arsenic acid, lead and other dangerous substances which eventually end up in the soil and in our environment and pose threats to public health and settlement. Some scientists have made some effort to come up with solution to treating toxins in soil. Ukpata and Bullem [6] suggest that if toxins are drained

through a collection of pipes and discharged into a sewer system where they can be retained incinerated or converted into fertilizer, then treatment of toxins can be possible. This method of treatment is easy and less expensive to practice, but due to the fact that many industries around the Lemna junction area dumpsites lack the awareness, they do not adopt these methods of treatment. Some future problems that will be faced by people living around and far away from the Lemna junction area dumpsites are leachate and greenhouse gas. Leachate is a liquid that forms when landfill waste breaks down and water filters through the waste and picks up toxins. Rain falling on the top of the landfill is the greatest contributor to leachate. This is in agreement with Igelle et al. [7] and Alawode et al. [8].

Groundwater enters the landfill leachate as well. As liquid seeps through the landfill and collects decomposed waste components, chemical reactions take place and produce toxins such as methane, carbon dioxide acids, alcohols, and aldehydes. Landfill can be treated in different ways. These include biological treatment and chemical-physical processes. Landfill can be treated by using many different filters to remove nitrogen and other biological compounds from the waste water. It can also be treated, through wet oxidation 31 processes and can be used if it's possible to oxidize organic compounds [9]. This includes activated carbon absorption, flocculation and ion exchange processes among others. Greenhouse gas: Organic materials such as food scraps and yard waste are usually very compacted when they are put into a landfill [10]. The problem is that this removes the oxygen and causes the materials to breakdown anaerobically. Overtime, the process will produce methane, a type of greenhouse gas that is 20 times more potent than carbon dioxide and wreaks havoc on our environment. Methane is also flammable and can be very dangerous in large concentration. There are number of treatment processes that can help prevent methane production. Open window or tunnel composting: this uses aerobic digestion to decompose organic matter without creating methane gas. In-vessel composting: this is an aerobic treatment that occurs in a closed container to facilitate the breakdown of waste by microorganism [11]. Other processes are available that uses anerobic digestion within a confined space. This allows the methane to be captured and converted into energy. These methods of treatment have been adopted and proven successful within the neighbourhood of Lemna dumpsites. In conclusion, waste that is buried in a landfill will breakdown slowly and present problems for future generations. These activities are still lagging in the knowledge of rural dwellers in Lemna Junction. On this premise, this research has focused on the Environmental Impact of Rural Dumpsite in Lemna Junction of Cross River State, Nigeria.

The aim of this research is to ascertain the Environmental impact of rural dumpsites in Lemna Junction of Calabar, Cross River State, Nigeria. The specific objectives are as follows:

1. Assess the impact of the Lemna dump site on surface water quality in the surrounding area in Calabar, Cross River State, Nigeria.
2. Investigate the presence of air pollutants emitted from the dump site.
3. Analyze the relationship between proximity to the dump site and the prevalence of health issues among residents.

2. Materials and Methods

2.1. Study Area

Study areas are presented in **Figures 1** and **2**.

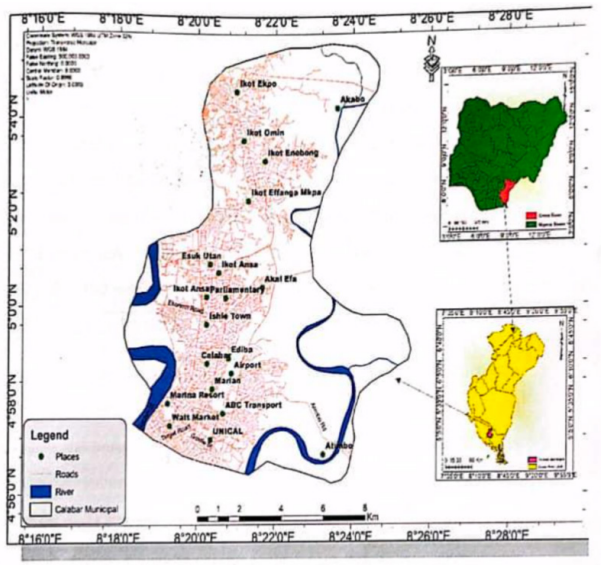

Figure 1. Map of Lemna enveloped by Calabar Municipality Local Government Area.
Source: GIS. LAB. Department of Geography and Environmental Science.

Figure 2. The characteristics of the Lemna dumpsite in the study.

2.1.1. Climate and Drainage Pattern

The climate is classified as tropical. Rainfall is significant in most months of the year, particularly between (March–October) and the short dry season (November–February) has little effect. This climate is considered to be Am according to the Koppen-Geiger climate classification. In Calabar Municipality, the average annual temperature is 26.1 °C. The average annual rainfall is 2,750 mm. at an average temperature of 27.3 °C, March is the hottest month of the year. August is the coldest month, with temperatures averaging 25.0 °C. The harmattan, which significantly influences weather in West Africa, is noticeably less pronounced in the city. There is also little variance between daytime and nighttime temperature, as temperatures at night are typically only a few degrees lower than the daytime high temperature. The area is an inter-fluvial settlement, built on a high land between two rivers adjacent valleys of the Great Qua River on the east which flows into the Cross River State estuary and the Calabar River on the west. Calabar is moderately undulating with land descending rather abruptly to the Calabar River at the western boundary of the town while the slope is towards the Qua River to the West. The coastal range of hills rises from the coastal plains about 40 km inland from the Atlantic coast, with elevations ranging from 60 to about 754 m above sea level. The coastal plains is linked with undulating hinterland on which the rest of the town is built by a number of channels and gaps, open primarily by heward erosion of former streamlets.

2.1.2. Vegetation and Soil

The vegetation of the Calabar Municipality is a mixture of mangrove and rainforest. The rainforest is further subdivided into the lowland rainforest and the freshwater swamp forest. The mangrove swamp is found in the Southern fringe of the area and stretches from the freshwater limits to the ocean beaches. The rich and luxuriant vegetation of Calabar Municipality has been subjected to severe degradation in the past; as such, the vegetation comprised secondary forest approaching climax. The soils are generally deep, porous and weakly structured, and well drained with low moderate status. A modal soil profile consists of very dark brown (10 YR 3/2) sandy loam surface overlying red (2.5 YR 4/6 or 2.5 YR 5/8) sandy clay loam. The soil unit covers about 112 ha and is a good agricultural land for cultivation of yam (_Dioscorearotundata_), maize (_Lea_ _mays_), melon (_Citrulluslanatus_) among others. The soils are derived from weathered shale and alluvial materials and are flooded during the rainy season. The soils are characterized by sandy loam or loam to sandy clay loam or clay loam texture; grey colour matrix of chromaless 2 and hues of 10 YR to 2.5 YR in most horizons, suggesting that the soils have aquic moisture regime for some months in the year. The alternate wetting and drying conditions in these soils resulted in the reduction and subsequent release of iron oxides which were accumulated in the form of strong brown, brown and red mottles in the subsurface of the profiles.

2.1.3. Population/Socio-Economic Activities

The population of Calabar Municipality stands at 330,399, as projected by the National Population Commission of Nigeria in 2024. Calabar Municipality people are mainly people from the greater Calabar district. The ethnic

groups that form the Calabar municipality population are the Quas and the Efiks. Socioeconomically, the traditional occupation of the people of Calabar municipality includes: fishing, farming and trading (Britannica, 2020). Calabar municipalities together with Calabar South are known as Calabar Metropolis. Calabar metropolis is generally acclaimed as one of the leading tourism destination in Nigeria because of its numerous tourism hotspots within the city [12].

2.2. Research Hypotheses

H1. *There is no significant difference in soil quality between areas near the Lemna dump site and the areas farther away.*

H2. *The Lemna dump site has no significant impact on ground water quality in the nearby communities.*

H3. *There is no significant concentration of air pollutant attributable to the Lamna dump site.*

H4. *The Lemna dump site has no significant effect on local biodiversity or vegetation health.*

H5. *There is no significant relationship between proximity to the dump site and the prevalence of health issues among resident.*

2.3. Location and Size

The study area is the Lemna dump site located in Calabar Municipality, which is at a latitude of 4°47′ North, 4°57′ South of the equator and longitude 8°25′ East of the Greenwich Meridian. Calabar Municipality is bounded to the North by Odukpani Local Government Area, to the South by Calabar South Local Government Area, to the East by Akpabuyo Local Government Area and to the West by the Atlantic Ocean. Calabar municipality has a land mass of 142 km^2.

2.4. Literature Review

Surface water quality is an essential indicator of environmental health, particularly in urban and peri-urban areas where human activities and waste generation are high. In developing regions like Nigeria, poor waste management practices and the absence of properly engineered landfills result in the proliferation of open dumpsites. These sites often lack leachate collection systems or containment barriers, thereby increasing the risk of pollutants being transported into nearby rivers, streams, and ponds, especially during the rainy season. The proximity of dumpsites to surface water bodies exacerbates the potential for contamination. In the case of the Lemna dumpsite in Calabar, its location near residential communities and water sources raises serious concerns over surface water pollution through leachate infiltration and surface runoff. Odey [13] averred the leachate is a toxic liquid produced when rainwater percolates through the layers of accumulated waste. This liquid carries with it a complex mix of dissolved organic matter, heavy metals, pathogenic microorganisms, ammonia, nitrates, and inorganic salts [14]. If left unmanaged, leachate migrates through soil and reaches surface water sources, altering the natural water chemistry and rendering it unsuitable for domestic, agricultural, or aquatic use.

Numerous empirical studies have established the adverse influence of open dumpsites on water quality. For example, Mor et al. [15] and Ogundiran and Afolabi [16] reported significantly elevated levels of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) in water bodies adjacent to dumpsites in India and Nigeria, respectively. Elevated BOD and COD levels are symptomatic of high organic matter content, which accelerates microbial activity and depletes dissolved oxygen (DO) in water. This in turn compromises aquatic biodiversity and may result in the death of sensitive aquatic organisms. Moreover, heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), and mercury (Hg) are frequently found in leachates originating from municipal dumpsites. A landmark study by Aderemi et al. [17] in Ibadan, Nigeria, found that water samples near a major dumpsite had dangerously high levels of heavy metals, especially lead and cadmium, compared to control sites. Such contamination poses long-term ecological and human health risks, including neurological disorders, kidney damage, and carcinogenic effects.

In addition to chemical contaminants, microbial pollution is a significant concern associated with dumpsites. Organic waste materials provide ideal breeding conditions for bacteria and other pathogens. Adejuwon and Adelakun [18] identified Escherichia coli, Salmonella spp., and Vibrio

cholerae in water samples from areas near open dumpsites, confirming the potential for faecal contamination and waterborne disease outbreaks such as cholera, dysentery, and typhoid fever. This poses a critical risk to low-income communities that rely on untreated surface water for drinking, bathing, and washing. The role of distance from the dumpsite is also critical in determining the level of contamination. Akinbile and Yusoff [19], in their study conducted in Lagos, Nigeria, found that surface water sources located within 500 m of a dumpsite exhibited significantly higher concentrations of BOD, COD, total coliforms, and heavy metals compared to those located farther away. Likewise, Aboho et al. [20] reported heightened levels of ammonia and nitrates in surface waters surrounding the Apete dumpsite in Ibadan, highlighting the mobility of these contaminants through surface and subsurface flow. Despite global guidelines on water quality such as those published by the World Health Organization [21], enforcement remains weak in many developing countries. Inadequate institutional capacity, lack of environmental monitoring infrastructure, and poor waste governance contribute to the continued degradation of water resources. In places like Calabar, the lack of properly engineered landfills means that most municipal waste is deposited in open dumpsites such as Lemna, with little or no control over leachate generation and movement.

The implications are dire. Odey et al. [22] inferred the contaminated water sources not only threaten the environment but also public health, food security, and sustainable urban development. Children, pregnant women, and the elderly are particularly vulnerable to the adverse health effects of drinking or coming into contact with polluted surface water. In conclusion, a review of existing literature provides strong evidence that open dumpsites pose a significant threat to surface water quality. The physicochemical and microbiological contamination of water near dumpsites is a consistent finding across Nigeria and other parts of the developing world. This calls for urgent action to assess, monitor, and mitigate the impact of the Lemna dumpsite on local water bodies. Strategies such as the relocation of dumpsites away from water sources, establishment of engineered sanitary landfills, regular water quality testing, and community education on water safety are essential to prevent further environmental and health deterioration.

The placement of dumpsites in close proximity to human settlements has emerged as a critical environmental health issue, especially in urban areas of developing countries like Nigeria. Dumpsites are often characterized by the accumulation of unsegregated municipal solid waste, which includes biodegradable materials, plastics, e-waste, industrial refuse, and in some cases, biomedical waste. As these materials decompose or are burned, they emit harmful gases and produce leachate, both of which adversely affect the surrounding environment and the health of nearby residents. Proximity to dumpsites has been shown to significantly influence the likelihood of exposure to multiple environmental hazards. According to Vrijheid [23], residents living near hazardous waste sites, including open dumps, consistently exhibit higher rates of health problems than those living at greater distances. The increased risk is linked to direct and indirect exposure pathways including inhalation of air pollutants, ingestion of contaminated water or food, dermal contact with polluted soil or surfaces, and the presence of disease vectors such as flies, mosquitoes, and rodents. In Nigeria, Ediene et al. [24] conducted a study in Ibadan and observed elevated cases of malaria, typhoid, diarrhea, and upper respiratory tract infections in communities living near a major dumpsite. The researchers identified key contributing factors such as inadequate waste segregation, poor drainage, exposure to decomposing organic matter, and inhalation of smoke from frequent burning of refuse. These exposures not only affect general health but also aggravate pre-existing conditions such as asthma, bronchitis, and cardiovascular diseases. Similarly, MacDonald et al. [25] in a study in Akure found that residents living within 500 m of a dumpsite experienced significantly higher rates of cough, fever, skin rashes, and gastrointestinal disturbances compared to those living beyond 1,000 m. The intensity and frequency of symptoms were strongly correlated with the duration of exposure and proximity to the dumpsite, underscoring spatial variation in health outcomes due to environmental degradation.

A major source of health risks near dumpsites is the open burning of waste, a practice that releases a complex mixture of air pollutants. Pollutants such as particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen oxides (NO_x) are well-documented triggers of acute and chronic respiratory problems.

According to Fatta et al. [26], residents of Enugu living close to an open dumpsite reported a high prevalence of chronic coughing, wheezing, and chest pain, which were linked to poor air quality caused by frequent burning of household and industrial waste. The issue of water pollution from leachate is also a significant health concern. Dumpsite leachate often contains fecal matter, organic waste, and heavy metals, which infiltrate nearby surface and groundwater sources, making them unsafe for consumption. The World Health Organization [21] has emphasized that communities using such contaminated water for drinking, cooking, or bathing are at increased risk of waterborne diseases such as cholera, hepatitis A, dysentery, and parasitic infections. Children and the elderly are particularly vulnerable to the health effects associated with dumpsite exposure. Omofonmwan and Eseigbe [27] found that children under the age of five living near a landfill in Lagos exhibited a higher incidence of diarrheal diseases and parasitic worm infections than their counterparts living further away. Children are more likely to play in contaminated environments, drink unfiltered water, or come into contact with polluted soil, all of which heighten their risk of illness. Similarly, elderly individuals and people with compromised immune systems suffer disproportionately from long-term exposure to polluted air and water around dumpsites. The correlation between distance from the dumpsite and health burden is a recurring theme in academic literature. Omofonmwan and Eseigbe [27], in a comprehensive study in Kano, found that individuals living within 300 m of a dumpsite reported twice the frequency of respiratory and digestive disorders compared to residents living more than 1,000 m away. This spatial trend further validates the hypothesis that proximity is a critical determinant of environmental exposure and related health outcomes. Furthermore, unplanned settlements near dumpsites, lack of zoning regulations, and absence of buffer zones between waste disposal facilities and residential areas contribute to continuous exposure and increased disease burden. These patterns are often observed in rapidly urbanizing areas such as Calabar, where population growth and waste generation outpace infrastructural development. In conclusion, the reviewed literature provides compelling evidence of a strong positive relationship between proximity to dumpsites and the prevalence of health issues among local populations. The health burden is most acute in communities closest to the dumpsites due to higher levels of exposure to pollutants in air, water, and soil. This situation necessitates urgent public health interventions, including the relocation or redesign of waste disposal sites, enforcement of environmental regulations, health screening for vulnerable populations, and education on hygiene and safe water practices. Such measures are critical to protecting the health of residents and ensuring sustainable urban living environments [4].

Dumpsites, particularly those that are open, poorly managed, or unregulated, represent one of the most significant anthropogenic sources of air pollution in many developing countries. These sites emit a wide array of hazardous gases and particulate matter into the atmosphere, thereby posing considerable environmental and health risks to surrounding communities. The primary drivers of these emissions include microbial decomposition of organic waste under anaerobic conditions, open-air burning of mixed solid waste, and chemical reactions involving industrial and domestic refuse. One of the most potent and concerning emissions from dumpsites is methane (CH_4), a colorless, odorless greenhouse gas produced through the anaerobic decomposition of organic materials. According to the Intergovernmental Panel on Climate Change [28], methane has a Global Warming Potential (GWP) approximately 25 times greater than that of carbon dioxide (CO_2) over a 100-year time frame. Dumpsites, therefore, are not only localized public health hazards but also significant contributors to global climate change. Methane emissions from decomposing food waste, paper, and other biodegradable materials represent a substantial source of short-lived climate pollutants (SLCPs) in urban environments. In addition to methane and carbon dioxide, open dumpsites release significant quantities of volatile organic compounds (VOCs) and sulfur compounds, such as hydrogen sulfide (H_2S). These gases originate from the degradation of organic waste and the breakdown of certain industrial by-products. Awomeso et al. [29] reported elevated concentrations of benzene, toluene, and H_2S in the air surrounding a major dumpsite in Abeokuta, Nigeria. These pollutants are not only responsible for the characteristic offensive odor around dumpsites but are also linked to nausea, eye irritation, respiratory distress, and in some cases, neurotoxicity upon long-term exposure.

Another major concern is particulate matter (PM),

particularly $PM_{2.5}$ and PM_{10}, which consists of fine airborne particles less than 2.5 or 10 μm in diameter. These particles are primarily generated through waste burning, mechanical agitation of dry waste, and vehicular movement around the dumpsite. According to the World Health Organization [30], $PM_{2.5}$ can penetrate deep into the lungs and even enter the bloodstream, leading to chronic respiratory conditions such as asthma, chronic obstructive pulmonary disease (COPD), cardiovascular diseases, and lung cancer. For instance, Ogbonna et al. [31] conducted an air quality study near a dumpsite in Port Harcourt, Nigeria, and found that PM_{10} levels far exceeded WHO guidelines, contributing to a surge in complaints of breathlessness, persistent coughing, and eye irritation among residents. These findings affirm the direct and measurable health consequences of prolonged exposure to air pollutants from unmanaged dumpsites. Moreover, the presence and concentration of air pollutants vary significantly based on proximity to the dumpsite, meteorological factors (such as wind speed and direction), and the type of waste disposed of. To determine the spatial distribution and intensity of air pollution, researchers commonly use portable gas analyzers, infrared spectroscopy, and gas chromatography to detect pollutants such as methane, carbon monoxide (CO), VOCs, and H_2S. Akinbile and Yusoff [19] used such instruments to demonstrate a decline in pollutant concentrations with increasing distance from a major dumpsite, reinforcing the idea that communities living closest to the site are at the highest risk.

In another landmark study, Adewole [32] assessed air quality around the Olusosun dumpsite in Lagos, one of the largest in Africa. His findings revealed alarmingly high levels of carbon monoxide (CO), hydrogen sulfide, and ammonia, highlighting the dangers of uncontrolled waste burning and decomposition. These emissions were linked to acute symptoms such as dizziness, fatigue, nausea, and aggravated respiratory conditions in both adults and children living within a 500 m radius. Beyond human health, the ecological consequences of air pollution from dumpsites are also severe. Methane, for instance, contributes significantly to the formation of ground-level ozone, a primary component of smog, which impairs photosynthesis and stunts plant growth. Nitrogen oxides and VOCs, when exposed to sunlight, undergo photochemical reactions to form ozone, further degrading air quality and contributing to climate change. The United Nations Environment Programme [33] emphasizes that air pollution from dumpsites can exacerbate urban heat islands, trigger acid rain, and reduce overall air visibility, with far-reaching consequences for biodiversity and environmental sustainability. Despite the alarming implications of these findings, air quality management around dumpsites in Nigeria remains largely inadequate. Most dumpsites lack gas collection infrastructure, fire suppression systems, or regulatory oversight. Lee et al. [34] recommended a shift from open dumpsites to engineered sanitary landfills equipped with gas capture and flaring technologies. These systems not only reduce atmospheric emissions but also enable the harnessing of landfill gas (LFG) for electricity generation and other productive uses, thus contributing to both environmental sustainability and energy security. In conclusion, Odey et al. [35] maintained the reviewed literature offers compelling evidence that dumpsites are significant point sources of a wide range of airborne pollutants, including greenhouse gases, VOCs, sulfur compounds, and particulate matter. The emissions from these sites are not only detrimental to local public health but also contribute to regional and global environmental degradation. Accurate measurement and analysis of pollutant concentrations around dumpsites like Lemna in Calabar are essential for informing waste management policies, urban planning, and environmental health interventions. Investing in modern waste treatment and air quality monitoring infrastructure is not only necessary but urgent, to safeguard human lives and support sustainable development goals.

2.5. Theoretical Framework

The Pollution Theory, as advanced by Eugene P. Odum [36], serves as a cornerstone in environmental science and ecological studies. Odum, widely regarded as one of the founding figures of modern ecology, introduced the theory in his influential text “Fundamentals of Ecology.” The theory articulates a fundamental ecological principle: that environmental degradation occurs when pollutants substances introduced into the environment through human activity exceed the natural system's capacity to absorb, neutralize, or recycle them. When these limits are surpassed, ecosystems become stressed, dysfunctional, or ultimately collapse, with dire consequences for both bio-

diversity and human health. According to Odum [36], every natural system has a carrying capacity and a self-purification threshold, which allows it to assimilate a certain degree of waste or foreign material without permanent damage. However, when pollutants accumulate beyond this threshold whether through continuous discharge, high toxicity, or poor environmental management they cause irreversible harm to the environment. Pollution can be physical (solid waste), chemical (toxic substances or heavy metals), or biological (pathogens and microbial contaminants), and it can affect all major environmental media: air, water, and soil. In applying Pollution Theory to real-world scenarios, one sees its utility in explaining environmental crises resulting from urbanization, industrialization, and unsustainable consumption patterns. This is particularly relevant in developing countries, where rapid urban growth is often unaccompanied by effective waste management systems. The theory underscores how unregulated human activities result in environmental stress and socio-ecological imbalance.

In the case of the Lemna dumpsite in Calabar, Cross River State, Pollution Theory offers a robust explanatory framework for assessing the environmental impacts of poorly managed municipal solid waste. The dumpsite is characterized by the indiscriminate accumulation of residential, commercial, and possibly biomedical waste without proper engineering controls or leachate management systems. As posited by Odum [36], this situation creates a condition where pollutants surpass the assimilative capacity of the local ecosystem. Water Pollution through Leachate Infiltration: Rainwater percolating through waste generates leachate, a toxic liquid mixture rich in heavy metals, organic pollutants, and microbial pathogens. This leachate infiltrates nearby surface water bodies such as streams and rivers, contaminating water used for drinking, fishing, and irrigation. According to Pollution Theory, the inability of aquatic ecosystems to assimilate these toxins leads to reduced oxygen levels, eutrophication, and aquatic biodiversity loss. Air Pollution from Open Burning and Decomposition: The practice of open burning at the Lemna dumpsite releases harmful gases such as methane (CH_4), carbon monoxide (CO), particulate matter ($PM_{2.5}$ and PM_{10}), and volatile organic compounds (VOCs). These pollutants exceed the atmospheric self-cleansing threshold, resulting in localized air quality deterioration, respiratory health issues, and climate-related implications. This directly ties into the theory's assertion that when natural sinks like the atmosphere are overloaded, ecological and human systems suffer.

1. Soil Contamination: The leaching of hazardous substances into surrounding soils alters their chemical structure, affecting fertility, reducing agricultural productivity, and leading to bioaccumulation of toxins in food crops. Soil, as an ecological medium, loses its capacity to support vegetation and beneficial organisms, consistent with Pollution Theory's warning on long-term ecosystem dysfunction due to pollutant overload.
2. Public Health Implications: The theory also emphasizes the interconnectedness between environmental health and human health. When pollutants accumulate in the air, water, and soil, residents near the Lemna dumpsite become vulnerable to respiratory illnesses, gastrointestinal infections, dermatological diseases, and other pollution-induced conditions. The theory helps frame these health outcomes not as isolated events, but as predictable consequences of environmental mismanagement.

2.6. Theoretical Contribution to the Study

Pollution Theory is not only relevant but foundational to the present study's analytical lens. It underpins all three key objectives:

1. assessing the impact on surface water quality (via leachate pollution),
2. analyzing the relationship between proximity and health risks (via exposure pathways of air, water, and soil),
3. investigating air pollutant concentrations (via gaseous emissions and particulate matter).

By positioning pollution as a function of systemic imbalance between waste generation and natural absorption, the theory enables a critical evaluation of how poor waste management, like that observed at the Lemna dumpsite, leads to ecological degradation, social injustice, and public health emergencies. Furthermore, Pollution Theory

aligns with the precautionary principle in environmental policy and advocates for preventive action and sustainable waste management practices. It calls for engineered landfills, environmental impact assessments, regular monitoring of environmental media, and inclusive urban planning that respects ecological thresholds. In summary, Pollution Theory by Odum [36] offers a comprehensive and scientifically grounded explanation for the adverse environmental and health impacts associated with uncontrolled waste disposal practices. In the context of the Lemna dumpsite in Calabar, the theory illuminates the ecological and human costs of exceeding environmental assimilation capacities and provides a conceptual foundation for proposing sustainable remediation and policy interventions. As such, it is a fitting theoretical framework for this study, offering both explanatory power and practical relevance in addressing urban environmental challenges in Nigeria and similar contexts.

2.7. Research Methodology

This study adopted a descriptive survey research design complemented by experimental and correlational methods. The descriptive approach enabled the systematic collection and analysis of qualitative and quantitative data from residents living in proximity to the Lemna dumpsite, focusing on their environmental and health experiences. This design was appropriate as it allowed the researcher to assess existing conditions, analyze relationships among variables, and draw inferences regarding the environmental and public health impacts of the dumpsite.

- Demographic data (sex, age, occupation, etc.);
- Physicochemical data;
- Bacteriological data;
- Air Quality data;
- Perception data.

The primary data were obtained through field measurements, laboratory analyses, and structured questionnaire. Additional tools that facilitated data collection included the Global Information System (GIS), which helped in pinpointing specific locations within the study area, and ArcGIS, which was used to refine and modify the maps generated during field research. The secondary data sources are also important to the research as they complement the primary sources of data. This data is informed by published and unpublished texts, reports, journals as well as the WHO/FEPA standards, prior assessments data. To effectively assess the environmental impact of the Lemna dumpsite in Calabar, a multi-stage sampling technique was employed to ensure that data collected is representative and relevant. The study area was first divided into zones based on proximity to the dumpsite such as areas within 500 m, between 500 and 1,000 m, and beyond 1,000 m. This stratification allows for the examination of how distance influences environmental degradation and health outcomes. Stratified sampling was used to categorize these zones, while systematic random sampling was applied to select households within each zone using a fixed interval method. This ensures a fair and unbiased representation of residents. Purposive sampling was used to select key informants, including environmental health officials, healthcare workers, and residents with relevant knowledge, as well as to identify specific surface water sources and air sampling locations near the dumpsite. This combination of sampling methods allows for a comprehensive analysis of both quantitative and qualitative data, ensuring that the study captures a full picture of the environmental and public health implications of the dumpsite. The approach is designed to support comparative analysis across proximity zones, enhance data reliability, and ensure that expert and community perspectives are integrated into the findings.

The procedure for data collection in this study was carefully structured to gather relevant information on the environmental and health impacts of the Lemna dumpsite. The process began with a reconnaissance survey to familiarize the researchers with the area, map out the proximity zones, and identify key sampling points for water and air quality assessments. Quantitative data were collected through structured questionnaires administered to residents within varying distances (e.g., 0–500 m, 501–1,000 m, and beyond 1,000 m) from the dumpsite. The questionnaire captured information on demographic characteristics, health symptoms experienced, perceived environmental changes, and duration of exposure to the area. For environmental sampling, surface water samples were collected weekly over a four-week period from streams and ponds close to the dumpsite and from a control location (Calabar River) far from the site. These samples were analyzed for

physico-chemical and bacteriological parameters in accordance with WHO standards. In addition, air quality measurements were conducted using portable air monitoring devices. Parameters such as Air Quality Index (AQI), particulate matter ($PM_{2.5}$), carbon dioxide (CO_2), and temperature were recorded. Measurements were taken at different times of the day to assess variation and consistency in pollutant levels. All data collected were carefully documented, coded, and prepared for statistical analysis using appropriate software to ensure accuracy, reliability, and objectivity. The population of Calabar municipality according to 2022 projection is 279,800. Therefore, the sample size was determined based on the formula developed by Taro Yarmane (1973) at 0.05 significance level:

$$n = \frac{N}{1 + N(e)^2}$$

where:

n = Required sample size from the population under study.

N = Whole population that is under study.

e = Precision or sampling error which is usually 0.05 or 0.01.

1 = Constant.

Substituting:

$$n = \frac{N}{1 + N(e)^2} = \frac{279,800}{1 + 279,800(0.05)^2} = \frac{279,800}{279,801\,(0.25)} = \frac{279,800}{69,950.25} = 399.9$$

Rounding up to the nearest whole number, the sample size for the study is determined to be 400. Data analysis was undertaken using qualitative as well as quantitative techniques. Descriptive statistics such as simple frequencies, percentages, etc. was employed in most of the analysis in summarizing trends, changes and comparisons across certain characteristics. The hypotheses formulated was tested using Chi-square and Pearson product moment correlation coefficient statistical tool for differences in responses by respondents. The hypothesis are as follows:

$H0_1$. *The Lemna dump site has no significant impact on the surface water quality in the surrounding area.*

$H1_1$. *The Lemna dump site has a significant impact on the surface water quality in the surrounding area.*

The Chi-square is given as:

$$x^2 = \frac{\sum(0 - E)^2}{E}.$$

Where:

x^2 is the chi-square statistics;

0 is the observed frequency of occurrence;

E is the expected value;

$\sum$ means of summation.

$H0_2$. *There is no significant relationship between proximity to the Lemna dump site and the prevalence of health issues among residents.*

$H1_2$. *There is a significant relationship between proximity to the Lemna dump site and the prevalence of health issues among residents.*

The Pearson product moment correlation coefficient is given as:

$$r = \frac{{}^1\!/\!_n \sum^n (x - \ddot{x})\,(y - \bar{y})}{sx \times sy}$$

where:

r = Correlation coefficient;

n = Number of pairs of observation;

sx = Standard deviation of independent variable;

sy = Standard deviation of dependent variable;

x = Independent variable;

y = Dependent variable.

3. Results and Discussion

3.1. Water Quality Analysis

In this chapter, a brief statistical analysis and result interpretation of the data collected from the study area through questionnaire instrument is presented (**Table 1**).

The paired samples test reveals statistically significant differences between observed values and WHO standards for all physico-chemical and bacteriological parameters of surface water quality at Lemna Dumpsite over four weeks (one month). The parameter with the highest positive mean difference is Colour, with a mean deviation of 165.50 TCU (t = 573.309, p = 0.000), indicating extremely elevated levels of coloration in the water compared to WHO standards. In contrast, the parameter with the lowest positive mean difference is Lead, with a mean deviation of 2.1025 mg/l (t = 439.198, p = 0.000), although still significantly above permissible limits. Additionally, some parameters such as pH (mean = −1.275, t = −51.000,

p = 0.000) and Dissolved Oxygen (DO) (mean = −2.875, t = −115.000, p = 0.000) show negative mean differences, indicating values below WHO standards. All p-values are less than 0.05, confirming that the differences are statistically significant and reflect a serious deviation from acceptable water quality limits.

This paired statistical sample is not supposed to match the table because the result simply indicates that the result is different from the expected sample result of World Health Organization. As such, the Lemna dumpsite is a threat to human health (**Table 2**).

The paired samples t-test assessed the differences in physico-chemical and bacteriological parameters between the Lemna dumpsite surface water and the Calabar River control point over four weeks making it one month. All parameters demonstrated statistically significant differences ($p < 0.05$), indicating notable water quality disparities between the dumpsite and the control site. The highest positive mean difference was recorded in Colour, with a mean difference of 175.50 TCU (t = 607.950, p = 0.000), indicating significantly more coloration in the dumpsite water, likely due to high levels of contaminants or organic matter. Similarly, Lead (2.1105 mg/L, t = 440.869) and Conductivity (−148.25 µS/cm, t = −593.000) also showed very high levels of significance and extreme deviations, underscoring severe contamination from heavy metals and dissolved solids. On the other hand, the lowest mean difference was observed in Odour, with a value of 2.75 t (t = 11.000, p = 0.002), still statistically significant but comparatively lower in magnitude than other parameters. This suggests that while odour was noticeable, other chemical indicators showed far greater deviations from control conditions. In conclusion, the results strongly indicate that the Lemna dumpsite significantly impacts water quality, with most tested parameters showing substantial and statistically significant deterioration compared to the control site in Calabar River (**Figure 3**).

This does not have to match the t-test result, this because the graph is an average standard recommended by World Health Organization. **Figure 4** Shows that the dumpsite at Lemna Calabar constitute health hazard.

The graph in **Figure 5** also exist in the work to show WHO basic requirement, which the Lemna dumpsite prevent the inhabitant of the area from achieving it.

Table 1. Paired samples test of physico-chemical and bacteriological parameters of surface water quality in Lemna dumpsite for four weeks.

Parameters	Unit of Measurement	Paired Differences					*t*	df	Sig. (2-Tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Feacal Coliform—WHO	CFU/10 mL	11.25000	1.50000	0.75000	8.86317	13.63683	15.000	3	0.001
Total Coliform— WHO	CFU/10 mL	13.50000	1.29099	0.64550	11.44574	15.55426	20.914	3	0.000
Turbidity—WHO	NTU	10.50000	1.29099	0.64550	8.44574	12.55426	16.267	3	0.001
PH—WHO	mol/L	−1.27500	0.05000	0.02500	−1.35456	−1.19544	−51.000	3	0.000
Nitrate—WHO	mg/L	25.87500	0.55000	0.27500	24.99983	26.75017	94.091	3	0.000
Nitrite—WHO	mg/L	2.45000	0.05774	0.02887	2.35813	2.54187	84.870	3	0.000
Lead—WHO	mg/L	2.10250	0.00957	0.00479	2.08727	2.11773	439.198	3	0.000
Iron—WHO	mg/L	3.32500	0.05000	0.02500	3.24544	3.40456	133.000	3	0.000
Chloride—WHO	mg/L	22.95000	0.50000	0.25000	22.15439	23.74561	91.800	3	0.000
Odour—WHO	t	3.72000	0.50000	0.25000	2.92439	4.51561	14.880	3	0.001
Colour—WHO	TCU	165.50000	0.57735	0.28868	164.58131	166.41869	573.309	3	0.000
Conductivity—WHO	µS/cm	16.75000	0.50000	0.25000	15.95439	17.54561	67.000	3	0.000
BOD—WHO	mg/L	28.25000	0.50000	0.25000	27.45439	29.04561	113.000	3	0.000
DO—WHO	mg/L	−2.87500	0.05000	0.02500	−2.95456	−2.79544	−115.000	3	0.000

Source: Fieldwork 2025.

Table 2. Paired samples test of physico-chemical and bacteriological parameters of surface water quality in Lemna dumpsite and Calabar River Control point for four weeks.

Parameters	Unit of Measurement	Paired Differences					*t*	df	Sig. (2-Tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Feacal Coliform— Calabar River Control point	CFU/10mL	9.25000	1.50000	0.75000	6.86317	11.63683	12.333	3	0.001
Total Coliform—Calabar River Control point	CFU/10mL	10.50000	1.29099	0.64550	8.44574	12.55426	16.267	3	0.001
Turbidity—Calabar River Control point	NTU	10.40000	1.29099	0.64550	8.34574	12.45426	16.112	3	0.001
PH—Calabar River Control point	mol/L	−1.97500	0.05000	0.02500	−2.05456	−1.89544	−79.000	3	0.000
Nitrate—Calabar River Control point	mg/L	63.37500	0.55000	0.27500	62.49983	64.25017	230.455	3	0.000
Nitrite—Calabar River Control point	mg/L	2.64000	0.05774	0.02887	2.54813	2.73187	91.452	3	0.000
Lead—Calabar River Control point	mg/L	2.11050	0.00957	0.00479	2.09527	2.12573	440.869	3	0.000
Iron—Calabar River Control point	mg/L	3.52500	0.05000	0.02500	3.44544	3.60456	141.000	3	0.000
Chloride—Calabar River Control point	mg/L	−26.85000	0.50000	0.25000	−27.64561	−26.05439	−107.400	3	0.000
Odour—Calabar River Control point	t	2.75000	0.50000	0.25000	1.95439	3.54561	11.000	3	0.002
Colour—Calabar River Control point	TCU	175.50000	0.57735	0.28868	174.58131	176.41869	607.950	3	0.000
Conductivity—Calabar River Control point	µS/cm	−148.25000	0.50000	0.25000	−149.04561	−147.45439	−593.000	3	0.000
BOD—Calabar River Control point	mg/L	28.25000	0.50000	0.25000	27.45439	29.04561	113.000	3	0.000
DO—Calabar River Control point	mg/L	−4.37500	0.05000	0.02500	−4.45456	−4.29544	−175.000	3	0.000

Source: Fieldwork 2025.

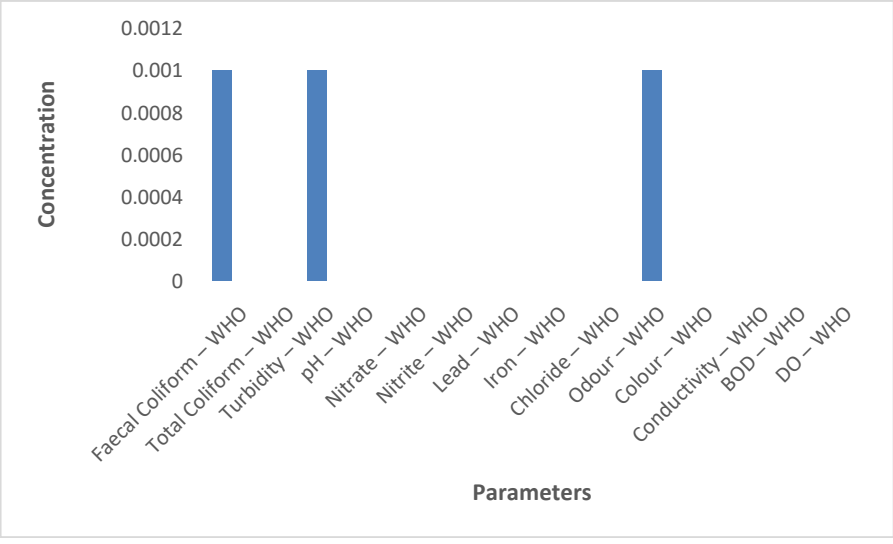

Figure 3. Bar chart of paired samples test of physico-chemical and bacteriological parameters of surface water quality in Lemna dumpsite for four weeks.

Source: Fieldwork 2025.

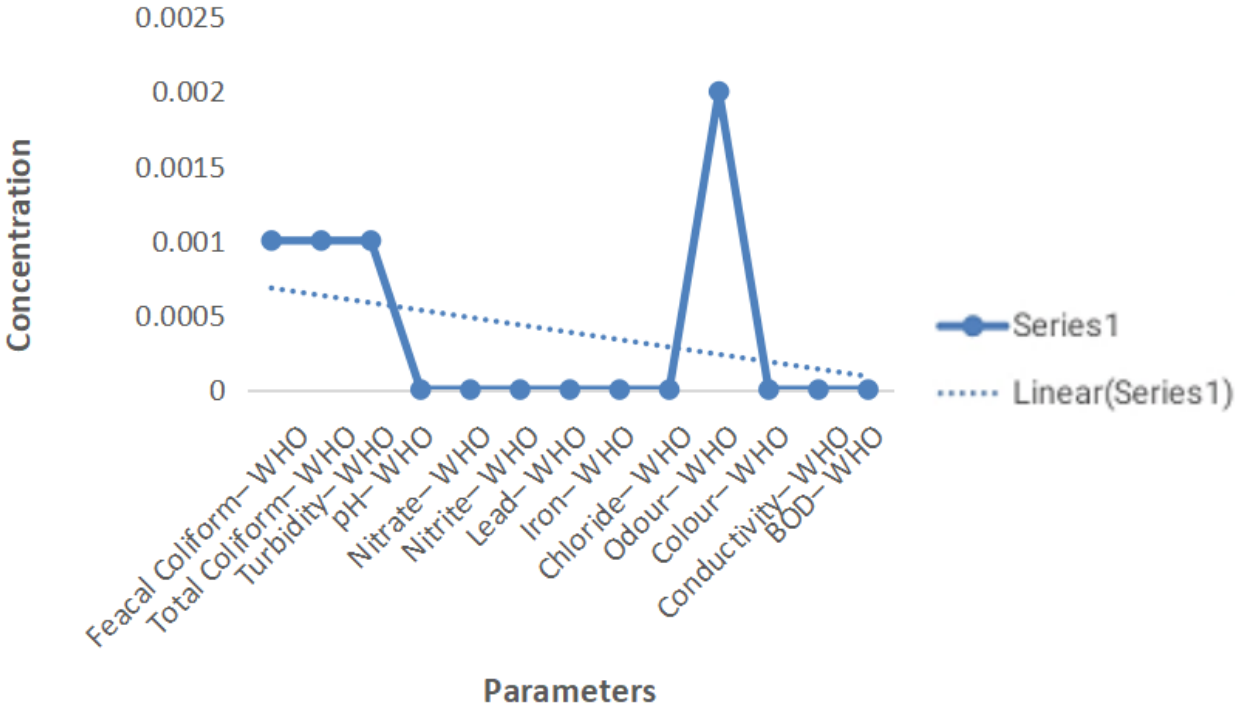

Figure 4. Line chart of paired samples test of physico-chemical and bacteriological parameters of surface water quality in Lemna dumpsite and Calabar River Control point for four weeks.
Source: Fieldwork 2025.

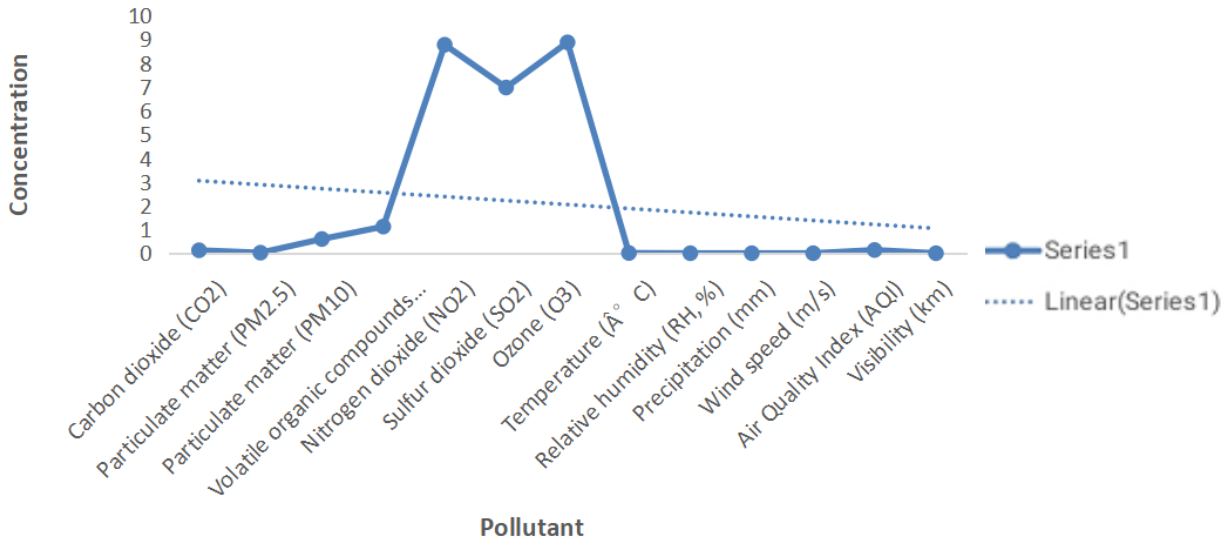

Figure 5. Air quality reading and meteorological pattern from Lemna dumpsite, Calabar.
Source: Fieldwork 2025.

Table 3 presents frequency distribution of demographic characteristics of the respondents. From the demographic profile of respondents (N = 400), the age group with the highest representation was 31–45 years, accounting for 35.8% (143 respondents), indicating that the study population is largely middle-aged. In contrast, the youngest group (under 18) had the lowest representation at just 2.0% (8 respondents).

Table 3. Demographic Information.

Category	Frequency	Percent (%)
Age		
Under 18	8	2.0
18–30	132	33.0
31–45	143	35.8
46–60	79	19.8
Above 60	38	9.5
Total	400	100.0
Gender		
Female	157	39.3
Male	243	60.8
Total	400	100.0
Educational Level		
No formal education	19	4.8
Primary	39	9.8
Secondary	164	41.0
Tertiary	178	44.5
Total	400	100.0
How long have you lived in your current residence		
Less than 1 year	52	13.0
1–5 years	172	43.0
6–10 years	91	22.8
More than 10 years	85	21.3
Total	400	100.0
Approximate distance of your residence from the Lemna dumpsite		
Less than 500 m	83	20.8
500–1,000 m	126	31.5
1,001–2,000 m	117	29.3
More than 2,000 m	74	18.5
Total	400	100.0

Source: Fieldwork 2025.

In terms of gender, males were the majority, comprising 60.8% (243 respondents), while females represented the lower proportion at 39.3% (157 respondents).

Regarding educational attainment, tertiary education had the highest frequency, reported by 44.5% (178 respondents), while those with no formal education were the least represented at 4.8% (19 respondents).

When asked about length of stay in their current residence, the highest group was those who had lived 1–5 years (43.0%), while the fewest had lived there less than 1 year (13.0%).

In terms of proximity to the Lemna dumpsite, the largest group lived 500–1,000 m away (31.5%), whereas the smallest group resided more than 2,000 m away (18.5%).

The data on health status and conditions among respondents presented in **Table 4** reveal that the most commonly reported health issue is frequent coughing, affecting 21.8% (87 individuals) of the population. This is closely followed by asthma or breathing difficulties at 21.0%. These high frequencies may be linked to environmental pollution, especially if respondents live near contaminated or degraded areas. In contrast, the least reported health issue is eye irritation, noted by only 10.8% (43 individuals), suggesting it is a relatively less prevalent symptom compared to others.

Table 4. Health Status and Conditions.

Category	Frequency	Percent (%)
Have you or any member of your household experienced any of the following health issues in the past year		
Frequent coughing	87	21.8
Asthma or breathing difficulties	84	21.0
Skin rashes/irritations	73	18.3
Eye irritation	43	10.8
Diarrhea or stomach issues	56	14.0
Headaches	57	14.2
Total	400	100.0
How often do these health issues occur		
Rarely	19	4.8
Occasionally	174	43.5
Frequently	120	30.0
Constantly	87	21.8
Total	400	100.0

Source: Fieldwork 2025.

Regarding the frequency of health occurrences, the majority of respondents reported that these health issues occur occasionally, accounting for 43.5% (174 individuals). On the other hand, only 4.8% (19 individuals) reported that the symptoms rarely occur. This indicates that while some experience symptoms sporadically, a substantial portion of the population suffers from them regularly, pointing to a persistent environmental or public health challenge in the area.

Table 5 presents perception of environmental and health risks. The survey data reveal that a significant majority of respondents perceive health risks associated with living near the Lemna dumpsite. Specifically, 80.5% (322 respondents) *strongly agreed* that residing close to the dumpsite adversely affects their health or that of their family, representing the highest level of concern. Conversely, only 1.3% (5 respondents) *disagreed*, indicating the lowest level of dissent and reinforcing the community's widespread belief in the dumpsite's negative health implications.

Table 5. Perception of Environmental and Health Risks.

Category	Frequency	Percent (%)
Do you believe that living near the Lemna dumpsite affects your health or that of your family		
Strongly agree	322	80.5
Agree	60	15.0
Disagree	5	1.3
Strongly disagree	13	3.3
Total	400	100.0
What environmental problems have you observed in your area		
Foul smell	79	19.8
Flies and rodents	77	19.3
Smoke from burning waste	106	26.5
Contaminated water	84	21.0
Flooding linked to waste blockage	54	13.5
Total	400	100.0

Source: Fieldwork 2025.

Regarding environmental observations, the most frequently reported issue was smoke from burning waste, cited by 26.5% (106 respondents), reflecting concerns over air pollution and respiratory health. In contrast, flooding linked to waste blockage had the lowest frequency, reported by just 13.5% (54 respondents), though still noteworthy. These results collectively underscore the dominant environmental and public health concerns stemming from improper waste management at the Lemna dumpsite.

The air quality assessment around the Lemna dumpsite reveals several critical exceedances of regulatory thresholds established by the Federal Environmental Protection Agency (FEPA), indicating significant environmental and public health concerns. The Air Quality Index (AQI) recorded an average of 466.7, far exceeding the regulatory limit of 10 ppm, indicating hazardous air conditions. Similarly, carbon dioxide (CO_2) levels averaged 499 ppm, well above the FEPA limit of 400 ppm, suggesting poor ventilation and potential risk of respiratory discomfort. Particulate Matter ($PM_{2.5}$) also recorded an average of 44.8 µg/m^3, surpassing the safe limit of 35 µg/m^3, which poses serious health risks, especially for vulnerable populations. In contrast, parameters such as volatile organic compounds (VOC), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and ozone (O_3) all remained well below their respective regulatory thresholds, indicating relatively acceptable levels for these pollutants (**Table 6**).

Meteorologically, temperature averaged 34 °C, aligning with typical tropical conditions, although erroneously listed against an unrealistic regulatory limit of 220 °C. Relative humidity was relatively high at 83.3%, and precipitation remained at 0.0 mm, suggesting dry atmospheric conditions during measurement. Wind speed was modest at 3.7 m/s, below the limit of 17 m/s, which could limit pollutant dispersion and worsen localized air quality. Visibility was consistently poor at 3 km, much lower than the standard threshold (1,000 mph, though likely a unit error), reinforcing the degraded air quality observed. Overall, the data suggest that while gaseous pollutants remain within regulatory safety margins, particulate matter and general air quality pose substantial risks, necessitating urgent mitigation measures at the Lemna dumpsite.

Table 6. Air quality reading and meteorological pattern from Lemna dumpsite, Calabar.

Parameter	Morning	Afternoon	Evening	Average	Regulatory Limit (FEPA)
Carbon dioxide (CO_2)	437	570	490	499	400 ppm
Particulate matter ($PM_{2.5}$)	43.1	47.8	43.6	44.8	35 µg/m^3
Particulate matter (PM_{10})	186	111	104	133.7	150 µg/m^3
Volatile organic compound (VOC)	0.015	0.020	0.017	0.017	435 µg/m^3
Nitrogen dioxide (NO_2)	11	15	9	11.7	200 µg/m^3
Sulfur dioxide (SO_2)	5.5	7.8	6.4	6.6	260 µg/m^3
Ozone (O_2)	18	11	13	14	235 µg/m^3
Temperature (°C)	36	34	32	34	22
Relative humidity (RH) (°)	85	66	99	83.3	80
Precipitation	0.0	0.0	0.0	0.0	2.00 mm
Wind pattern	4	3	4	3.7	17 m/s
Air Quality Index (AQI)	450	800	150	466.7	10 ppm
Visibility	3 km	3 km	3 km	3	1,000 mph

Descriptive Statistics for Lemna dumpsite

	N	Mean		Std. Deviation
	Statistic	Statistic	Std. Error	Statistic
Test variables	13	100.0398	48.37641	174.42363

Source: Fieldwork 2025.

3.2. Test of Hypothesis One

Table 7 presents Chi-Square analysis data collected on the impact of Lemna dump site on surface water quality in the surrounding area.

Table 7. Test Statistics.

Chi-Square	df	Asymp. Sig.
349.690[a]	1	0.000
28.700[b]	4	0.000

Note: a0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 200.0; b0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 80.0.

The Chi-Square test results reveal a statistically significant relationship between the presence of the Lemna dumpsite and the quality of surface water in the surrounding area. The higher Chi-Square value of 349.690 (df = 1) indicates a very strong association, suggesting that the dumpsite has a pronounced impact on nearby water quality. Similarly, the lower Chi-Square value of 28.700 (df = 4) still shows a statistically significant association. In both cases, the *p*-value (Asymp. Sig.) of 0.000 confirms that the results are highly significant at the 0.05 level. Furthermore, the assumptions of the Chi-Square test are met, as 0 cells had expected frequencies less than 5, indicating that the analysis is valid and reliable. These findings strongly suggest that waste activities at the Lemna dumpsite are likely contributing to the degradation of surface water quality in the area.

3.3. Test of Hypothesis Two

The Pearson correlation analysis reveals a significant negative relationship between the distance of residence from the Lemna dumpsite and the perception that living near the dumpsite affects health, with a correlation coefficient of −0.277 (p = 0.000). This indicates that as the distance from the dumpsite increases, the perception or reported impact on health tends to decrease. In other words, individuals living closer to the dumpsite are more likely to experience or perceive negative health effects. The correlation is statistically significant at the 0.01 level (2-tailed), confirming that the relationship is unlikely due to chance, and suggests spatial proximity to the dumpsite plays a critical role in perceived health outcomes (**Table 8**).

Table 8. Correlation analysis data collected on the relationship between proximity to the Lemna dump site and the prevalence of health issues among residents.

Living Near the Lemna Dumpsite Affects Health			Distance of Residence from the Lemna Dumpsite		
Pearson Correlation	Sig. (2-tailed)	N	Pearson Correlation	Sig. (2-tailed)	N
1		400	−0.0277	0.000	400
−0.277**	0.000	400	1		400

Note: **p < 0.01; Correlation is significant at the 0.01 level (2-tailed).

Source: Fieldwork 2025.

3.4. Health Impact Assessment

The study set out to examine the environmental impact of the Lemna dumpsite in Calabar, with particular emphasis on the relationship between proximity to the dumpsite and the prevalence of health issues among residents. The findings across various assessments, physico-chemical and bacteriological water quality, air quality, health data from questionnaires, and statistical analyses consistently underscore a significant degradation of environmental quality and associated public health risks in the vicinity of the dumpsite.

The paired samples *t*-test revealed statistically significant deviations between surface water samples near the Lemna dumpsite and the WHO standards. Parameters such as Colour (mean deviation = 165.50 TCU) and Lead (2.1025 mg/L) showed particularly elevated levels, far exceeding permissible limits, indicating severe contamination likely originating from unmanaged solid waste and leachates. Notably, negative mean differences in pH and Dissolved Oxygen (DO) reflect acidic and oxygen-depleted water conditions, further confirming the degraded quality of water bodies around the dumpsite. These findings point to the dumpsite as a critical source of surface water pollution, posing serious health and ecological risks.

Further *t*-test comparisons between the dumpsite water and a control point at Calabar River reaffirmed the sig-

nificantly higher levels of contamination around the dumpsite. The highest mean differences, again in Colour (175.50 TCU) and Lead (2.1105 mg/L), strengthen the inference that the dumpsite is a major contributor to local water quality deterioration. The strong contrast in conductivity and other parameters underscores the wide disparity between contaminated and cleaner water sources, with heavy metal pollution and organic matter accumulation being key concerns.

The air quality assessment also indicates critical environmental concerns. The Air Quality Index (AQI) was alarmingly high at 466.7, classifying air quality as hazardous. Similarly, CO_2 (499 ppm) and $PM_{2.5}$ (44.8 μg/m³) levels exceeded FEPA limits, underscoring the risk of respiratory illnesses, especially among children and vulnerable populations. While other gaseous pollutants (NO_2, SO_2, VOCs) remained within safe thresholds, the particulate load and reduced visibility (3 km) signal poor air conditions likely caused by open burning of waste and lack of containment measures.

From the questionnaire data, the 31–45 age group constituted the highest respondent category, showing that the study captures a critical segment of economically active individuals. The predominance of males (60.8%) and respondents with tertiary education (44.5%) suggests a population with some level of environmental awareness.

Health data reveals a high prevalence of respiratory symptoms, with frequent coughing (21.8%) and asthma or breathing difficulties (21.0%) topping the list of reported illnesses. These findings correlate strongly with both water and air pollution data. The occasional and frequent occurrence of symptoms (43.55% and 26.0%, respectively) reinforces the persistent nature of health problems in the area.

Statistical analyses show that residence proximity to the Lemna dumpsite plays a significant role in determining both perceived and actual health impacts. The Pearson correlation coefficient (−0.277, $p = 0.000$) demonstrates a strong inverse relationship; those living closer to the dumpsite reported more health issues. This is corroborated by the Chi-Square test results, which indicate statistically significant relationships between proximity to the dumpsite and poor water quality.

In addition, a significant majority (80.5%) of residents strongly agreed that living near the dumpsite negatively affects their health, reflecting widespread concern and community awareness of environmental health hazards. The most frequently cited environmental problem was smoke from burning waste (26.5%), further linking environmental degradation to respiratory health issues.

In summary, the findings provide clear and statistically significant evidence that the Lemna dumpsite has a profound negative impact on both environmental quality and human health. Contaminated water, hazardous air quality, and elevated levels of heavy metals and particulate matter collectively create an unsafe living environment for nearby residents [37,38]. The close correlation between proximity to the dumpsite and health symptoms underscores the urgent need for regulatory intervention, public health support, and improved waste management strategies.

4. Conclusions

This study investigates the environmental impact of the Lemna dumpsite in Calabar, Cross River State, Nigeria, focusing on the degradation of water and air quality as well as the health implications for nearby residents. The study utilized both field data and statistical analysis to assess water and air quality, as well as the health conditions among those living in close proximity to the dumpsite. The first phase of the study involved the assessment of surface water quality, where the paired samples *t*-test revealed significant differences between the observed values at the Lemna dumpsite and WHO standards. Parameters such as Colour, Lead, pH, and Dissolved Oxygen were notably out of compliance with acceptable standards, with Colour showing the highest deviation (165.50 TCU), indicating severe contamination. Water quality comparisons between the dumpsite and a control site along Calabar River confirmed the adverse impact of the dumpsite on local water bodies, with significant disparities in key parameters like Conductivity and Lead levels. The second phase assessed air quality around the dumpsite. The Air Quality Index (AQI) revealed hazardous conditions (466.7), with CO_2 levels (499 ppm) and $PM_{2.5}$ levels (44.8 μg/m^3) exceeding regulatory thresholds. These findings suggest that the burning of waste at the dumpsite significantly contributes to air pollution, posing a risk to respiratory health, particularly among vulnerable populations. A demographic survey

of 400 respondents indicated that the majority of the population affected by the dumpsite's environmental impact are middle-aged males with tertiary education. The health survey revealed that common symptoms such as frequent coughing (21.8%) and breathing difficulties (21.0%) were prevalent in the area, with a majority of residents (80.5%) strongly agreeing that the dumpsite adversely affects their health. These symptoms correlate with both the poor water and air quality in the region.

Finally, statistical analysis confirmed a significant negative relationship between the proximity to the dumpsite and the perceived health effects. Residents living closer to the dumpsite were more likely to report health problems, including respiratory issues, reinforcing the conclusion that environmental degradation due to the dumpsite significantly impacts the well-being of nearby communities. In conclusion, the Lemna dumpsite poses substantial environmental and public health risks to the surrounding population, contributing to water and air pollution, which in turn leads to various health issues. The findings highlight the need for effective waste management strategies and public health interventions to mitigate the adverse impacts of the dumpsite on the residents of Calabar. The environmental impact of the Lemna dumpsite in Calabar, Cross River State, Nigeria, is profound and far-reaching, affecting both the natural environment and the health of surrounding communities. This study has provided strong evidence that the dumpsite is a significant source of water and air pollution, with surface water quality parameters such as Colour, Lead, pH, and Dissolved Oxygen exhibiting severe deviations from WHO standards. The contamination of water bodies around the dumpsite has detrimental implications for local aquatic ecosystems and poses a threat to the health and livelihoods of residents relying on these water sources.

The air quality around the dumpsite also raises major concerns, with dangerously high levels of Particulate Matter ($PM_{2.5}$) and Carbon Dioxide (CO_2) recorded, indicating hazardous air conditions. The burning of waste at the site is likely a primary contributor to these elevated pollution levels, increasing the risk of respiratory and other health issues, particularly among vulnerable populations such as children and the elderly. The study further revealed a clear association between proximity to the dumpsite and the prevalence of health problems, with residents living closer to the dumpsite reporting more frequent respiratory symptoms such as frequent coughing and breathing difficulties. The high prevalence of these health issues, coupled with the widespread belief among residents that the dumpsite adversely affects their health, underscores the urgent need for targeted public health interventions. Conclusively, the Lemna dumpsite presents significant environmental and public health challenges that cannot be ignored. Immediate action is needed to improve waste management practices, mitigate pollution, and address the health risks faced by nearby residents. Public awareness campaigns, stricter enforcement of environmental regulations, and the implementation of sustainable waste disposal solutions are crucial steps toward alleviating the adverse impacts of the dumpsite on the environment and the well-being of Calabar's residents.

5. Recommendations

Based on the findings of this study, the following recommendations are made to mitigate the adverse effects of the dumpsite on both the environment and public health:

1. The government and relevant agencies should establish more efficient waste management strategies, including the segregation of waste at the source, recycling programs, and proper disposal of hazardous materials. Encouraging the use of sanitary landfills instead of open dumping can significantly reduce pollution.
2. Given the significant amount of waste being generated and burnt at the dumpsite, the government should consider the development of waste-to-energy (WTE) facilities. This would not only help in reducing the amount of waste but also provide a source of renewable energy, thus reducing environmental pollution.
3. The government should implement targeted water quality remediation programs to address contamination of nearby water bodies. This could include the installation of filtration systems to remove harmful pollutants, the restoration of affected aquatic ecosystems, and the implementation of regular water quality monitoring programs.
4. The government should increase public awareness

and education on the health risks associated with living near a dumpsite. Health campaigns could focus on proper sanitation practices, personal protective measures, and the importance of using clean water sources.

5. Government and relevant NGOs should give consideration to relocating residents who live within close proximity to the dumpsite, especially those in high-risk areas. Alternatively, the establishment of buffer zones, where development is restricted, could help reduce the exposure of vulnerable communities to the harmful effects of the dumpsite.

Author Contributions

Conceptualization, O.I.E. and H.J.T.; methodology, I.A.; software, G.M.E.; validation, J.E.E., G.B.N. and E.U.E.; formal analysis, E.E.A.; investigation, I.I.U.; resources, C.A.A.; data curation, E.E.E.; writing—original draft preparation, H.J.T.; writing—review and editing, E.A.O.; visualization, E.A.O.; supervision, M.N.; project administration, G.E.B.-I.; funding acquisition, A.A.E. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was conducted in accordance with the Faculty of Arts Ethical Clearance Committee, University of Calabar and approved by the Faculty of Arts Ethics Committee Review Board (or Ethics Committee) of University of Calabar (approval number UC/FA/EC/25/009 and date: 25 May 2025).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Data is available for further inquiry and can be access through the authors.

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Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Ibor, O.R., Eni, G., Andem, A.B., et al., 2020. Biotransformation and oxidative stress responses in relation to tissue contaminant burden in Clarias gariepinus exposed to simulated leachate from a solid waste dumpsite in Calabar, Nigeria. Chemosphere. 253, 126630. DOI: https://doi.org/10.1016/j.chemosphere.2020.126630

[2] Udofia, U.U., Okoro, F.T., Joseph, A.P., 2021. Toxicological Impact of Leachates from Lemna Refuse Dump Site on African Catfish (Clarias gariepinus, Burchell 1882) Fingerlings Under Laboratory Condition. Annual Research & Review in Biology. 23–37. DOI: https://doi.org/10.9734/arrb/2021/v36i730396

[3] Adie, P.I., Afu, S.M., Olim, D.M., et al., 2022. Heavy Metals Concentration In Soils And Bioaccumulation In Earthworm (Lumbricus Terrestris) At Lemna Solid Wastes Dumpsite, Calabar, Cross River State. Global Journal of Pure and Applied Sciences. 28(2), 131–139. DOI: https://doi.org/10.4314/gjpas.v28i2.2

[4] Ibor, O.R., Mpama, N.-O.L., Okoli, C.P., et al., 2023. Occurrence, identification and characterization of plastic pollution from an open solid waste dumpsite in Calabar, Southern Nigeria. Environmental Advances. 11, 100338. DOI: https://doi.org/10.1016/j.envadv.2022.100338

[5] Ibor, O.R., Khan, E.A., Arkuwe, A., 2023. A bioanalytical approach for assessing the effects of soil extracts from solid waste dumpsite in Calabar (Nigeria) on lipid and estrogenic signaling of fish Poeciliopsis lucida hepatocellular carcinoma-1 cells in vitro and in vivo African catfish (Clarias gariepinus). Journal of Toxicology and Environmental Health, Part A. 86(20), 774–789. DOI: https://doi.org/10.1080/15287394.202

3.2240839

[6] Ukpata, M.O., Bullem, B.S., 2023. Residents Perception of the Social and Ecological Implications of Waste Dump Repository at Lemna Waste Dump Site, Calabar, Cross River State, Nigeria. International Journal of Research Publications. 127(1). DOI: https://doi.org/10.47119/IJRP1001271620235115

[7] Igelle, E.I., Phil-Eze, P.O., Obeta, M.C., et al., 2024. Predicting heavy metal transport in groundwater around Lemna dumpsite: implications for residence utilizing borehole water in Cross River State, Nigeria. Applied Water Science. 14(8), 174. DOI: https://doi.org/10.1007/s13201-024-02230-2

[8] Alawode, A.J., Stephen, J.T., Adeyemi, G.T., 2009. Health, Safety and Environmental Issues in Nigerian Manufacturing and Processing Industries. Journal of Engineering and Applied Sciences. 3, 634–641.

[9] Ekeng, E.E., Ibiang, I.E., 2025. Assessing the Environment, Social and Economic Impacts of Landfill Sites on Nearby Communities and Ecosystem in Cabalar Metropolis. The International Journal of Science & Technoledge. 12(12). DOI: https://doi.org/10.24940/theijst/2024/v12/i12/ST2412-005

[10] Igelle, E.I., Phil-Eze, P.O., Akim, O.O., et al., 2024. Spatial analysis of leachate penetration at Lemna dumpsite, Calabar: Implications for sustainable waste management in Cross River State. Heliyon. 10(9), e30097. DOI: https://doi.org/10.1016/j.heliyon.2024.e30097

[11] LennTech, 2014. Matter cycles and pollution. Available from: https://www.lenntech.com/matter-cycles-pollution.htm (cited 15 June 2025).

[12] Udiba, U., Udofia, L.E., Ezike Nkechi, N., et al., 2016. Assessment of the Impact of Solid Waste Dumps on Ground Water Quality, Calabar Municipality, Nigeria. Journal of Advance Research in Pharmacy & Biological Science. 2(4), 18–34. DOI: https://doi.org/10.53555/nnpbs.v2i4.705

[13] Odey, E.A., 2008. Religion and traditional medicine in Africa. African Pentecost: Journal of Theology, Psychology and Social Work. 1(2), 15–35.

[14] Kjeldsen, P., Barlaz, M.A., Rooker, A.P., et al., 2002. Present and Long-Term Composition of MSW Landfill Leachate: A Review. Critical Reviews in Environmental Science and Technology. 32(4), 297–336. DOI: https://doi.org/10.1080/10643380290813462

[15] Mor, S., Ravindra, K., Dahiya, R.P., et al., 2006. Leachate Characterization and Assessment of Groundwater Pollution Near Municipal Solid Waste Landfill Site. Environmental Monitoring and Assessment. 118(1–3), 435–456. DOI: https://doi.org/10.1007/s10661-006-1505-7

[16] Ogundiran, O.O., Afolabi, T.A., 2008. Assessment of the physicochemical parameters and heavy metals toxicity of leachates from municipal solid waste open dumpsite. International Journal of Environmental Science & Technology. 5(2), 243–250. DOI: https://doi.org/10.1007/BF03326018

[17] Aderemi, A.O., Oriaku, A.V., Adewumi, G.A., et al., 2011. Assessment of groundwater contamination by leachate near a municipal solid waste landfill. African Journal of Environmental Science and Technology. 5(10). Available from: https://www.researchgate.net/publication/255178792_Assessment_of_Groundwater_Contamination_by_Leachate_near_a_Municipal_Solid_Waste_Landfill

[18] Adejuwon, J.O., Adelakun, M.A., 2012. Physicochemical and Bacteriological Analysis of Surface Water in Ewekoro Local Government Area of Ogun State, Nigeria: Case Study of Lala, Yobo and Agodo Rivers. International Journal of Water Resources and Environmental Engineering. 4, 66–72.

[19] Akinbile, C.O., Yusoff., M.S., 2011. Environmental Impact of Leachate Pollution on Groundwater Supplies in Akure, Nigeria. International Journal of Environmental Science and Development. 81–86. DOI: https://doi.org/10.7763/IJESD.2011.V2.101

[20] Aboho, S.Y., Anhwange, B.A., Onianwa, P.C., et al., 2012. Assessment of Surface Water Quality around Dumpsites in the City of Ibadan Metropolis, Oyo State, Nigeria. International Journal of Chemistry. 4(1), 39. DOI: https://doi.org/10.5539/ijc.v4n1p39

[21] World Health Organization (WHO), 2017. Guidelines for Drinking-Water Quality, 4th ed. WHO: Geneva, Switzerland.

[22] Odey, E.A., Ekeke, C.E., Asuquo, O.O., et al., 2023. Pentecostal Environmentalism: A Symbiosis for Eco-Theology and Biodiversity Conservation. Pharos Journal of Theology. 104(2). DOI: https://doi.org/10.46222/pharosjot.104.220

[23] Vrijheid, M., 2000. Health effects of residence near hazardous waste landfill sites: a review of epidemiologic literature. Environmental Health Perspectives. 108(suppl 1), 101–112.

[24] Ediene, V.F., Akeh, L.B., Iren, O.B., et al., 2021. Environmental Implications of Municipal Dump Site on Soil Nitrogen in Calabar Metropolis, Nigeria. Mediterranean Journal of Social Sciences. 12(6), 116. DOI: https://doi.org/10.36941/mjss-2021-0062

[25] MacDonald, A.M., Bonsor, H.C., Dochartaigh, B.É.Ó., et al., 2012. Quantitative maps of groundwater resources in Africa. Environmental Research Letters.

7(2), 024009. DOI: https://doi.org/10.1088/1748-9326/7/2/024009

[26] Fatta, D., Papadopoulos, A., Loizidou, M., 1999. A study on the landfill leachate and its impact on the groundwater quality of the greater area. Environmental Geochemistry and Health. 21(2), 175–190. DOI: https://doi.org/10.1023/A:1006613530137

[27] Omofonmwan, S.I., Eseigbe, J.O., 2009. Effects of Solid Waste on the Quality of Underground Water in Benin Metropolis, Nigeria. Journal of Human Ecology. 26(2), 99–105. DOI: https://doi.org/10.1080/09709274.2009.11906171

[28] Intergovernmental Panel on Climate Change (IPCC), 2014. AR5 Synthesis Report: Climate Change 2014. IPCC: Geneva, Switzerland.

[29] Awomeso, J.A., Taiwo, A.M., Gbadebo, A.M., et al., 2010. Waste Disposal and Pollution Management in Urban Areas: A Workable Remedy for the Environment in Developing Countries. American Journal of Environmental Sciences. 6(1), 26–32.

[30] World Health Organization (WHO), 2021. Health and Climate Change Survey Report: Tracking Global Progress. WHO: Geneva, Switzerland.

[31] Ogbonna, D.N., Amangabara, G.T., Ekere, T.O., 2007. Urban solid waste generation in Port Harcourt metropolis and its implications for waste management. Management of Environmental Quality: An International Journal. 18(1), 71–88. DOI: https://doi.org/10.1108/14777830710717730

[32] Adewole, A.T., 2009. Waste management towards sustainable development in Nigeria: A case study of Lagos State. International NGO Journal. 4(4), 173–179. Available from: https://academicjournals.org/article/article1380901268_Adewole.pdf

[33] United Nations Environment Programme (UNEP), 2018. Waste Management Outlook for Africa. UNEP: Nairobi, Kenya.

[34] Lee, S., Hyun, Y., Lee, S., et al., 2020. Groundwater Potential Mapping Using Remote Sensing and GIS-Based Machine Learning Techniques. Remote Sensing. 12(7), 1200. DOI: https://doi.org/10.3390/rs12071200

[35] Odey, E.A., Asuquo, O.O., Amokaha, G.S., et al., 2023. Symbol in African Religion and Philosophy: The Tiv Experience. Pharos Journal of Theology. 104(2). Available from: https://www.pharosjot.com/uploads/7/1/6/3/7163688/article_11_vol_104_2__nigeria.pdf

[36] Odum, E.P., 1971 Fundamentals of Ecology, 3rd ed. W.B. Saunders Company: Philadelphia, PA, USA.

[37] Odey, E.A., 2020. Differential dimensions between pentecostals and Aladura movements in Nigeria. LWATI: A Journal of Contemporary Research. 17(1), 105–123.

[38] Odey, E.A., 2013. Ethical transformation and value reorientation in Nigeria: A Religious perspective. Academic Discourse: An International Journal. 5(2), 283–297.