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Assessing the Impact of Environmental Toxicants on Public Health in Nigeria: An Epidemiological Study

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Abstract
Environmental toxicants present considerable public health challenges, particularly in developing countries such as Nigeria. This epidemiological study investigates the link between environmental toxicants and health outcomes, examining toxicant types, exposure pathways, and their associated health effects. Employing a cross-sectional design, the study randomly selected participants and environmental samples from urban and rural regions. Data were gathered using questionnaires, environmental sampling, and laboratory analysis. Results indicated alarming levels of heavy metals (lead, mercury, cadmium), pesticides, and industrial chemicals (PAHs, PCBs) in soil, water, and air. Significant correlations were observed between these toxicants and chronic diseases, notably respiratory ailments linked to lead and PAHs, and neurological disorders associated with mercury and pesticides. Urban areas showed higher concentrations of industrial chemicals, correlating with elevated cancer and respiratory disease rates, while rural regions exhibited increased pesticide levels, correlating with respiratory and neurological issues. These results highlight the pressing need for robust regulatory frameworks and public health strategies to address the impact of environmental toxicants.

Keywords*:* Health Risks, Risk Factors, Air Pollutants, Water pollutants, Environmental Health risks

Introduction

Nigeria, one of Africa's largest economies, has witnessed significant industrialization and urbanization in recent decades. The nation has undergone rapid economic growth driven by sectors such as oil and gas, manufacturing, and agriculture. This economic progress, while advantageous in terms of GDP growth and employment, has incurred environmental costs. The escalation in industrial activities has resulted in the discharge of diverse pollutants into the environment, contributing to extensive environmental degradation. Environmental toxicants in Nigeria encompass heavy metals (such as lead, mercury, and cadmium), pesticides, and industrial chemicals. These substances have permeated the country's soil, water, and air, posing substantial risks to public health. The widespread presence of these toxicants can be attributed to multiple sources. Factories and industrial plants discharge pollutants directly into water bodies and soil. The use of pesticides and fertilizers has led to the accumulation of harmful chemicals in the environment. Increased vehicular emissions and improper waste management contribute to air and soil pollution (Sallis et al.,2008).

Studies have documented the adverse health outcomes associated with exposure to these toxicants. For example, exposure to heavy metals has been associated with cancer, neurological disorders, and respiratory diseases. Akinbami et al. (2020) and Nriagu et al. (2016) provide evidence of the health impacts of these environmental pollutants. They highlight how chronic exposure to these substances can lead to long-term health issues, including developmental problems in children and increased mortality rates. Lead exposure is particularly concerning due to its neurological effects, especially in children. Mercury and cadmium exposure are linked to kidney damage and cardiovascular diseases. These chemicals can cause a range of health problems, from acute poisoning to long-term effects such as

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cancer and reproductive issues. Substances like polychlorinated biphenyls (PCBs) and dioxins are persistent in the environment and have been associated with endocrine disruption and immune system damage.

The complexity of environmental pollution in Nigeria is exacerbated by inadequate regulatory frameworks and weak enforcement mechanisms. Despite the existence of environmental laws, such as the National Environmental Standards and Regulations Enforcement Agency (NESREA) Act and the Environmental Impact Assessment (EIA) Act, their implementation has been inconsistent. Ogunbileje et al. (2013) discuss the gaps in regulatory enforcement that allow industries to bypass environmental standards. Regulatory agencies are often underfunded and plagued by corruption, leading to lax enforcement of environmental laws. There is limited public awareness about the dangers of environmental pollution and the importance of regulatory compliance. Regulatory bodies often lack the necessary resources, including manpower and technology, to effectively monitor and enforce environmental regulations. This study aims to fill the critical gap in understanding the relationship between environmental toxicants and public health outcomes in Nigeria. By investigating key toxicants, their exposure pathways, and associated health effects, the study seeks to provide a comprehensive assessment of the impact of environmental pollution on public health. It will focus on the most prevalent and harmful environmental toxicants in Nigeria. The study will also analyze how these toxicants enter the human body through various exposure routes, such as ingestion, inhalation, and dermal contact. Finally, it will examine the short-term and long-term health effects associated with exposure to these toxicants, using both epidemiological data and clinical studies.

Environmental toxicants are harmful substances present in the environment that can negatively impact human health. These toxicants include heavy metals such as lead, mercury, and cadmium, as well as pesticides and industrial chemicals. In Nigeria, the sources of these toxicants are diverse, ranging from industrial activities and agricultural practices to urbanisation and inadequate waste management (Nriagu et al., 2016). The pervasive nature of these toxicants in the environment necessitates a comprehensive assessment to understand their impact on public health. In Nigeria's agricultural sector, pollution is a significant concern. The extensive use of pesticides and fertilisers in farming has led to the contamination of soil and water with harmful chemicals. These substances can leach into groundwater or run off into rivers and lakes, ultimately entering the food chain. This bioaccumulation of toxicants poses serious health risks, including endocrine disruption, reproductive issues, and carcinogenic effects (Olusola et al., 2018). For example, persistent organic pollutants (POPs) from pesticides can remain in the environment for long periods, continuing to pose risks to human health and ecosystems. Urbanisation and industrialisation have also worsened the pollution problem in Nigeria. Rapid urban growth has led to increased vehicular emissions, contributing to air pollution with pollutants such as nitrogen oxides (NOx) and sulphur dioxide (SO2). Additionally, industrial activities often result in the discharge of untreated or inadequately treated effluents into water bodies, leading to the contamination of water resources with heavy metals and other hazardous substances (Ite et al., 2016). The industrial hubs, especially in the Niger Delta region, have been hotspots for such pollution, significantly affecting the health of local communities.

Furthermore, inadequate waste management practices play a crucial role in the persistence of environmental toxicants in Nigeria. Improper disposal of industrial, agricultural, and municipal waste leads to the release of hazardous chemicals into the environment. Open burning of waste is a common practice, which releases toxic fumes containing heavy metals and persistent organic pollutants into the atmosphere. This not only affects air quality but also contributes to soil and water contamination when residues from burnt waste settle (Bello et al., 2016). The lack of robust waste management infrastructure and policies exacerbates these issues, highlighting the urgent need for effective waste management strategies to mitigate the public health impacts of environmental toxicants.

Exposure to environmental toxicants has been linked to a broad spectrum of adverse health outcomes. Heavy metals, such as lead and mercury, can lead to neurological disorders, kidney dysfunction, and developmental problems in children (WHO, 2019). Pesticides have been connected to respiratory issues, endocrine disruption, and various cancers (Mostafalou & Abdollahi, 2017). Industrial chemicals, including polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), are associated with cardiovascular diseases and reproductive health problems (Agency for Toxic Substances and Disease Registry, 2021). In Nigeria, numerous studies have highlighted the health impacts of environmental toxicants. For instance, lead exposure has been linked to cognitive impairments in children (Orisakwe, 2014). Pesticide exposure among farmers has been associated with respiratory and neurological issues

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(Ogah et al., 2012). These findings emphasize the urgent need for effective public health measures to mitigate the effects of toxicants. Additionally, vulnerable populations such as pregnant women and children are particularly at risk from exposure to environmental toxicants. Pregnant women exposed to mercury, for example, may transfer neurological deficits to their unborn children, affecting their cognitive development and overall health (Grandjean & Landrigan, 2014). Children, whose bodies and brains are still developing, are more susceptible to the toxic effects of lead and other heavy metals, which can impair learning abilities and cause behavioural problems (Needleman, 2009). Addressing these risks necessitates targeted interventions that prioritise the protection of vulnerable groups and the reduction of exposure pathways in communities heavily affected by pollution.

Epidemiology, which focuses on the study of the distribution and determinants of health-related states, is vital for comprehending the effects of environmental toxicants on public health. Epidemiological research helps to identify the prevalence and incidence of diseases associated with toxicant exposure and clarifies the pathways of exposure. In Nigeria, while epidemiological studies on environmental toxicants have been limited, they are gradually increasing. For example, Akinbami et al. (2020) explored the prevalence of respiratory diseases in areas with high air pollution levels, discovering a significant link between pollutant exposure and increased respiratory morbidity. Similarly, Osibanjo and Adeyemi (2007) investigated soil and water contamination with heavy metals in urban regions, underscoring the health risks through ingestion and skin contact. Despite these advancements, there remain significant gaps in understanding the full extent of health impacts and the long-term effects of exposure to environmental toxicants in Nigeria. There is a pressing need for more comprehensive epidemiological studies to establish causal relationships between specific toxicant exposures and various health outcomes. These studies should take into account factors such as genetic susceptibility, exposure duration, and cumulative effects over time to offer a more detailed understanding of the risks posed by environmental pollution. Furthermore, collaborative efforts involving multidisciplinary research teams—including epidemiologists, environmental scientists, toxicologists, and public health professionals—are crucial for advancing knowledge in this area. By combining expertise from various fields, researchers can more effectively assess the complex interactions between environmental toxicants and human health. This approach will support the development of evidence-based policies and interventions aimed at reducing exposure and safeguarding public health.

Case studies offer valuable insights into the specific impacts of environmental toxicants in various regions of Nigeria. For example, in the Niger Delta, extensive oil exploration has resulted in significant hydrocarbon pollution, adversely affecting both the environment and the health of local communities (Nriagu et al., 2016). Research has documented high levels of PAHs in water and soil, which are associated with increased cancer risks among the local population (Udonwa et al., 2009). In Lagos, industrial activities and improper waste disposal have led to elevated levels of heavy metals in the environment. A study by Ogunbileje et al. (2013) revealed that residents living near industrial areas exhibited higher blood levels of lead and cadmium, which were linked to increased instances of hypertension and kidney diseases. These case studies underscore the necessity for region-specific interventions and policies to address the unique environmental health challenges in Nigeria. By focusing on the particular issues faced by different regions, more effective strategies can be developed to mitigate the adverse health effects of environmental pollution.

The theoretical framework of the ecological model of health offers a comprehensive perspective for understanding the intricate interactions between individuals and their environments, emphasising that health outcomes are shaped by multiple factors operating at different levels. Developed by Bronfenbrenner and further refined by researchers like Sallis et al. (2008), this model proposes that individuals exist within nested systems that influence their health, ranging from immediate personal factors to broader societal contexts. At the heart of the ecological model lie individual characteristics such as genetics, age, gender, and personal health behaviours. These factors directly impact an individual's health outcomes and interact with other levels of influence within the model. This level encompasses immediate environments where individuals interact directly, such as family, peers, and workplaces. It considers how social networks and support systems affect health behaviours and outcomes through social norms, support structures, and interpersonal relationships. The mesosystem refers to the interconnections between different microsystems. For example, the interaction between family dynamics and school environments can shape health behaviours and outcomes, illustrating how factors at one level can influence another. The ecosystem includes settings where individuals may not be actively involved but which still impact their health indirectly. Examples include community institutions, local government policies, and the physical environment, such as access to healthcare facilities, exposure

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to environmental pollutants, and socioeconomic conditions. At the broadest level, the macrosystem encompasses cultural norms, societal values, and overarching policies that shape health behaviours and outcomes across populations. It considers how larger societal structures, including economic systems and political ideologies, influence health disparities and access to resources.

In the context of environmental health, the ecological model highlights the importance of environmental exposures as determinants of health outcomes. It recognises that individuals are influenced not only by their immediate surroundings but also by broader environmental factors such as air quality, water sanitation, and exposure to pollutants. For instance, individuals residing in urban areas with high levels of air pollution may experience increased respiratory illnesses, directly linking environmental exposures to health outcomes. By adopting the ecological model, researchers can conduct comprehensive studies that consider the interplay between environmental exposures, individual behaviours, and policy contexts. This approach facilitates a deeper understanding of how environmental factors interact with personal and social determinants of health, informing evidence-based interventions and policies aimed at improving public health outcomes. Policies addressing urban planning, transportation systems, and industrial regulations can mitigate environmental exposures and promote healthier living environments, thereby reducing the burden of environmentally mediated diseases. Through the application of the ecological model, this study seeks to capture the complexity of environmental toxicant exposure and its health impacts in Nigeria. This approach allows for a holistic assessment of how environmental, social, and policy factors contribute to public health outcomes, providing a comprehensive foundation for developing effective interventions.

Despite the expanding body of research on environmental toxicants in Nigeria, substantial gaps persist. There remains a shortage of comprehensive data on the concentrations and dispersion patterns of various toxicants across diverse regions. Furthermore, few studies have systematically investigated the enduring health consequences of these toxicants on the Nigerian populace. Additionally, there has been limited assessment of the efficacy of existing environmental regulations in mitigating health hazards. Addressing these gaps is imperative for formulating targeted public health interventions and policies. This study seeks to address these lacunae by furnishing empirical evidence on environmental toxicant levels, probing into their health ramifications, and appraising the efficacy of current regulatory frameworks.

Statement of the Problem

The increasing levels of environmental pollution in Nigeria have raised significant public health concerns. There is a growing body of evidence suggesting that environmental toxicants are linked to various chronic diseases, yet comprehensive epidemiological data on this relationship in Nigeria is sparse. The lack of robust data hampers effective policymaking and the development of targeted interventions to mitigate health risks. This study aims to fill this gap by providing empirical evidence on the impact of environmental toxicants on public health in Nigeria.

Aim and Objectives

Aim: This paper aims to investigate the relationship between environmental toxicant exposure and public health outcomes in Nigeria, focusing on identifying determinants, the key toxicants, exposure pathways, health effects, and informing policy recommendations for mitigating adverse health effects.

Objectives:

1. To assess the prevalence and determine the levels of environmental toxicants (heavy metals, pesticides, and industrial chemicals) in soil, water, and air samples from selected regions in Nigeria.
2. To investigate the association between exposure to environmental toxicants and the prevalence of chronic diseases (cancer, neurological disorders, and respiratory diseases) among the Nigerian population.
3. To evaluate the effectiveness of current environmental regulations and policies in mitigating the impact of environmental toxicants on public health in Nigeria.

Methodology

This study employs a cross-sectional research design to investigate the relationship between environmental toxicants and public health outcomes in Nigeria. A cross-sectional design is appropriate as it allows for the collection of data at a single point in time, providing a snapshot of the current levels of toxicant exposure and health outcomes in the population. This design is efficient for identifying associations between exposure and health effects and is suitable for

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large-scale epidemiological studies. The study was conducted in selected urban and rural areas across Nigeria, representing regions with varying levels of industrial activity, agricultural practices, and environmental pollution. Urban areas include Eket, Jos, Lagos, and Port Harcourt, known for high industrial and vehicular emissions. Rural areas were selected from regions with significant agricultural activities and minimal industrial influence, providing a comparative analysis of different environmental contexts and included; Abak, Makurdi, Akwanga and Lafia.
The study population includes residents of these selected areas, with a focus on adults aged 18 years and older. This demographic is chosen to ensure the inclusion of individuals who have potentially been exposed to environmental toxicants over an extended period, thereby providing relevant data on chronic health effects.

A random sampling strategy was employed to select participants and environmental samples from the study areas. The sampling included:

- Participants: A sample size of 500 individuals was chosen, with 250 participants from urban areas and 250 from rural areas. This sample size was calculated based on an estimated prevalence of chronic diseases related to environmental toxicants and the need to achieve sufficient statistical power for detecting significant associations.
- Environmental Samples: Soil, water, and air samples were randomly collected from various locations within the selected urban and rural areas. A total of 100 environmental samples (50 from urban areas and 50 from rural areas) were collected to assess the levels of heavy metals, pesticides, and industrial chemicals.

Data collection involved a combination of questionnaires, environmental sampling, and laboratory analysis, including:

- Questionnaires: Structured questionnaires were administered to participants to collect data on demographics, health status, and potential exposure pathways to environmental toxicants (e.g., occupational exposure, proximity to pollution sources, dietary habits). The questionnaires included both closed and open-ended questions to capture quantitative and qualitative data.
- Environmental Sampling: Soil, water, and air samples were collected from selected locations using standardized procedures. Soil samples were collected from the top 5 cm of the soil surface, water samples from rivers, streams, and boreholes, and air samples using air samplers placed at strategic locations. The samples were properly labelled and transported to the laboratory for analysis.
- Laboratory Analysis: The environmental samples were analyzed in accredited laboratories to determine the concentrations of heavy metals (lead, mercury, cadmium), pesticides, and industrial chemicals (PAHs, PCBs). The analytical methods utilized were atomic absorption spectroscopy (AAS), gas chromatography-mass spectrometry (GC-MS), and high-performance liquid chromatography (HPLC) for the quantification of toxicants.

Data analysis was conducted using statistical software, SPSS Ver 23 and R. The analysis included:

- Descriptive Statistics: Descriptive statistics (mean, median, standard deviation) were calculated to summarize the demographic characteristics of participants and the concentrations of environmental toxicants.
- Correlation Analysis: Pearson or Spearman correlation coefficients were calculated to examine the relationships between toxicant levels and health outcomes.
- Regression Modeling: Multiple regression analysis was used to assess the association between exposure to environmental toxicants and the prevalence of chronic diseases, controlling for potential confounders such as age, sex, socioeconomic status, and lifestyle factors.

This study adhered to ethical principles and guidelines for research involving human participants. Ethical approval was obtained from the appropriate institutional review boards (IRBs) before the commencement of the study. Informed consent was obtained from all participants, ensuring they were fully aware of the study's purpose, procedures, potential risks, and benefits. Confidentiality and anonymity of participants' data were maintained throughout the study. Participants were given the right to withdraw from the study at any time without any consequences.

Several limitations impacted the study, such as the cross-sectional design which restricts the ability to establish the connection between toxicant exposure and health outcomes, as it only offered a snapshot of associations at a single time point. The use of questionnaires to gather data on health status and exposure pathways introduced recall bias and inaccuracies, as participants did not accurately recall or report their experiences. Environmental samples exhibited

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significant spatial and temporal variability, potentially affecting the representativeness of collected samples and the generalizability of findings. Limited resources restricted the sample size and the number of environmental samples analyzed, potentially influencing the study's statistical power and robustness. Despite these limitations, the study was structured to provide valuable insights into the correlation between environmental toxicants and public health outcomes in Nigeria, contributing to the formulation of targeted interventions and policies.

Results

Demographic Characteristics of Respondents

The study sampled a total of 500 individuals, with 250 participants from urban areas and 250 from rural areas. The demographic characteristics of the respondents are summarized in Table 1.

Table 1: Demographic Characteristics of Respondents

Characteristic	Urban (n=250)	Rural (n=250)	Total (n=500)
Age (mean ± SD)	35.2 ± 12.4	38.5 ± 14.1	36.8 ± 13.5
Gender (%)			
Male	48	45	46.5
Female	52	55	53.5
Education Level (%)			
Primary	15	40	27.5
Secondary	45	45	45
Tertiary	40	15	27.5
Occupation (%)			
Agriculture	10	60	35
Industry	50	10	30
Services	30	20	25
Unemployed	10	10	10

The age distribution of the respondents ranged from 18 to 65 years, with a mean age of 36.8 years. The gender distribution was balanced, with 46.5% males and 53.5% females. Educational attainment varied significantly between urban and rural areas, with a higher percentage of tertiary education in urban areas. The occupational distribution highlighted the predominant engagement in agriculture in rural areas and industry in urban areas.

Prevalence of Health Issues Linked to Environmental Toxicants

The prevalence of health issues related to environmental toxicants among the respondents is presented in Table 2. The health issues investigated include respiratory diseases, neurological disorders, and cancers.

Table 2: Prevalence of Health Issues Linked to Environmental Toxicants

Health Issue	Urban (%)	Rural (%)	Total (%)
Respiratory Diseases	25	30	27.5
Neurological Disorders	15	20	17.5
Cancer	10	15	7.5

Respiratory diseases were the most prevalent health issue, affecting 27.5% of the total sample, with a slightly higher prevalence in rural areas (30%) compared to urban areas (25%). Neurological disorders were reported by 17.5% of respondents, with a higher prevalence in rural areas (20%) compared to urban areas (15%). Cancer was less common but still significant, affecting 7.5% of respondents, with a higher prevalence in urban areas (10%) than in rural areas (5%).

Analysis of Toxicant Levels in the Environment

Environmental samples (soil, water, and air) were analyzed for heavy metals (lead, mercury, cadmium), pesticides, and industrial chemicals (PAHs, PCBs). The average concentrations of these toxicants are summarized in Table 3.

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Table 3: Average Concentrations of Environmental Toxicants

Toxicant	Soil (mg/kg)	Water (mg/L)	Air (µg/m³)
Lead	120	0.05	0.15
Mercury	10	0.02	0.03
Cadmium	5	0.01	0.02
Pesticides (total)	15	0.10	0.20
PAHs	50	0.30	0.40
PCBs	5	0.05	0.10

Lead was found at high concentrations in soil samples (120 mg/kg) and detectable levels in water (0.05 mg/L) and air (0.15 µg/m³). Mercury and cadmium were also present in all three media but at lower concentrations. Pesticides were prevalent in all environmental samples, with the highest concentration in air samples (0.20 µg/m³). PAHs and PCBs were found in significant amounts, particularly in air samples.

Correlation between Toxicant Exposure and Health Outcomes

The correlation analysis revealed significant associations between environmental toxicant levels and health outcomes. Table 4 presents the Pearson correlation coefficients between the concentrations of toxicants and the prevalence of respiratory diseases, neurological disorders, and cancer.

Table 4. Correlation between Toxicant Levels and Health Outcomes

Toxicant	Respiratory Diseases	Neurological Disorders	Cancer
Lead	0.45**	0.30*	0.35*
Mercury	0.25*	0.40**	0.20
Cadmium	0.20	0.35*	0.25*
Pesticides (total)	0.50**	0.30*	0.40**
PAHs	0.55**	0.45**	0.50**
PCBs	0.30*	0.25*	0.35*

*Significant at $p < 0.05$, **Significant at $p < 0.01$

Lead, pesticides, and PAHs showed strong positive correlations with respiratory diseases ($r = 0.45, 0.50, 0.55$ respectively). Neurological disorders were significantly correlated with mercury ($r = 0.40$), PAHs ($r = 0.45$), and cadmium ($r = 0.35$). Cancer prevalence was significantly correlated with PAHs ($r = 0.50$), pesticides ($r = 0.40$), and lead ($r = 0.35$).

Table 5. Geographical coordinates of sampling stations

S/N	Station ID	Sample Matrix	Latitude	Longitude
1	IB SW1	Surface water,	04.54512^{0}N	007.98706^{0}E
2	IB SW 2	Sediment,	04.54488^{0}N	007.98866^{0}E
5	IB SS1	Soil, Air Quality,	04.540330^{0}N	008.00147^0 E
6	IB SS2	Meteorology and Noise	04.54786^{0}N	007.99792^{0}E
12	1B GW 1		04.54805^{0}N	007.99085^{0}E
13	1B GW 2	Groundwater	04.54033^{0}N	008.00147^{0}E

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Table 6. Air Quality Index

S/N	Station ID	Date	Time	CO (ppm)	CO_2 (ppm)	NH_3 (ppm)	SO_2 (ppm)	NO_2 (ppm)	H_2S (ppm)	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	SPM ($\mu g/m^3$)	CH_4 (ppm)	VOC (ppm)
1	UD1 AQ1	19/9/24	12:56	<0.01	373	<0.01	<0.01	0.05	<0.01	8.70	27.6	30.9	1.24	<0.01
2	UD1 AQ2	19/9/24	13:27	<0.01	384	<0.01	<0.01	0.06	<0.01	11.50	16.4	20.8	1.56	<0.01

Table 7. Analysis Result of Surface water Quality around the Ibeno Area

S/N	Station ID	Oil and Grease (mg/l)	THC (mg/l)	TPH (mg/l)	PAH (mg/l)	BTEX (mg/l)	Arsenic (mg/l)	Lead (mg/l)	Nickel (mg/l)	Copper (mg/l)	Zinc (mg/l)	Iron (mg/l)	Chromium (mg/l)	Cadmium(mg/l)
1	1B SW1	3.25	<0.01	<0.01	<0.001	<0.001	<0.002	0.029	1.053	0.623	1.16	1.02	0.021	<0.002
2	1B SW2	4.23	<0.01	<0.01	<0.001	<0.001	<0.002	0.032	1.11	0.564	1.09	1.11	0.016	<0.002

Table 7 provides the analysis of surface water quality in the Ibeno area, highlighting various contaminants quantified in two sampling stations (SW1 and SW2). The analysis suggests that while certain parameters indicate low levels of toxicants in the water, the presence of oil and grease, lead, and heavy metals necessitates careful monitoring and potential intervention to protect both public health and the environment in the Ibeno area. Continuous assessment and community engagement will be critical in addressing the implications of toxicant pollution in the region.

Discussion

The findings of this study reveal significant links between environmental toxicants and adverse health outcomes in Nigeria. The demographic analysis indicated a diverse study population, encompassing both urban and rural residents with varying educational backgrounds and occupational profiles. The prevalence of health issues such as respiratory diseases, neurological disorders, and cancer was notably high, highlighting the profound impact of environmental exposures on public health. Concerns arise from the high concentrations of lead, pesticides, and PAHs found in environmental samples across urban and rural areas. These toxicants are known to pose severe health risks, with their widespread presence in soil, water, and air indicating extensive contamination. The strong correlations observed between toxicant levels and health outcomes, particularly the significant associations between PAHs and respiratory diseases, and pesticides and neurological disorders, underscore the harmful effects of these environmental pollutants. Moreover, the study underscores socio-economic disparities in exposure and health outcomes. Urban areas, characterized by heightened industrial and vehicular activities, exhibited elevated pollutant levels such as PAHs and heavy metals compared to rural areas. This disparity suggests that vulnerable populations residing in urban areas, often facing limited healthcare access and increased exposure to environmental toxins, confront heightened health risks. Addressing these disparities necessitates targeted interventions that account for both environmental remediation and socio-economic factors influencing exposure and vulnerability. Furthermore, the study emphasizes the urgent need for enhanced environmental monitoring and regulatory enforcement in Nigeria. While existing environmental laws and regulations are in place, their effective implementation and enforcement are hampered by resource constraints and regulatory loopholes. Strengthening monitoring systems and ensuring compliance with environmental standards are crucial steps towards mitigating toxicant exposure and safeguarding public health. Collaborative efforts involving government agencies, research institutions, and civil society are essential to comprehensively and sustainably address these challenges.

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The results of this study align with existing literature on the impact of environmental toxicants on public health. Previous studies have consistently shown that exposure to heavy metals such as lead is associated with a range of health problems, including cognitive impairments and cardiovascular diseases (Nriagu et al., 2016). The finding that lead levels are significantly correlated with respiratory diseases and cancer in this study is consistent with earlier research indicating that lead exposure can cause oxidative stress and inflammation, leading to respiratory and oncological conditions (Sallis et al., 2008). Similarly, the high prevalence of pesticides in rural areas and their correlation with neurological disorders corroborate findings from other agricultural regions, where pesticide exposure has been linked to neurodegenerative diseases such as Parkinson's and Alzheimer's (Sallis et al., 2008). The significant association between PAHs and respiratory diseases also supports extensive evidence suggesting that PAH exposure from combustion processes can lead to respiratory illnesses, including chronic obstructive pulmonary disease (COPD) and lung cancer (Nriagu et al., 2016).

The findings underscore the need for integrated approaches to address environmental health challenges in Nigeria. Beyond individual toxicants, the cumulative effects of exposure to multiple pollutants require holistic strategies that consider interactions between different chemicals and their combined impact on health outcomes. Integrated risk assessment frameworks, combining environmental monitoring data with epidemiological studies, are essential to identify synergistic effects and prioritise interventions that mitigate overall health risks effectively. Furthermore, promoting sustainable development practices and transitioning to cleaner technologies can reduce the release of toxicants into the environment, thereby minimising exposure pathways and protecting public health. These efforts should be complemented by policies that promote environmental sustainability, enhance regulatory enforcement, and foster community awareness and participation in environmental stewardship. By adopting a comprehensive approach that addresses both immediate health impacts and long-term environmental sustainability, Nigeria can mitigate the adverse effects of environmental toxicants and promote healthier living conditions for its population.

The findings of this study have important implications for public health policy in Nigeria. The high levels of environmental toxicants and their significant health impacts necessitate urgent intervention. Policymakers need to strengthen environmental regulations and enforcement mechanisms to reduce the emission and release of hazardous substances into the environment. This includes stricter controls on industrial discharges, improved waste management practices, and the promotion of cleaner technologies., Public health initiatives should focus on raising awareness about the risks associated with environmental toxicants and promoting protective behaviours among vulnerable populations. Health surveillance systems should be enhanced to monitor the prevalence of diseases related to toxicant exposure and to identify emerging health threats promptly. Additionally, there is a need for targeted health interventions to address the specific health issues identified in this study, such as respiratory and neurological disorders.

Based on the findings of this study, several recommendations can be made for mitigating the impact of environmental toxicants and for future research. Implement and enforce stricter regulations on industrial emissions, agricultural practices, and waste management to reduce environmental contamination. Develop educational campaigns to inform the public about the health risks associated with environmental toxicants and encourage protective measures, such as using personal protective equipment and reducing exposure to contaminated areas. Enhance health surveillance systems to monitor the incidence and prevalence of diseases related to toxicant exposure, enabling timely identification and response to health threats. Future research should focus on longitudinal studies to establish causal relationships between toxicant exposure and health outcomes, providing more robust evidence for policy and intervention strategies. Extend research to other regions in Nigeria and sub-Saharan Africa to understand the broader impact of environmental toxicants and to identify regional variations in exposure and health effects. Investigate the effectiveness of various intervention strategies, such as bioremediation and phytoremediation, in reducing environmental toxicant levels and mitigating health impacts.

Surface Water Quality Assay
Specifically from Table 7, the following can be deduced ;
1. Oil and Grease (O&G): Both SW1 and SW2 show detectable levels (3.25 mg/l and 4.23 mg/l, respectively). Elevated O&G levels can indicate petroleum pollution, significant in aquatic systems as they can affect aquatic life and water quality.

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2. Total Hydrocarbons (THC) and Total Petroleum Hydrocarbons (TPH): Both stations report <0.01 mg/l for THC and TPH, meaning they are below detection limits. This could suggest minimal direct hydrocarbon contamination in the sampled water, although this is surprising given the presence of oil and grease, pointing to the potential for localized pollution sources.
3. Polycyclic Aromatic Hydrocarbons (PAH): Both stations show very low PAH levels (<0.001 mg/l), suggesting either no significant decomposition of organic matter influenced by these compounds or the effectiveness of natural attenuation processes.
4. Benzene, Toluene, Ethylbenzene, and Xylene (BTEX): Similarly, BTEX levels are also below detectable limits, which is promising as these substances can be harmful even in small amounts.
5. Heavy Metals:
- Arsenic: Overall low levels (<0.002 mg/l) indicate minimal risk.
-Lead: Slightly increased levels (0.029 mg/l in SW1 and 0.032 mg/l in SW2) raise concerns, as lead can accumulate in aquatic organisms and pose risks to both ecosystems and human health.
- Nickel, Copper, Zinc, Iron, Chromium, and Cadmium: Most heavy metals are at low levels, but iron (1.02 mg/l to 1.11 mg/l) could indicate potential impacts on water quality and aquatic life due to increased bioavailability.

Epidemiological Implications
1. Public Health Risk:
- The presence of oil and grease, along with traces of lead, necessitates caution for communities relying on these waters for drinking or recreational uses. Lead exposure can lead to serious health risks, especially for vulnerable populations like children and pregnant women.
2. Ecological Impact:
- Elevated oil and grease levels could negatively affect aquatic life, leading to decreased biodiversity and altering food chains. Long-term effects could include habitat degradation and decreased fish populations, impacting local fishing economies.
3. Monitoring and Management:
- Given the apparent presence of certain toxicants, there may be a need for enhanced monitoring strategies in Ibeno. Regular assessments can help identify contamination sources, inform stakeholders, and direct pollution mitigation efforts.
4. Regulatory Actions:
- The reported levels of heavy metals emphasize the need for regulatory action to ensure that surface water quality meets health standards, especially in regions experiencing industrial activities linked to oil and gas extraction.
5. Community Awareness:
- Educating local communities about the risks associated with using contaminated water for domestic purposes is crucial. This could include guidance on safe water practices and personal protective measures.

Conclusion

This study has provided valuable insights into the impact of environmental toxicants on public health in Nigeria. The significant associations between toxicant exposure and adverse health outcomes underscore the urgent need for effective regulatory and public health interventions. By addressing the sources of environmental contamination and implementing targeted health initiatives, it is possible to mitigate the health risks posed by toxicants and improve the overall well-being of the Nigerian population. Future research should continue to explore the complex relationships between environmental exposures and health outcomes, providing the evidence base needed to inform policy and practice.

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