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Assessment of Environmental Contamination and Pollutant Exposure Pathways Among Households Surrounding Informal Solid-Waste Disposal Sites in Obio/Akpor, Rivers State

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Abstract- Informal solid-waste disposal is a major environmental and public-health concern in rapidly urbanizing communities. This study assessed informal solid-waste disposal practices and associated environmental and potential public-health risks in Obio/Akpor Local Government Area, Rivers State, Nigeria. A cross-sectional study was conducted using structured household questionnaires and environmental assessment of air, soil and water around informal waste-disposal sites. Of 427 questionnaires administered, 389 were valid, representing a 91.1% response rate. Descriptive statistics were used to assess waste-management practices, household proximity and reported exposure pathways, while environmental measurements were compared with relevant guideline values. Informal disposal was common, with 35.2% of households using informal dumpsites, 22.9% practising open burning and 12.3% disposing waste through drains or waterways. Overall, 70.4% relied on these unsafe disposal practices, while 61.2% of households were located within 250 m of informal disposal sites. Mean $PM_{2.5}$ (48.6 µg/m³) and PM_{10} (92.4 µg/m³) exceeded WHO 24-hour guideline values. Soil lead (84.6 mg/kg), cadmium (3.8 mg/kg) and total petroleum hydrocarbons (1,850 mg/kg) exceeded adopted reference values. Water showed acidic pH (5.91), elevated lead (0.028 mg/L), cadmium (0.009 mg/L), iron (0.87 mg/L) and E. coli (146 CFU/100 mL). Reported exposure pathways included offensive odour (77.6%), dust/particulates (71.5%), smoke (62.0%), soil/waste contact (50.9%) and potentially contaminated water (42.9%). Informal waste disposal in Obio/Akpor is associated with environmental contamination and multiple plausible exposure pathways. Improved formal waste collection, elimination of open dumping and burning, environmental monitoring, and protection of water and drainage systems are recommended.

Keywords: informal waste disposal, environmental contamination, public health, air quality, heavy metals, water quality.

I. INTRODUCTION

Rapid population growth, urbanization and changing consumption patterns have substantially increased municipal solid-waste generation worldwide. Where collection, treatment and final disposal systems are inadequate, waste accumulation and informal disposal can become persistent sources of environmental contamination and human exposure. Globally, approximately 2.24 billion tonnes of municipal solid waste are generated annually, with a substantial proportion inadequately managed or openly dumped. Such practices facilitate the release and transport of pollutants through air, soil and water and create conditions conducive to vector proliferation and disease transmission, particularly in low- and middle-income countries (United Nations Environment Programme [UNEP], 2024).

Nigeria faces significant challenges in managing the environmental consequences of increasing waste generation, particularly in rapidly expanding urban centres. Evidence from dumpsite-affected areas indicates that waste disposal can alter soil quality and increase concentrations of potentially toxic metals. In Port Harcourt Metropolis, Afolabi and Eludoyin (2021) reported considerable heavy-metal contamination around active and abandoned

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dumpsites, suggesting potential ecological and human-health implications. Similar investigations in other Nigerian locations have identified elevated concentrations of potentially toxic metals in soils and groundwater surrounding waste-disposal sites, demonstrating that contamination can extend beyond the immediate boundaries of dumpsites (Laniyan & Adewumi, 2019; Olorunfemi et al., 2021; Ogboeli et al., 2024).

Water and air represent important pathways through which contaminants can reach nearby populations. Decomposition of waste produces leachate that can infiltrate soil and groundwater, while rainfall and surface runoff can transport contaminants into adjacent drainage systems and surface-water bodies. Studies in Nigeria have reported contamination of groundwater in the vicinity of waste-disposal sites, raising concerns regarding the use of such water for domestic urposes (Ibe et al., 2020; Ogboeli et al., 2026). In addition, open burning of waste can generate particulate matter and other combustion-related pollutants. Exposure to particulate matter, particularly $PM_{2.5}$ and PM_{10}, is associated with adverse respiratory and cardiovascular outcomes (World Health Organization [WHO], 2021).

These concerns are particularly relevant to Obio/Akpor Local Government Area, a densely populated and rapidly urbanizing part of the Port Harcourt metropolitan area where informal waste-disposal practices persist. Previous research has documented the proliferation of irregular household-waste dumpsites in the Niger Delta and highlighted their potential public-health implications (Okpara et al., 2021). However, available evidence has generally focused on individual dimensions of the problem, including dumpsite distribution, specific environmental contaminants or reported health outcomes, with limited integration of environmental contamination and the pathways through which pollutants are encountered by households living around informal disposal sites.

This study therefore assesses environmental contamination and pollutant exposure pathways among households surrounding informal solid-waste disposal sites in Obio/Akpor. By examining contamination across relevant environmental media and characterizing exposure through inhalation, ingestion and dermal contact, the study provides an integrated assessment of household-level environmental risk. The findings are expected to inform evidence-based waste-management interventions, environmental monitoring, exposure reduction strategies and public-health planning in the study area.

II. THEORETICAL FRAMEWORK

1. Source–Pathway–Receptor (SPR) Model

The Source–Pathway–Receptor (SPR) model provides a useful framework for understanding how environmental hazards originate, are transported through environmental media, and ultimately reach exposed populations. The model conceptualizes environmental risk as a chain linking a contaminant source to one or more transport pathways and a receptor. Contemporary environmental-health and exposure-assessment studies have applied this approach to trace contaminants from their sources through air, soil and water to human populations (Hines et al., 2019; Ziajahromi et al., 2020). In the context of the present study, informal solid-waste disposal sites represent the primary sources of contamination, generating pollutants through waste decomposition, leachate formation, wind-blown dust and open burning. Air, soil, surface water and groundwater constitute potential environmental pathways, while households living around the disposal sites represent the principal receptors. Exposure may subsequently occur through inhalation, ingestion and dermal contact. The SPR model therefore provides the principal theoretical basis for linking waste-disposal practices with environmental contamination and household pollutant exposure in Obio/Akpor.

2. Social Ecological Model

The Social Ecological Model (SEM), developed by McLeroy et al. (1988), explains health and environmental outcomes as products of interactions among factors operating at multiple levels. These include individual, interpersonal, organizational, community and policy influences. Rather than attributing exposure or health outcomes to individual behaviour alone, the model recognizes that household practices are embedded within broader social, institutional and environmental contexts. Subsequent research has applied ecological perspectives to environmental and occupational health problems, including waste-related exposures and risks among populations living or working around waste-disposal environments (Schröder et al., 2019). The SEM is relevant to the present study because household exposure to pollutants from informal waste sites may be influenced by distance from disposal sites, household waste-handling practices, awareness of environmental risks, community disposal practices, availability of formal waste-collection services, institutional enforcement and environmental regulations. These interacting factors can increase or reduce household vulnerability even where households are exposed to similar environmental conditions. The SEM therefore complements the SPR model by explaining the social and institutional factors that shape exposure and vulnerability among households surrounding informal solid-waste disposal sites.

III. MATERIALS AND METHODS

Study Area: The study was conducted in Obio/Akpor Local Government Area (LGA), Rivers State, Nigeria, within the Port Harcourt metropolitan area. The area is characterized by rapid urbanization, high population density, mixed residential, commercial and industrial land uses, and increasing municipal solid-waste generation. Informal waste disposal is common in several communities, with waste frequently deposited in vacant plots, roadsides, drainage corridors and other unauthorized locations. The humid tropical environment, characterized by high rainfall, may facilitate contaminant mobilization through leachate infiltration and surface runoff. These environmental and demographic characteristics make Obio/Akpor an appropriate setting for assessing contamination associated with informal solid-waste disposal and potential exposure among surrounding households.

Study Design and Population: A community-based cross-sectional design integrating household surveys, environmental sampling and spatial analysis was employed. The study population comprised households residing within communities containing identified informal solid-waste disposal sites. Adult household representatives who had resided in the selected communities for at least six months were eligible to participate. Individuals unable to provide informed responses or visitors who did not ordinarily reside in the study area were excluded.

Identification of Informal Waste-Disposal Sites: Informal solid-waste disposal sites were identified through field reconnaissance, direct observation, community information and review of available spatial information. A site was classified as an informal disposal site where solid waste was routinely deposited outside an authorized or formally managed waste-disposal facility. The geographic coordinates of identified sites were recorded using a handheld GPS receiver. Site characteristics, including waste composition, evidence of open burning, proximity to residential buildings, drainage channels and water bodies, and surrounding land use, were documented using a standardized observation checklist.

Sampling Procedure and Sample Size: A multistage sampling procedure was used to select communities and households. Identified communities were grouped according to the presence and spatial distribution of informal disposal sites. Households were subsequently selected systematically within predefined proximity zones around the disposal sites. For exposure assessment, distance-based zones of ≤100 m, 101–250 m, 251–500 m and >500 m were used, where applicable.

The minimum household sample size was determined using the Cochran formula for cross-sectional studies:

$$n = \frac{Z^2pq}{d^2}$$

where $n$is the required sample size, $Z = 1.96$(corresponding to a 95 % confidence level), $p = 0.50$(estimated proportion), $q = 1 - p$, and $d = 0.05$(margin of error).

Substitution of the values yields:

$$n = \frac{(1.96)^2(0.50)(0.50)}{(0.05)^2} = 384$$

A 10 % allowance for non-response was added, resulting in a target sample size of approximately 427 respondents.

Household Survey: Data on household characteristics and potential exposure pathways were collected using

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a structured interviewer-administered questionnaire. Variables included sociodemographic characteristics, duration of residence, distance from informal disposal sites, household waste-management practices, exposure to waste-related dust, smoke and odour, use of potentially contaminated water sources, contact with waste materials, hygiene practices and awareness of environmental risks.

The questionnaire was pretested among households in a comparable community outside the study area. Necessary modifications were made to improve clarity, consistency and contextual appropriateness before the main survey. Trained research assistants administered the final instrument following standardized procedures.

Environmental Sampling: Environmental sampling focused on ambient air, soil and water as the principal environmental media through which pollutants could reach surrounding households.

Soil samples were collected from predetermined locations around selected informal disposal sites, including areas close to waste deposits and comparison locations outside the immediate influence of the sites. Samples were collected using appropriate sampling equipment, placed in labelled containers and transported to the laboratory under prescribed conditions.

Water samples were collected from accessible groundwater and surface-water sources used by or located near surrounding households. Sampling points were georeferenced, and samples were collected in sterile, appropriately labelled containers. Samples intended for microbiological analysis were handled aseptically and transported under refrigerated conditions.

Ambient air quality was assessed at selected locations surrounding the disposal sites. Measurements focused primarily on $PM_{2.5}$ and PM_{10}, with monitoring locations selected to represent areas of high and lower potential exposure. Measurements were conducted using calibrated portable air-quality monitoring equipment according to the manufacturer's operating procedures.

Laboratory Analysis: Collected soil and water samples were analyzed using established standard analytical procedures. Soil samples were assessed for physicochemical characteristics and selected potentially toxic metals, including lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni) and zinc (Zn), where applicable. Water samples were analyzed for relevant physicochemical and microbiological parameters, including pH, total dissolved solids, electrical conductivity, turbidity and Escherichia coli, together with selected metals.

Appropriate quality-control procedures, including instrument calibration, blanks, duplicates and analytical standards, were incorporated into laboratory analysis. Environmental measurements were interpreted against applicable Nigerian and international environmental-quality guidelines.

Assessment of Pollutant Exposure Pathways: Potential exposure pathways were evaluated by integrating household responses, environmental measurements, field observations and spatial proximity. Three principal routes of exposure were considered: inhalation, ingestion and dermal contact.

Inhalation exposure was assessed based on proximity to disposal sites, exposure to dust and smoke, open waste burning and measured particulate-matter concentrations. Ingestion exposure included consumption or domestic use of potentially contaminated water, accidental ingestion of contaminated soil or dust, and possible contamination of food within waste-affected environments. Dermal exposure was assessed in relation to direct contact with contaminated soil, waste materials and potentially contaminated water.

The Source–Pathway–Receptor (SPR) model guided the integration of these pathways, with informal disposal sites regarded as contamination sources, air, soil and water as environmental pathways, and surrounding households as receptors.

Spatial Analysis: Spatial data were analyzed using Geographic Information System (GIS) techniques. Coordinates of informal disposal sites, environmental sampling locations and relevant household locations were imported into GIS software for mapping and

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spatial analysis. Buffer zones were generated around disposal sites to classify households according to distance and potential exposure.

Spatial overlay was used to examine the relationship between informal disposal sites, residential areas, drainage networks and nearby water sources. Nearest Neighbour Analysis was employed to determine whether disposal sites exhibited clustered, random or dispersed spatial patterns. The spatial distribution of environmental contamination was subsequently examined in relation to household proximity to disposal sites.

Statistical Analysis: Questionnaire and environmental data were analyzed using SPSS version 26/27. Descriptive statistics, including frequencies, percentages, means and standard deviations, were used to summarize household characteristics, waste-disposal practices, environmental measurements and reported exposure pathways.

The distribution of continuous variables was assessed before inferential analysis. Differences in contaminant concentrations across sampling locations or proximity categories were examined using analysis of variance (ANOVA), independent-samples t-tests or appropriate non-parametric tests, as applicable. Associations between categorical variables were assessed using the chi-square test.

Where appropriate, multivariable logistic regression was used to identify factors independently associated with selected exposure outcomes. Results were presented as adjusted odds ratios (AORs) with corresponding 95% confidence intervals (CIs). Statistical significance was established at $p < 0.05$.

Quality Assurance and Ethical Considerations: Quality assurance was maintained throughout data collection, environmental sampling and laboratory analysis. Field personnel were trained and supervised, sampling equipment was calibrated before use, and samples were appropriately labelled, preserved and transported. Laboratory quality-control procedures included blanks, duplicates, standards and instrument calibration. Completed questionnaires were checked for completeness and consistency before data entry and analysis.

Ethical approval was obtained from the Rivers State University ethics committee before commencement of the study. Permission was also obtained from appropriate community authorities. Participants provided informed consent before participation. Participation was voluntary, and confidentiality and anonymity were maintained throughout the study. No personally identifying information was included in the analytical dataset.

IV. RESULT

Response Rate and Socio-demographic Characteristics

A total of 427 questionnaires were administered to eligible household representatives across the selected communities in Obio/Akpor Local Government Area. Of these, 389 questionnaires were correctly completed and included in the analysis, giving a response rate of 91.1%. The respondents varied in age, sex, educational attainment and duration of residence.

The largest age group was 28–37 years (28.8%), followed by 38–47 years (24.9%). Females constituted 54.8% of respondents, while males accounted for 45.2%. Regarding educational attainment, secondary education was the most common level (40.4%), followed by tertiary education (26.0%). Nearly half of the respondents (48.1%) had lived in the study area for more than 10 years.

Table 1. Socio-demographic Characteristics of Respondents

Variable	Category	n	%
Age (years)	18–27	68	17.5
	28–37	112	28.8
	38–47	97	24.9
	48–57	71	18.3
	≥58	41	10.5
Sex	Male	176	45.2
	Female	213	54.8
Educational attainment	No formal education	42	10.8
	Primary	89	22.9
	Secondary	157	40.4
	Tertiary	101	26.0
Duration of residence	<5 years	78	20.1
	5–10 years	124	31.9

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	>10 years	187	48.1
Total		389	100.0

Household Proximity to Informal Waste-Disposal Sites

Table 2 shows that 238 respondents (61.2%) lived within 250 m of an informal waste-disposal site, comprising 97 (24.9%) within 100 m and 141 (36.2%) between 101 and 250 m. The remaining 151 respondents (38.8%) lived more than 250 m from an informal disposal site.

Table 2. Distribution of Households by Proximity to Informal Waste-Disposal Sites

Distance from disposal site	n	%
≤100 m	97	24.9
101–250 m	141	36.2
>250 m	151	38.8
Total	389	100.0

Household Waste-Management Practices

Table 3 presents the waste-management practices reported by the 389 households surveyed. Disposal at informal dumpsites was the most common practice, reported by 137 households (35.2%). This was followed by formal waste collection, reported by 93 households (23.9%), and open burning, reported by 89 households (22.9%). Disposal of waste in drains or waterways was reported by 48 households (12.3%), while 22 households (5.7%) reported other disposal methods.

Overall, the findings indicate that informal and potentially environmentally unsafe waste-disposal practices were more common than formal waste collection among the surveyed households. In particular, the combined proportion reporting disposal at informal dumpsites, open burning, or disposal in drains/waterways was 70.4% (274/389), indicating substantial reliance on practices that may facilitate environmental pollution and household exposure.

Table 3. Household Waste-Management Practices

Waste-management practice	n	%
Formal waste collection	93	23.9
Disposal at informal dumpsite	137	35.2
Open burning	89	22.9
Disposal in drains/waterways	48	12.3
Other	22	5.7
Total	389	100.0

Ambient Air Quality around Informal Waste-Disposal Sites

Table 4 presents the measured ambient air-quality parameters around the informal waste-disposal sites. The mean concentrations of $PM_{2.5}$ (48.6 µg/m³) and PM_{10} (92.4 µg/m³) were above their respective 24-hour guideline values of 15 µg/m³ and 45 µg/m³. The mean CO concentration was 4.8 mg/m³, which was within the stated 8-hour guideline value of 10 mg/m³.

The mean concentrations of NO_2 (0.09) and SO_2 (0.07) were above the respective guideline ranges presented in the table. Similarly, the mean H_2S concentration of 0.12 exceeded the stated odour/reference threshold of 0.008–0.01. Overall, the findings indicate elevated particulate and gaseous pollutant levels around the informal waste-disposal sites, particularly for $PM_{2.5}$, PM_{10}, NO_2, SO_2 and H_2S.

Table 4. Ambient Air Quality around Informal Waste-Disposal Sites

Parameter	Mean concentration	Unit	Guideline	Status
$PM_{2.5}$	48.6	µg/m³	15 (24-h)	Above
PM_{10}	92.4	µg/m³	45 (24-h)	Above
CO	4.8	mg/m³	10 (8-h)	Within
NO_2	0.09	mg/m³	0.04–0.06	Above
SO_2	0.07	mg/m³	0.04–0.05	Above
H_2S	0.12	mg/m³	0.008–0.01	Above

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			(odour)

Soil Quality around Informal Waste-Disposal Sites

Table 5 presents the mean soil physicochemical characteristics and concentrations of potentially toxic contaminants around the informal waste-disposal sites. The mean soil pH was 5.8, indicating slightly acidic soil conditions relative to the reference range of 6.0–8.5.

The mean concentration of lead (Pb) was 84.6 mg/kg, exceeding the stated reference value of 70.0 mg/kg. Similarly, cadmium (Cd) was 3.8 mg/kg, which was above the reported reference range of 0.8–3.0 mg/kg. In contrast, the mean chromium (Cr) concentration of 42.5 mg/kg was below the reference value of 100 mg/kg.

The mean concentrations of copper (Cu), zinc (Zn), iron (Fe), and total petroleum hydrocarbons (TPH) were 68.3, 215.7, 12,450 and 1,850 mg/kg, respectively. Cu and Zn were within the respective reference ranges presented, while Fe and TPH were higher than the background/intervention values reported. Overall, the results indicate elevated concentrations of selected potentially toxic contaminants, particularly Pb, Cd and TPH, in soils around the informal waste-disposal sites

Table 5. Soil Quality and Potentially Toxic Contaminants around Informal Disposal Sites

Parameter	Mean concentration	Reference value	Status
pH	5.8	6.0–8.5	Slightly acidic
Pb (mg/kg)	84.6	70.0	Above reference
Cd (mg/kg)	3.8	0.8–3.0	Above reference
Cr (mg/kg)	42.5	100	Within reference
Cu (mg/kg)	68.3	36–100	Within reference range
Zn (mg/kg)	215.7	140–300	Within reference range
Fe (mg/kg)	12 450	Background value	Elevated
TPH (mg/kg)	1 850	50–1,000	Elevated

Source: Study data

Water Quality around Informal Waste-Disposal Sites

Table 6 presents the physicochemical and microbiological characteristics of water sampled around the informal waste-disposal sites. The mean pH was 5.91, which was below the stated guideline range of 6.5–8.5, indicating acidic water conditions. The mean concentrations of TDS (286.4 mg/L), EC (478), nitrate (18.6 mg/L), chloride (62.4 mg/L), and sulphate (41.2 mg/L) were within their respective stated guideline values.

In contrast, the mean concentrations of Pb (0.028 mg/L), Cd (0.009 mg/L), and Fe (0.87 mg/L) exceeded the corresponding guideline values of 0.01, 0.003, and 0.3 mg/L, respectively. Microbiological analysis also detected 146 CFU/100 mL of E. coli, whereas the stated guideline value for drinking water is zero. This indicates faecal contamination of the sampled water.

Overall, the findings demonstrate acidic conditions and elevated concentrations of selected potentially toxic metals, together with microbiological contamination, in water around the informal waste-disposal sites.

Table 6. Physicochemical and Microbiological Characteristics of Water

Parameter	Mean concentration	Unit	Guideline value	Interpretation
pH	5.91	—	6.5–8.5	Acidic
TDS	286.4	mg/L	500–1,000	Within guideline
EC	478	µS/cm	1,000	Within guideline

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Nitrate	18.6	mg/L	50	Within guideline
Chloride	62.4	mg/L	250	Within guideline
Sulphate	41.2	mg/L	100–250	Within guideline
Pb	0.028	mg/L	0.01	Above guideline
Cd	0.009	mg/L	0.003	Above guideline
Fe	0.87	mg/L	0.3	Above guideline
E. coli	146	CFU/100 mL	0	Contaminated

Pollutant Exposure Pathways among Households
Table 7 presents the environmental exposure pathways reported by households residing around informal waste-disposal sites. Offensive odour was the most commonly reported exposure condition, with 302 respondents (77.6%), followed by dust/particulate exposure, reported by 278 respondents (71.5%). Smoke or exposure from open waste burning was reported by 241 respondents (62.0%).

Contact with soil or waste materials was reported by 198 respondents (50.9%), while 167 respondents (42.9%) reported contact with or use of potentially contaminated water. Possible ingestion of contaminated soil or dust was reported by 112 respondents (28.8%).

Overall, the results indicate that respondents experienced multiple reported exposure conditions associated with informal waste-disposal environments, with offensive odour, particulate/dust exposure and smoke/open-burning exposure being the most frequently reported conditions. The findings also show that households reported exposure through air, soil/waste and water-related pathways. These results represent reported exposure conditions and do not constitute direct measurements of individual pollutant uptake or absorbed dose.

Table 7. Reported Pollutant Exposure Pathways among Households

Exposure pathway/condition	n	%
Offensive odour	302	77.6
Dust/particulate exposure	278	71.5
Smoke/open-burning exposure	241	62.0
Contact with soil/waste materials	198	50.9
Contact/use of potentially contaminated water	167	42.9
Possible ingestion of contaminated soil/dust	112	28.8

Integrated Source–Pathway–Receptor Assessment
The integrated source–pathway–receptor assessment identified informal waste-disposal sites as potential sources of particulate, chemical and microbiological contamination. Ambient air provided a plausible inhalation pathway, contaminated soil provided potential ingestion and dermal-contact pathways, while contaminated water represented a potential ingestion and dermal-contact pathway. The proximity analysis further indicated that 61.2% of households were located within 250 m of informal disposal sites, suggesting substantial spatial opportunity for household exposure.

Table 8. Integrated Environmental Contamination and Household Exposure Pathways

Source	Environmental medium/pathway	Evidence from study	Plausible exposure route
Informal waste disposal	Ambient air	$PM_{2.5}$ = 48.6 μg/m³; PM_{10} = 92.4 μg/m³	Inhalation
Informal waste disposal	Soil	Pb = 84.6 mg/kg	Ingestion/dermal contact

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Informal waste disposal	Water	pH = 5.91; *E. coli* = 146 CFU/100 mL	Ingestion/dermal contact
Informal waste disposal	Air/dust	Dust reported by 71.5%	Inhalation
Informal waste disposal	Waste environment	Offensive odour reported by 77.6%	Inhalation/indirect exposure
Informal waste disposal	Residential environment	61.2% within 250 m	Increased potential exposure

Spatial Risk Classification

Table 9 presents the spatial classification of informal waste-disposal sites based on their location relative to residential settlements and nearby water bodies. Sites classified as high risk were those located within settlements and in close proximity to water bodies, indicating a higher potential for household and water-mediated exposure. Sites located within settlements but away from water bodies were classified as medium risk, reflecting a moderate potential for household exposure. Sites situated outside settlements and away from water bodies were classified as low risk, indicating relatively lower potential for direct household exposure

Table 9. Spatial Risk Classification of Informal Waste-Disposal Sites

Risk category	Spatial characteristics	Environmental exposure implication
High	Within settlement and close to water bodies	High potential for household and water-mediated exposure
Medium	Within settlement but away from water bodies	Moderate potential for household exposure
Low	Outside settlement and away from water bodies	Relatively lower potential for direct household exposure

V. DISCUSSION OF FINDINGS

The study revealed substantial environmental and potential public-health concerns associated with informal solid-waste disposal in Obio/Akpor Local Government Area. Of the 427 questionnaires administered, 389 were valid, giving a response rate of 91.1%. Almost half of the respondents (48.1%) had lived in the study area for more than 10 years, while 61.2% of households were located within 250 m of informal waste-disposal sites. This spatial proximity is important because households living close to unmanaged waste may experience repeated contact with contaminated air, soil, water and waste-derived pollutants. However, proximity alone does not establish actual exposure or adverse health effects, since exposure is also influenced by waste characteristics, duration of contact, meteorological conditions, drainage, household practices and individual behaviour.

The finding that 70.4% of households disposed of waste through informal dumpsites, open burning or drains/waterways demonstrates considerable dependence on environmentally unsafe disposal practices. This pattern is consistent with evidence of widespread irregular household waste dumpsites in the Niger Delta, where inadequate waste-management systems and limited public-health monitoring have been identified as persistent environmental concerns (Okpara et al., 2021; Agbovu et al., 2026). The finding also supports the broader position of the United Nations Environment Programme (UNEP, 2024) that poorly managed municipal waste generates environmental pollution and hidden health and socioeconomic costs. The predominance of informal disposal in the present study therefore appears to reflect not only household behaviour but also deficiencies in accessible and reliable formal waste-collection services.

The ambient air measurements further indicated potential exposure concerns around informal waste-disposal locations. The mean concentrations of PM2.5 (48.6 µg/m³) and PM10 (92.4 µg/m³) were above the World Health Organization (WHO) 24-hour guideline

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values of 15 and 45 μg/m³, respectively (World Health Organization [WHO], 2021). The elevated particulate concentrations may reflect the combined influence of exposed waste, resuspended dust, vehicular activities and open burning. This interpretation is strengthened by the finding that 71.5% of respondents reported exposure to dust or particulate matter and 62.0% reported exposure to smoke from open burning. WHO (2021) identifies particulate air pollution as an important risk factor for respiratory and cardiovascular diseases. Consequently, persistent particulate exposure around unmanaged waste sites may represent an important environmental-health concern in densely populated communities.

The concentrations of NO_2 and SO_2 were also reported to exceed the comparison values adopted in the study, whereas CO was within the stated reference value. These findings should, however, be interpreted according to the specific averaging periods and standards used for each pollutant. WHO (2021) provides pollutant-specific guideline concentrations for different exposure periods; therefore, comparisons should not be made across different averaging periods without appropriate adjustment. The elevated sulphur- and nitrogen-containing pollutants may partly reflect combustion associated with open waste burning, although other urban emission sources may also contribute. Thus, informal waste disposal should be regarded as a plausible contributor rather than the sole source of measured gaseous pollutants.

Soil analysis revealed evidence of chemical contamination around the waste-disposal environment. Soil pH was slightly acidic (5.8), while lead (84.6 mg/kg), cadmium (3.8 mg/kg) and total petroleum hydrocarbons (1,850 mg/kg) exceeded the respective comparison values adopted in the study. In contrast, chromium, copper and zinc were within their stated reference ranges. These findings are broadly consistent with studies demonstrating heavy-metal contamination around Nigerian dumpsites. Afolabi and Eludoyin (2021), for example, reported significant heavy-metal contamination and high pollution indices in soils surrounding active and abandoned dumpsites in Port Harcourt. The present finding is therefore particularly relevant because contaminated soil can provide pathways for human exposure through incidental ingestion of contaminated soil or dust and dermal contact, especially where waste sites are located close to residential areas.

The detection of elevated lead and cadmium is of particular environmental-health importance because both metals can persist in environmental media and may pose health concerns following sufficient exposure. Nevertheless, the concentrations reported in this study demonstrate environmental contamination rather than quantified human-health risk. A complete health-risk assessment would require exposure parameters and calculation of chronic daily intake or average daily dose, hazard quotient, hazard index and, where applicable, cancer risk. This distinction is important because environmental concentration alone cannot determine the magnitude of individual health risk.

Water-quality results similarly demonstrated selected contamination concerns. Although total dissolved solids, electrical conductivity, nitrate, chloride and sulphate were within the stated reference values, water pH was acidic (5.91), while lead (0.028 mg/L), cadmium (0.009 mg/L), iron (0.87 mg/L) and Escherichia coli (146 CFU/100 mL) exceeded the comparison criteria used in the study. The presence of E. coli indicates faecal contamination and raises concern regarding the sanitary quality of the water. The findings are consistent with evidence from Nigeria showing that groundwater around exposed dumpsites can be affected by potentially toxic metals and may present long-term environmental-health concerns (Laniyan & Adewumi, 2019).

The occurrence of lead, cadmium and iron in the water suggests that waste-derived contaminants may be entering or interacting with local water systems. However, source attribution should be made cautiously because groundwater and surface-water quality can also be affected by geological conditions, septic systems, agricultural activities and other anthropogenic sources. The present findings therefore demonstrate water-quality deterioration in the study environment but do not, by themselves, establish that informal waste disposal was the exclusive source of the contaminants.

Reported exposure pathways provided additional evidence of potential household contact with waste-

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related environmental hazards. Offensive odour was the most frequently reported exposure condition (77.6%), followed by dust or particulate exposure (71.5%), smoke from open burning (62.0%), contact with soil or waste (50.9%), contact with potentially contaminated water (42.9%) and possible ingestion of contaminated soil or dust (28.8%). Because respondents could report more than one pathway, these percentages represent multiple-response categories and should not be interpreted as mutually exclusive exposures. The findings nevertheless demonstrate that households experience several simultaneous environmental conditions through which waste-related contaminants may be encountered.

An important strength of the study is the convergence between reported exposure pathways and environmental measurements. For example, the high proportion reporting dust exposure corresponds with elevated PM2.5 and PM10 concentrations, while reported contact with soil and waste is consistent with the detection of elevated lead, cadmium and total petroleum hydrocarbons in soil. Similarly, reported contact with potentially contaminated water corresponds with the detection of selected chemical and microbiological contaminants. This convergence provides stronger evidence of potential exposure than reliance on either self-reported information or environmental measurements alone.

The spatial findings further reinforce the potential exposure concern. Approximately six out of every ten households (61.2%) were located within 250 m of informal waste-disposal sites. The study's classification of locations into high-, medium- and low-risk areas provides a useful screening framework for identifying communities requiring priority intervention. Areas located within settlements and close to water bodies were classified as having the greatest potential exposure because of the combined possibility of direct household contact and water-mediated contaminant movement. Nevertheless, such classifications should be regarded as screening-level assessments unless supported by quantitative GIS-based exposure modelling, measured contaminant gradients and population-specific risk estimates.

Summarily, the findings demonstrate a chain linking inadequate waste management with environmental contamination and multiple plausible exposure pathways. The pattern is consistent with the broader evidence that poorly managed waste creates interconnected pollution and public-health challenges (UNEP, 2024). The findings also support previous Nigerian studies documenting contamination of soils and groundwater around waste-disposal sites (Afolabi & Eludoyin, 2021; Laniyan & Adewumi, 2019). However, the present study should not infer disease causation from environmental contamination alone. Its principal contribution is the demonstration of a spatially concentrated waste-management problem accompanied by elevated environmental contaminants and multiple potential exposure routes.

The results have important implications for environmental-health management in Obio/Akpor. Priority interventions should include expansion of reliable formal waste-collection services, elimination of open dumping and uncontrolled burning, improved protection of drains and water bodies, routine monitoring of air, soil and water quality, and GIS-based identification of households located in high-exposure areas. Environmental-health surveillance should also be strengthened around informal disposal sites. These measures would address the environmental pathways identified in the study while reducing the likelihood of prolonged exposure to waste-associated pollutants.

VI. CONCLUSION

The study established that informal solid-waste disposal is a significant environmental concern in Obio/Akpor Local Government Area. A substantial proportion of households depended on informal dumpsites, open burning, drains and waterways for waste disposal, while many households were located within close proximity to informal disposal sites. These conditions indicate inadequate waste-management practices and increased opportunities for household exposure to waste-related environmental hazards.

Environmental assessment further revealed elevated concentrations of $PM_{2.5}$, PM_{10}, selected heavy metals and total petroleum hydrocarbons in soil, as well as chemical and microbiological contamination of water. The reported exposure pathways, particularly dust, smoke, offensive odour, contact with contaminated soil and potentially contaminated water, corresponded with the environmental findings and indicate multiple plausible routes of human exposure. However, the findings demonstrate environmental contamination and potential exposure rather than direct causation of specific health outcomes.

Summarily, the study highlights the need for improved formal waste-collection services, elimination of uncontrolled dumping and open burning, protection of drainage and water systems, and routine environmental monitoring in affected communities. Priority should be given to households located close to informal disposal sites and water bodies. Strengthening environmental-health surveillance and implementing GIS-based risk prioritization could support more targeted interventions and reduce potential public-health risks associated with poor solid-waste management.

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