



# An Integrated Ward-Level Analysis of Environmental Exposure and Health Vulnerability in the Federal Capital Territory, Nigeria



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**ABSTRACT:** Nigeria's Federal Capital Territory has experienced urban expansion, notably spurred by rural-urban migration, resulting in growing health vulnerabilities in underserved communities. The problem of growing environmental hazards and the associated health risks has not been properly researched and dimensioned in the FCT. This study investigated environmental exposure and urban health vulnerability across informal settlements in 15 Wards of Abuja Municipal, Bwari, and Gwagwalada Area Councils of the Federal Capital Territory (FCT). The research employed a quantitative design, combining household data from 1,137 questionnaires administered to residents on exposure to ceiling materials, solid waste management methods, and drinking water quality. In addition to the household data, field environmental samples (air, noise, and water) were collected and tested both on-site and in the laboratory to determine constituent concentrations. A Composite Vulnerability Index (CVI) was constructed from the six datasets, consolidating all variables into a single dataset for each ward within the study area. The findings show that values across the study area range from 0.32 to 0.91, with Zuba identified as the most vulnerable ward due to significant levels of air, water, and noise pollutants. The study recommends using health hazard communication tools for low-literacy populations, as well as community safety audits and local health hazard awareness index cards in highly vulnerable wards, to reduce health risks and improve residents' well-being.

**KEYWORDS:** Hazards, Urban vulnerability, Informal settlement, Environmental risk, Pollution

[Received Jan. 25, 2025; Revised Feb. 19, 2026; Accepted Feb. 22, 2026]

Print ISSN: 0189-9546 | Online ISSN: 2437-2110

## I. INTRODUCTION

Nigeria's urban population in 1960 was fewer than 375,000 residents, distributed across merely 50 towns (Bloch et al., 2015). Currently, rural settlements have evolved into substantial towns, and smaller cities have expanded into immense metropolises (Bodo, 2019). The population of the Federal Capital Territory (FCT) has risen from 1,406,239 in 2006 to over three million in 2022 (UNDESA, 2022; NBS, 2024). This rapid growth in the urban population, fuelled by massive rural-urban migration, has overwhelmed public sector resources (Adam et al., 2023). This form of urbanisation also poses significant challenges to residents' health and well-being, rendering them susceptible to health hazards stemming from inadequate sanitation, substandard housing, restricted access to healthcare, and unfavourable environmental conditions.

Urban residents live in informal housing on the most marginal lands, where they are exposed to various health hazards (Avis, 2019). The dwellers survive in poor environmental conditions with limited access to public services such as water, sewerage, security, and fire protection. Infant mortality is high, and residents battle poor physical and mental health. The precariousness of housing, fragile socio-environmental conditions, and exposure to natural and anthropogenic hazards combine to create a continuous process of disaster risk (Cai and Mustapha, 2023). Residents of informal settlements are often

marginalised from cities' formal development processes, making it difficult for them to access opportunities, including health-related ones. Consequently, this marginalisation increases their vulnerability to health issues hazards (Sandoval and Sarmiento, 2020).

Vulnerability to health in informal settlements has been linked to the prevalence and effects of overcrowding, increased dilapidation, and the risk of exposure to, and transmission of, infectious diseases such as tuberculosis (TB), as well as an increased risk of mental health issues (Okoro et al., 2023). Kimemia et al. (2021) cited the unsafe utilisation of paraffin, coal, and wood for cooking, heating, and lighting due to limited access to electricity. These fuels have been recognised as contributing factors to physical injuries within informal settlements. Additionally, respiratory diseases such as allergies and asthma have been associated with dampness and mould in residential buildings in informal settlements (Fakunle et al., 2023). These factors can expose inhabitants to both physical and environmental risks associated with overcrowding. This study is focused on issues of poor physical development and the associated environmental health hazards. It analyses housing and environmental health hazards as well as the level of health vulnerability levels in selected informal settlements within the Federal Capital Territory, Nigeria. The findings from this study are expected to provide guidance to decision-makers on strengthening environmental health governance and supporting the attainment of Sustainable Development Goal

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11. This will enhance residents' health outcomes and contribute to sustainable urban development in the study area.

**II. THEORETICAL FRAMEWORK**

The theory relevant to this study is the pressure-and-release model. The Pressure and Release (PAR) model, which dates to the first version of At Risk in 1994, posited that disasters result primarily from the structure and evolution of human societies. Wisner et al. (2012) suggested that the basis for the

PAR idea is that a disaster is the interaction of two opposing forces: processes that generate vulnerability on one side and the natural hazard on the other (Figure 1). The PAR has become the internationally accepted model for explaining the progression of vulnerability and the progression toward safety (risk reduction). The Pressure Model indicates that underlying causes, dynamic pressures, and unsafe conditions contribute to vulnerability (UNISDR, 2017). Linking the above to a hazardous trigger event increases the risk in communities (Pigeon and Rebotier, 2016).

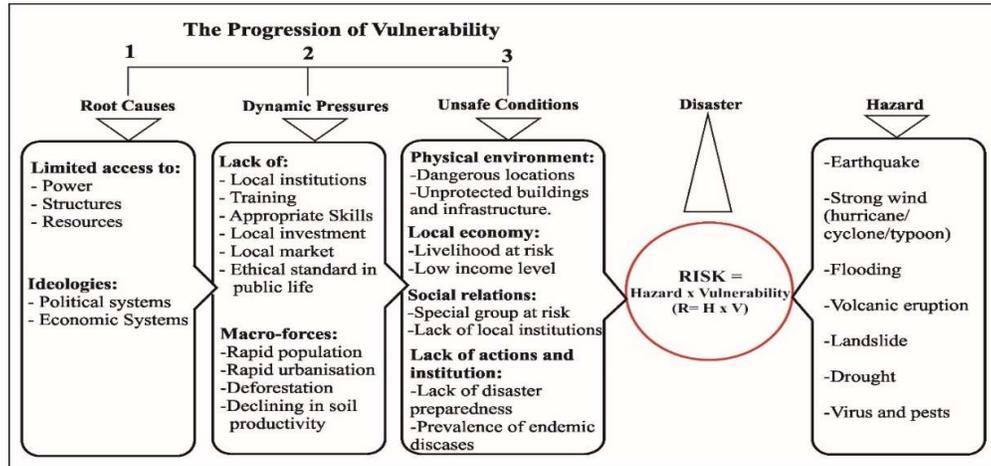


Figure 1 The Pressure and Released Model (PAR)  
Source: Wisner et al. (2012)

Although the PAR model succeeded in explaining vulnerability progression and vulnerability metrics, it fails to capture information systemically. Notwithstanding its shortcomings, the PAR model is considered relevant to this study because it helps analyse underlying risk factors, factors contributing to the progression of vulnerability, and the hazards faced within a community.

**III. MATERIALS AND METHOD**

**A. The Description of the Study Area**

The Federal Capital Territory, Nigeria, lies between latitudes 8° 25' and 9° 25' North of the Equator and longitudes 6° 45' and 7° 45' East of the Greenwich Meridian.

The Territory serves as the seat of Nigeria's capital (Abuja). Located at the geographic centre of the country, the FCT covers approximately 8,000 km<sup>2</sup> and was created in 1976 to serve as a neutral administrative centre, away from the political and ethnic tensions in Lagos (Obateru, 2004). The territory is divided into six area councils: Abuja Municipal, Bwari, Gwagwalada, Kuje, Abaji, and Kwali (NPC, 2006) (Figure 1). The Federal Capital City (FCC) is situated within the Abuja Municipal Area Council and functions as the administrative and political centre of Nigeria.

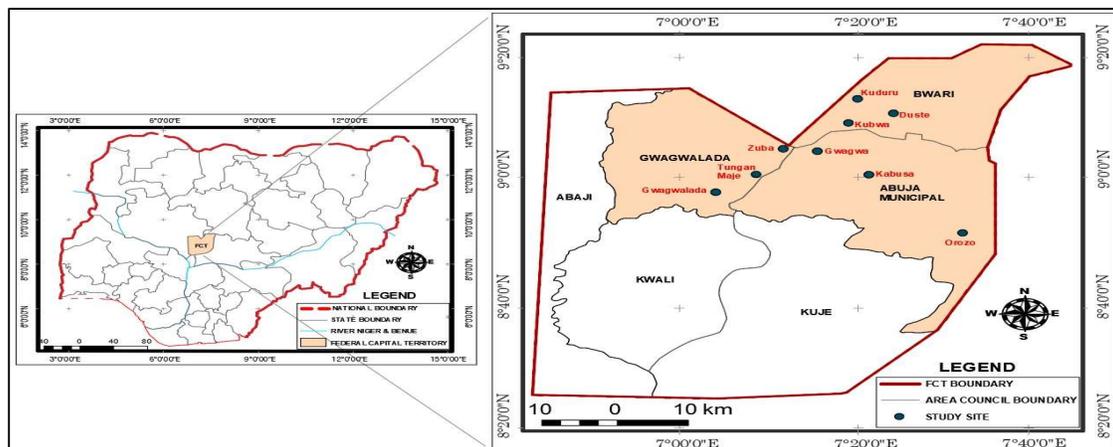


Figure 1 Location of the Study Area  
Source: Federal Capital Development Authority, 2020

### B. The Population and Sampling Method

This study utilises quantitative research methodology to provide a comprehensive analysis of urban environmental health hazards and the degree of vulnerability in selected wards of the FCT. The investigation focused on 15 wards situated within three Area Councils of the FCT: Bwari, Abuja Municipal, and Gwagwalada. These sites were deliberately selected owing to their high density of informal housing and rapid urbanisation (Agunbiade et al., 2020). A total of 1,137

respondents were sampled from the 76,096 households in the study area, using Frankfort-Nachmias' (2008) formula at a 95% confidence level and a 5% margin of error (Table 1). The study used stratified random sampling to select households, and each of the 15 political wards served as a stratum. The housing and environmental data encompassed air quality, water quality, noise level, solid waste disposal, quality of portable water, and materials used for the ceiling.

Table 1 Distribution of Household Sample in the Study Area

S/No	Ward	No. of Household	Sample Selected
1	Gui	7,654	83
2	Gwagwa	6,146	74
3	Jiwa	6,573	75
4	Kabusa	6,865	82
5	Orozo	4,934	69
6	Bwari Central	4,389	68
7	Byazhin	4,819	77
8	Dutse	6,012	87
9	Kubwa	5,970	85
10	Kuduru	4,235	61
11	Gwagwalada Central	4,050	79
12	Gwako	4,293	84
13	Ikwa	4,012	77
14	Tungan Maje	3,032	67
15	Zuba	3,110	69
<b>Total</b>		<b>76,094</b>	<b>1,137</b>

Source: Adapted from INEC (2023)

### C. Field Data Collection and Method of Analysis

The noise data was collected using an integrating sound level metre, which was converted into an index. The noise index is a measure used to quantify noise pollution over time, and the data collected from the study area are in time-specific intervals (10 minutes) for the period of 60 minutes. The discrete measurement formula, as a sub-component of the Equivalent Continuous Sound Level ( $L_{eq}$ ) method, was used to compute the  $L_{eq}$  for each ward, as shown in Equation (1).

$$L_{eq} = 10 \log_{10} \left( \frac{1}{T} \sum_{i=1}^n t_i 10^{\frac{L_i}{10}} \right) \quad (1)$$

where  $L_i$  is the Noise level during the time interval  $t_i$ ;  $T$  is the total time for the day and night (minutes), and  $n$  is, number of measurements.  $PM_{2.5}$  and pH of air and water were measured using a nephelometer and a pH metre, respectively. Other air component data (ozone, nitrogen dioxide, sulphur dioxide, and carbon monoxide) were also collected and subjected to laboratory tests. The data were converted to an Air Quality Index (AQI) using Equation 2.

$$I_p = \frac{(I_{hi} - I_{lo})}{(C_{hi} - C_{lo})} \times (C_p - C_{lo}) + I_{lo} \quad (2)$$

where  $I_p$  is the AQI for the pollutant,  $C_p$  is the measured pollutant concentration,  $C_{hi}$ ,  $C_{lo}$  are the breakpoint concentrations surrounding  $C_p$  and  $I_{hi}$ ,  $I_{lo}$  are the

corresponding AQI values. Water samples (Turbidity, Arsenic, Nitrate, and Total coliforms) were also collected from each ward and tested in the laboratory. The water quality index (WQI) was computed using Equation 3.

$$WQI = \frac{\sum(Q_n - W_n)}{\sum W_n} \quad (3)$$

where  $Q_n$  is the quality rating scale, and  $W_n$ , the assigned weight.

The collected data were harmonised using a composite index to construct an Urban Health Vulnerability Index (UHVI). This method integrates multiple indicators across six critical dimensions of household characteristics and environmental health hazards into a single composite index that reflects the overall level of health vulnerability in the study area. According to Rothenberg et al. (2014), the selection of specific indicators for the urban and environmental hazards index depends on their availability and purpose. For this reason, the selection of appropriate indicators is not prescriptive about which indicators must or should be selected. Rather, the selection is flexible and can be modified.

The UHVI was derived from six indicators through a multi-step process; these indicators were carefully selected for their relevance to urban health hazards and their ability to capture different levels of vulnerability in the study (Figure 2). In order to reflect the unequal contribution of each indicator to health vulnerability, weights were assigned to each indicator. These weights were determined by expert judgement, reflecting the perceived significance and

potential impact of each variable on urban health outcomes. Min-max normalisation was applied, scaling values (0 – 1), where 0 represents the lowest vulnerability and 1 the highest. The final UHVI for each ward was computed by multiplying each indicator's normalised value by its corresponding weight and summing the results. This aggregation yielded the Composite Vulnerability Index (CVI) for each ward in Abuja Municipal, Bwari, and Gwagwalada. The formula for calculating the composite vulnerability index is shown in Equation 4.

$$CVI = \sum_{i=1}^n w_i X'_i \quad (4)$$

Where  $w_i$  is the weight of the  $i^{th}$  indicator and  $X'_i$  = normalised value of the  $i^{th}$  indicator. The results were further interpreted to categorise the study area into very low (0.0 – 0.20), low (0.21 – 0.40), moderate (0.41 – 0.60), high (0.61 – 0.80), and very high vulnerability (0.81 – 1.0) areas using defined thresholds. This index enables quantitative comparison of health vulnerability across different wards and provides a robust analytical foundation for identifying priority areas for intervention.

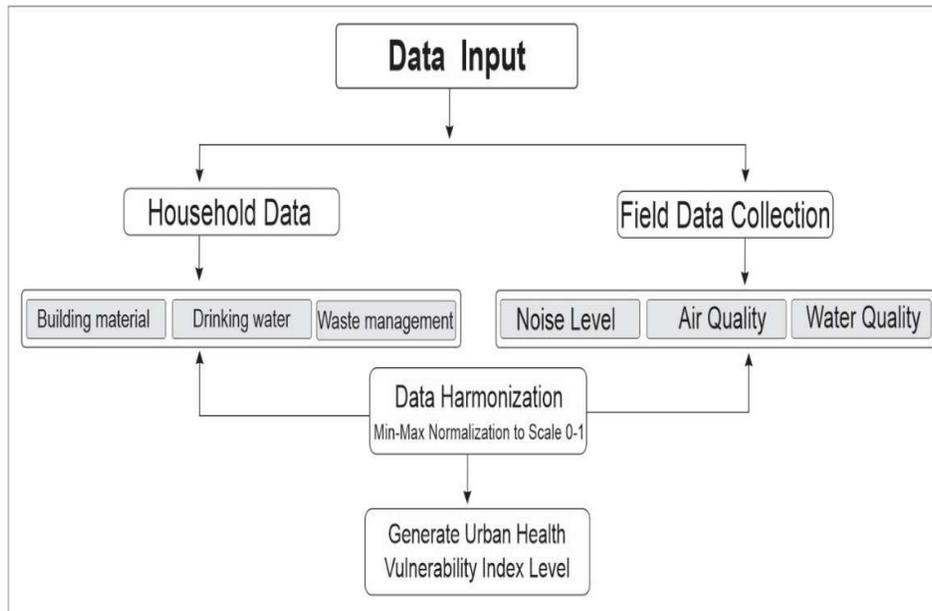


Figure 2 Research Methodological Flowchart  
Source: Author's Construct, 2025

#### D. Ethical Consideration

The study adhered to ethical standards in research involving human participants. Informed consent was obtained from all respondents, and confidentiality of information was ensured.

## IV. RESULTS AND DISCUSSION

#### A. Materials Used for Ceiling

The distribution of ceiling materials across the study area is shown in Figure 3. The findings indicate that asbestos was the predominant material for residential ceilings, accounting for an average of 62.42% of responses across the surveyed wards. This overwhelming prevalence indicates a strong regional preference for asbestos as the primary ceiling material among homeowners. The data also reveal notable spatial variations, with wards such as Orozo, Kuduru, and Ikwa showing higher adoption of modern alternatives such as PVC and POP, which offer practical and aesthetic advantages. This shift may be attributed to socioeconomic differences, greater health awareness of asbestos risks, or improved access to contemporary building supply markets.

The widespread use of asbestos ceilings, particularly in wards such as Gwagwa, Gwako, and Zuba, raises serious public health concerns that demand urgent attention. Over time, these materials can deteriorate, releasing microscopic fibres that, when inhaled, lodge in lung tissue, causing chronic inflammation and scarring. Prolonged exposure is linked to life-threatening diseases such as asbestosis, lung cancer, and mesothelioma (Thives et al., 2022). The continued use of asbestos in residential construction is driven by its affordability, fire resistance, and widespread availability in local markets. However, these short-term benefits are outweighed by severe long-term health risks, as families face decades of continuous exposure to carcinogenic fibres. The health risks associated with environmental contaminants in the study area are further underscored by the findings of Moda et al. (2018) and Curado et al. (2024), who assessed the environmental and public health impacts of asbestos in Nigeria and Portugal. Their research highlights its widespread use, environmental persistence, and severe health consequences for human populations.

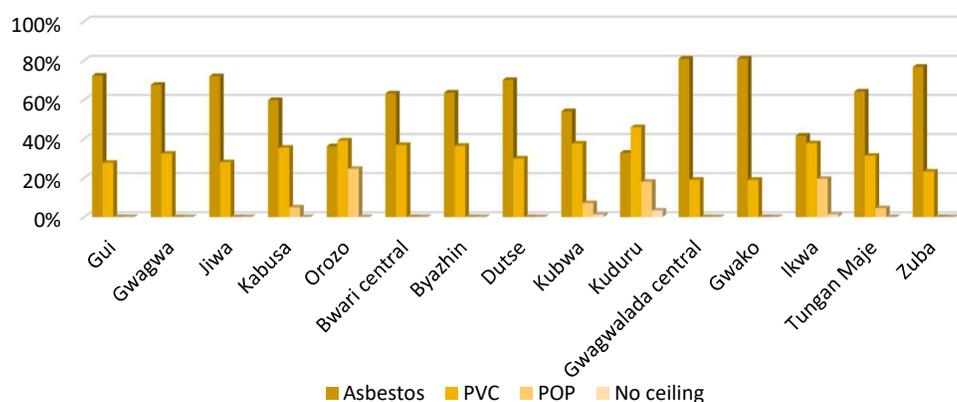


Figure 3 Materials Used for Ceiling

### B. Status of Drinking Water

The analysis of household water sources revealed that a significant majority (65.2%) of respondents relied on informal sources for their daily drinking water (Table 2). These sources, which may include unprotected wells, surface water, and unregulated private vendors, are often susceptible to contamination due to a lack of sanitary protection and quality oversight. Despite the heavy reliance on these vulnerable sources, a consistent and concerning pattern of households consuming untreated water was observed across numerous Wards. This practice was notably prevalent in Gui, Gwagwa, Jiwa, Orozo, Byazhin, Dutse, Kubwa, Gwako, Ikwa, Tungan Maje, and Zuba. In these areas, 52.3% of residents are effectively consuming water directly from the source without household-level treatment.

The primary barrier to safe water consumption in these communities is a critical lack of access to basic water

treatment facilities and resources. Residents face a multi-faceted challenge: they lack the means to boil water due to an absence of reliable energy sources; they do not have access to essential treatment chemicals, such as chlorine or water guard, to effectively disinfect their water and kill pathogens; and there is a likely gap in knowledge regarding simple, low-cost treatment methods. This convergence of energy poverty, lack of material access, and potential information deficits leaves a large portion of the population vulnerable to waterborne diseases, posing a significant public health risk. The results corroborate the findings of Idigbe et al. (2024), which describe inconsistent safe water treatment practices in Nigeria. Their study attributed this inconsistency to a combination of factors: inadequate understanding of the importance of water treatment, particularly among vulnerable groups such as pregnant women and young children; limited availability of household treatment products, such as chlorine; and sensory objections to the taste and smell of treated water.

Table 2 Status of Drinking Water

S/N	Political Ward	Treated	Not Treated	Total
1	Gui	39 (47.0%)	44 (53.0%)	83 (100%)
2	Gwagwa	26 (35.1%)	48 (64.9%)	74 (100%)
3	Jiwa	34 (45.4%)	41 (54.6%)	75 (100%)
4	Kabusa	47 (56.1%)	36 (43.9%)	82 (100%)
5	Orozo	25 (36.2%)	44 (63.8%)	69 (100%)
6	Bwari central	36 (52.9%)	32 (47.1%)	68 (100%)
7	Byazhin	29 (37.7%)	48 (62.3%)	77 (100%)
8	Dutse	43 (49.9%)	44 (50.1%)	87 (100%)
9	Kubwa	38 (44.7%)	44 (55.3%)	85 (100%)
10	Kuduru	35 (57.4%)	26 (42.6%)	61 (100%)
11	Gwagwalada central	43 (54.4%)	36 (45.6%)	79 (100%)
12	Gwako	39 (46.5%)	45 (53.6%)	84 (100%)
13	Ikwa	34 (44.2%)	43 (55.8%)	77 (100%)
14	Tungan Maje	30 (44.8%)	37 (55.2%)	67 (100%)
15	Zuba	27 (39.1%)	43 (60.9%)	69 (100%)
	Total	527 (47.7%)	610 (52.3%)	1137(100%)

C. Method of Household Solid Waste Management

The analysis of household solid waste disposal practices (Figure 4) reveals a pervasive reliance on improper methods across the study area. Open dumping was the most prevalent practice, with 80.50% of respondents in Ikwa ward disposing of refuse in open areas—a pattern consistently observed across all 15 political wards. This indiscriminate dumping creates unsanitary conditions that serve as breeding grounds for disease vectors. Additional concerning practices were documented: in Zuba ward, 30.4% of households reported burning solid waste as a volume reduction method, while 11.9% of respondents across the study area admitted to disposing of refuse directly into drainage systems, contributing to blockages and water contamination. Alarming, only 3.0% of households used designated collection centres, contributing to a severe shortage of formal waste management infrastructure.

The prevalence of improper solid waste management practices has grave environmental and public health

implications. Accumulated waste in open dumps provides ideal habitats for disease vectors, including mosquitoes that breed in stagnant water trapped in discarded containers and rodents that scavenge for food scraps. This significantly increases the risk of vector-borne diseases, including malaria, dengue fever, and leptospirosis, thereby exacerbating the community's overall disease burden. While refuse burning may be perceived as a convenient method for volume reduction, it poses serious environmental and health hazards. Obayomi et al. (2023) attributed the nature and causes of urban liveability challenges directly to poor waste-disposal practices, particularly the dangers of uncontrolled combustion. The burning of materials such as plastics, metals, and mixed household waste releases harmful emissions, including particulate matter, dioxins, furans, and heavy metals. These pollutants degrade local air quality and increase significant respiratory and carcinogenic risks to those exposed, further compounding the public health crisis stemming from inadequate waste management.

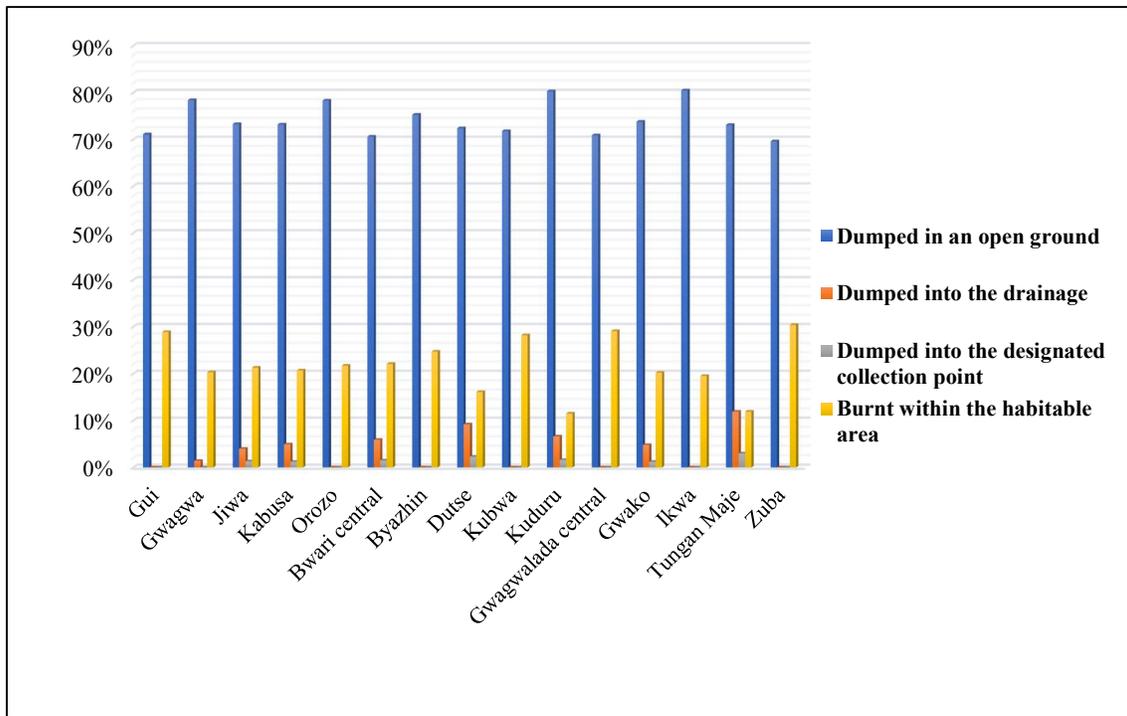


Figure 4 Method of Household Solid Waste Management  
Source: Author's Computation, 2025

D. Equivalent Continuous Noise Level (Leq) in the Study Area

Figure 5 illustrates the spatial distribution of noise pollution across the study area, revealing a significant gradient in acoustic environments. Recorded noise levels ranged from 59.3 dB in Kubwa to 79.0 dB in Gwako, indicating conditions ranging from "moderate" to "very noisy." This variation underscores the heterogeneous nature of human activity and urban development across the surveyed wards. The lowest noise level was documented in Kubwa ward at 59.3 dB, which falls within the upper limit of a moderate noise zone. Slightly elevated but still

comparatively low levels were also recorded in Jiwa, Kabusa, and Tungan Maje. These relatively quieter conditions are attributable to a combination of factors, including the strategic location of noisy commercial or industrial activities away from residential clusters. In contrast, Gwako ward recorded the highest noise level at 79.0 dB, categorising it as a "very noisy" zone. This high noise level results from the ward's role as a commercial hub, characterised by bustling markets, heavy vehicular traffic, light industrial activities, and frequent public gatherings, all of which create a persistently high acoustic footprint that significantly exceeds recommended ambient noise standards.

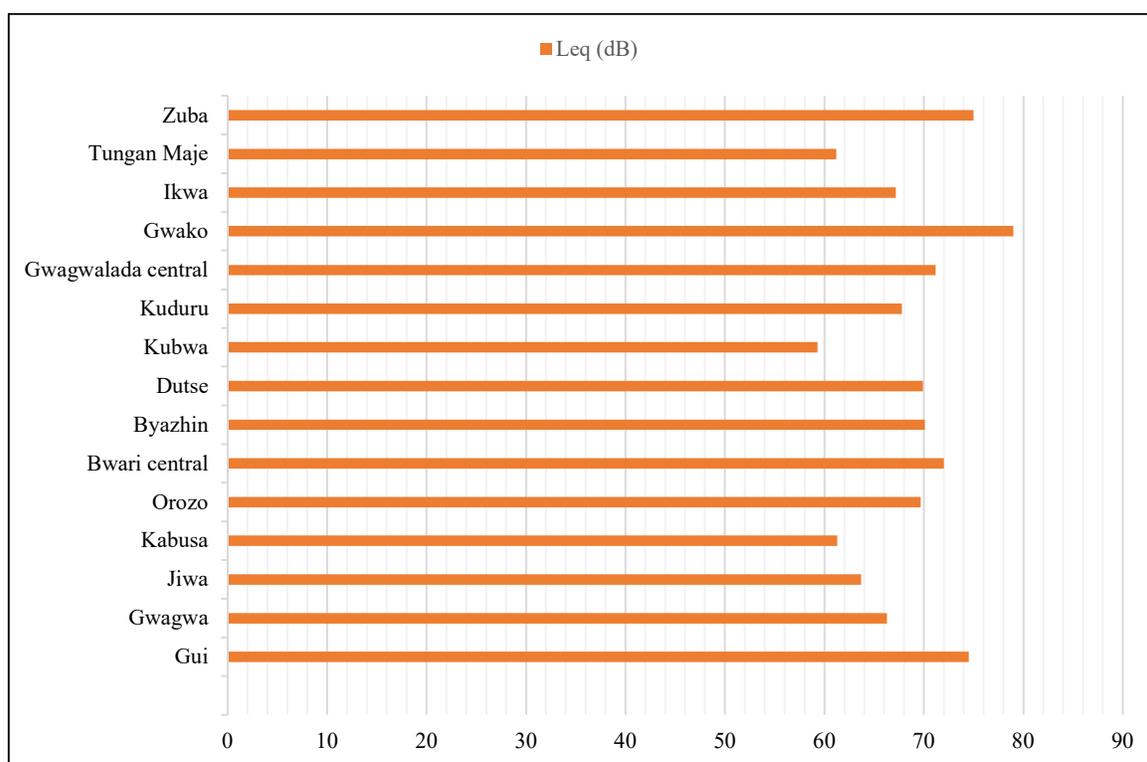


Figure 5 Equivalent Continuous Noise Level (Leq) in the Study Area  
Source: Author's Computation, 2025

*Leq scale:* <55 = quiet/acceptable; 55-65 = moderate; 66-75 = noisy; >75 = very noisy

Critically, the data indicate that noise levels across the majority of the study area consistently exceeded the 60 dB threshold. This is a concerning finding, as prolonged exposure to environmental noise above this level is associated with a range of non-auditory health effects, including sleep disturbance, cardiovascular stress, and impaired cognitive performance. The peak levels observed in wards like Gwako, approaching 80 dB, are particularly alarming. This finding aligns with the research of Dickson-Gómez et al. (2022), who found that sustained exposure to noise levels exceeding 70 dB is not only intrusive but also poses tangible, harmful risks to human health and well-being.

#### E. Air Quality Index (AQI) for each Pollutant by Political Ward

The Air Quality Index (AQI) analysis across the study area (Figure 6) reveals significant spatial variability, with values ranging from 89 in Orozo to 173 in Zuba, indicating conditions from "Moderate" to "Unhealthy." This range poses considerable health risks, particularly to sensitive groups such as children, the elderly, and individuals with pre-existing respiratory or cardiovascular conditions. Orozo recorded the lowest AQI at 89, placing it in the upper

"Moderate" category. While air quality here is generally acceptable, it may pose a slight concern for individuals with unusually sensitive airways. The relatively cleaner air is likely attributable to lower local emissions from combustion sources, such as vehicular traffic and industrial activities. In contrast, Zuba emerged as the most polluted ward with an AQI of 173, classified as "Unhealthy." At this level, the general population may begin to experience adverse health effects. The high AQI is attributed to critical pollutants, with SO<sub>2</sub> at 173 being the most significant, followed by PM<sub>2.5</sub> (149), O<sub>3</sub> (134), and CO (98).

Across the 15 wards surveyed, the dominant contributors to poor air quality were fine PM<sub>2.5</sub> and SO<sub>2</sub>, which emerged as the most frequent and critical pollutants. The prevalence of these specific pollutants represents a severe public health hazard due to their physiological impact. PM<sub>2.5</sub> is particularly dangerous because its microscopic size allows it to bypass the body's natural respiratory defences, penetrate deeply into the alveolar regions of the lungs, and even enter the circulatory system. Chronic exposure to high levels of PM<sub>2.5</sub> is well-documented to increase the incidence of chronic obstructive pulmonary disease (COPD), ischaemic heart disease, stroke, and premature mortality (WHO, 2023). The high levels of SO<sub>2</sub> further compound these risks, as it is a respiratory irritant that can cause bronchoconstriction and exacerbate asthma, particularly in vulnerable populations.

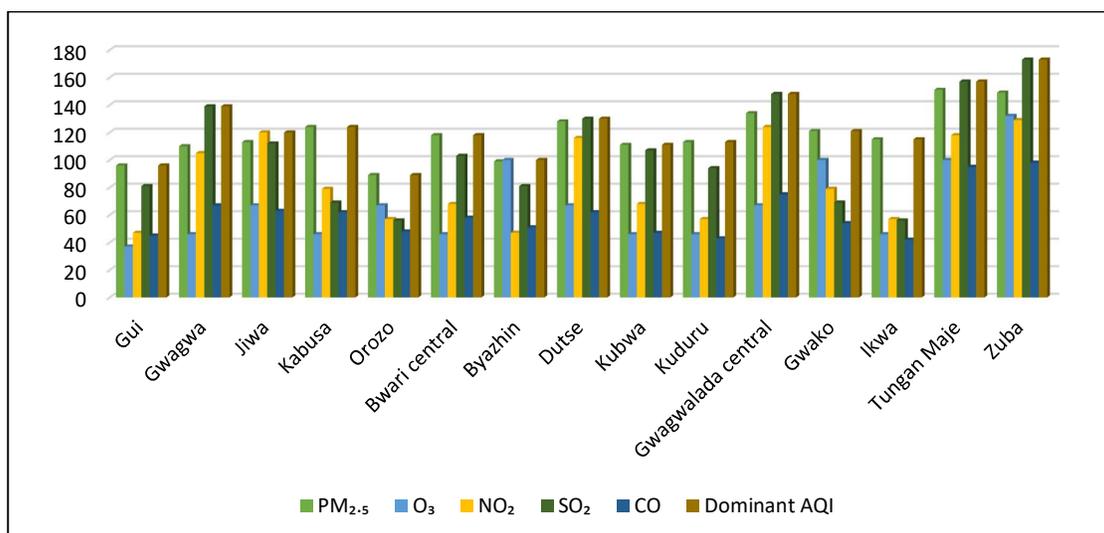


Figure 6 Air Quality Index (AQI) for each Pollutant by Political Ward

Source: Author's Computation, 2025

*AQI Range: 0 - 50 = Good, 51 - 100 = Moderate, 101 - 150 = Unhealthy for sensitive group, 151 - 200 = Unhealthy, 201 - 300 = Very unhealthy, 301 - 500 = Hazardous*

#### F. Water Quality Index in the Study Area

The results of the water quality in the study area are presented in Table 3. Kubwa (19.51) is the only ward with an excellent WQI rating, attributed to the availability of pipe-borne water. In Gui, Gwagwa, Kabusa, Orozo, and Kuduru, all WQI values fall within the good range of 45.69 – 49.73, indicating that water sources in this area are suitable for human consumption. However, in Jiwa, Bwari Central, Byazhin Dutse, Gwagwalada Central, Gwako, Ikwa, Tunga Maje and Zuba, the WQI ranges from 52.15 to 74.51,

indicating that the water quality in the area is 'poor' and unsafe for human consumption unless further measures are taken to treat the water. Further insight into Table 3 shows that Byazhin had the highest computed WQI in the study area, raising concerns about residents consuming unsafe water, which could be harmful to their health. Wards with  $WQI > 50$  in the study area showed significantly impaired water quality. These high WQI scores are primarily driven by three critical parameters: turbidity, total *coliform* counts, and arsenic concentrations, thereby posing chronic health risks, including carcinogenic effects. The presence of total coliforms indicates microbial contamination and potential exposure to waterborne pathogens, in violation of the WHO guideline, which stipulates 0 CFU/100 mL for *E. coli* in potable water (WHO, 2018).

Table 3 Water Quality Index in the Study Area

S/No	Political Ward	Weight Quality Rating					WQI
		PH	Turbidity	Arsenic	Nitrate	Total Coliforms	
1	Gui	1.45	28.86	12.73	2.65	0	45.69
2	Gwagwa	-2.93	22.94	24.88	2.94	1.9	49.73
3	Jiwa	8.8	19.98	21.85	3.08	3.8	57.51
4	Kabusa	-1.47	34.04	13.87	2.51	0	48.95
5	Orozo	-4.4	37.74	12.54	1.52	1.9	49.30
6	Bwari Central	5.87	25.9	14.44	2.14	3.8	52.15
7	Byazhin	7.33	48.1	17.29	1.72	0	74.44
8	Dutse	-10.27	34.04	23.37	3.58	7.6	58.32
9	Kubwa	-13.2	15.5	15.95	1.26	0	19.51
10	Kuduru	2.93	35.52	5.32	2.04	0	45.81
11	Gwagwalada Central	1.47	31.82	22.8	3.12	5.7	64.91
12	Gwako	-1.47	35.52	16.53	1.84	0	52.42
13	Ikwa	8.8	25.16	14.44	2.84	1.9	53.14
14	Tungan Maje	5.87	36.26	15.93	4.17	3.8	66.03
15	Zuba	10.23	30.34	18.62	3.82	9.5	72.51

Source: Author's Computation, 2025

*WQI Range: 0 - 25 = Excellent, 26 - 50 = Good, 51 - 75 = Poor, 76 - 100 = Very Poor, above 100 = Unsuitable for use*

#### G. Composite Vulnerability Level (CVL)

As shown in Table 4 and details provided in Appendix I, Ikwa and Kubwa Wards have the lowest Composite Vulnerability Index (CVI) scores of 0.32 and 0.36, respectively in the study area. This places the settlement in the low-vulnerability classification across all six indicators. Six Wards show moderate health vulnerability (CVI: 0.45 – 0.60). These Wards typically exhibit partial issues across the indicators; however, these areas may not indicate immediate health crises. They could be in a precarious middle ground, where further strain on the indicators rapidly increases vulnerability. The moderate classification thus represents a window of opportunity for cost-effective, pre-emptive interventions before conditions deteriorate further. In contrast, seven Wards score notably higher CVI values (>0.60), placing them in the high to very high vulnerability categories. These areas recorded high AQI and WQI, a high noise index, untreated water sources, poor solid waste management, and a high rate of asbestos in the ceiling. The convergence of both poor environmental and household attributes in these Wards produces cumulative health burdens, including higher risks of waterborne diseases,

respiratory infections from indoor air pollution, and hearing impairment.

The wide variability in CVI scores (0.32 - 0.91) empirically validates the PAR model's emphasis on heterogeneous vulnerability outcomes arising from micro-scale differences in infrastructure and environmental conditions, precisely the dynamic pressures that mediate between root causes (living in an informal area, limited institutional support) and the unsafe conditions that, when combined with environmental hazards such as air pollution, noise, or asbestos exposure, ultimately determine health outcomes. These findings align with that of Obe et al. (2023), who documented substantial spatial disparities in urban CVI scores across Nigerian cities. Their work highlights that even within relatively small geographic units such as Wards, vulnerability is rarely uniform; rather, it is shaped by the intersection of ageing or absent infrastructure, unplanned urban expansion, and differential household coping capacities. In particular, Obe et al. found that areas with CVI values approaching 0.90 face compounding pressures from solid waste accumulation, contaminated drainage channels, and high housing density, conditions that mirror the upper tier of scores recorded in this assessment.

Table 4 Composite Health Vulnerability Level in the Study Area.

S/No	Political Ward	Composite Vulnerability Index (CVI)	Health Vulnerability Level (HVL)
1	Gui	0.44	Moderate
2	Gwagwa	0.74	High
3	Jiwa	0.66	High
4	Kabusa	0.51	Moderate
5	Orozo	0.41	Moderate
6	Bwari Central	0.65	High
7	Byazhin	0.69	High
8	Dutse	0.74	High
9	Kubwa	0.36	Low
10	Kuduru	0.54	Moderate
11	Gwagwalada Central	0.56	High
12	Gwako	0.47	Moderate
13	Ikwa	0.32	Low
14	Tungan Maje	0.54	Moderate
15	Zuba	0.91	Very high

Source: Author's Computation, 2025

*CVI rating: 0.00 – 0.20 = very low; 0.21 – 0.40 = low; 0.41 – 0.60 = moderate; 0.61 – 0.80 = high; 0.80 – 1.00 = very high*

#### V. LIMITATIONS OF THE STUDY

The cross-sectional nature of this study limits the ability to determine cause-and-effect relationships between the environmental factors measured and the observed outcomes. In particular, the omission of key socioeconomic variables limits a deeper understanding of vulnerability and resilience. Additionally, single-time-point sampling fails to capture

seasonal variations in air pollution, underscoring the need for future longitudinal research to validate and expand upon these findings. Despite these limitations, this study provides important insights by quantifying disparities in health vulnerabilities across wards in FCT and by linking physical and environmental hazard factors to ward-level risks.

#### VI. CONCLUSION

The lack of regulatory planning in informal settlements, particularly in developing nations, exposes inhabitants to risks of infectious diseases, poor infrastructure, and injuries.

The findings highlight issues with housing and environmental conditions, including hazardous materials such as asbestos, unsafe water, and poor waste disposal. Environmental measurements show noise, air, and water quality sometimes exceed limits, especially in wards such as Zuba, Gwagwalada Central, and Kabusa. The environmental problem and the associated health risks in the study area are issues of public concern that require urgent attention. In order to improve urban health and sustainable development, recommended actions include land use zoning to separate residential areas from noisy activities in wards like Gwako, Gui, and Bwari Central; regular water testing and distribution purification kits in Gwagwa and Orozo; hazard assessments and mapping to guide mitigation actions; and ward-specific health and environmental programmes such as community safety audits and local health hazard awareness index card in Zuba, Dutse, Byazhin, Jiwa, and Gwagwa based on high CVI ratings.

#### AUTHOR CONTRIBUTIONS

**A. R. Suleiman:** Conceptualized the topic Methodology, Validation, Writing the original draft. **A. M. Junaid:** Supervision, Preparation of data instruments, Writing – review & editing. **L. M. Sanni:** Co-supervision, field data collection, Writing – review & editing. **C. B. Ohadugha:** Co-supervision, processing, prepared the figures and tables

#### ACKNOWLEDGMENTS

We appreciate the respondents for making themselves available and for providing responses that were crucial to the success of this study. We appreciate Myrtle Laboratories, Utako, Abuja, for their precise analysis of environmental samples. Their expertise and dedication enhanced the accuracy and credibility of the research results.

#### FUNDING

The work was unfunded.

#### CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding this article.

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## APPENDIX I

Political Ward	Indicator						Composite Vulnerability Index (CVI)	Health Vulnerability Level (HVL)
	Air Quality Index (AQI)	Water Quality Index (WQI)	% of untreated water before drinking	% of asbestos material used for the ceiling	Noise index	% of improper solid waste disposal		
Gui	0.04	0.0	0.07	0.10	0.15	0.08	0.44	Moderate
Gwagwa	0.25	0.09	0.15	0.09	0.06	0.10	0.74	High
Jiwa	0.16	0.25	0.10	0.05	0.03	0.07	0.66	High
Kabusa	0.18	0.07	0.09	0.07	0.0	0.10	0.51	Moderate
Orozo	0.0	0.08	0.14	0.02	0.10	0.07	0.41	Moderate
Bwari Central	0.15	0.15	0.06	0.07	0.15	0.07	0.65	High
Byazhin	0.0	0.25	0.15	0.07	0.13	0.09	0.69	High
Dutse	0.25	0.18	0.08	0.05	0.12	0.06	0.74	High
Kubwa	0.09	0.0	0.11	0.1	0.0	0.06	0.36	Low
Kuduru	0.11	0.12	0.03	0.08	0.10	0.10	0.54	Moderate
Gwagwalada Central	0.14	0.16	0.04	0.09	0.08	0.05	0.56	High
Gwako	0.03	0.0	0.1	0.10	0.15	0.09	0.47	Moderate
Ikwa	0.0	0.01	0.11	0.06	0.05	0.09	0.32	Low
Tungan Maje	0.18	0.08	0.11	0.07	0.0	0.10	0.54	Moderate
Zuba	0.25	0.25	0.15	0.06	0.12	0.08	0.91	Very high