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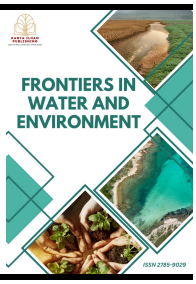

Environmental Risks and the Effects of Noise on Residents' Quality of Life and Well-being in Nigerian Urban Residential Environment

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ABSTRACT

Environmental noise pollution is becoming a major concern in cities around the world, with serious consequences for public health and quality of life. In Nigeria, increasing urbanisation and uncontrolled urban growth have exacerbated noise pollution from transportation, industrial activity, and commercial hubs. This study examined environmental risks connected with noise pollution and its impact on residents' quality of life in Nigerian cities. The study used a mixed-methods approach, integrating noise level measurements (using a sound pressure level meter), resident questionnaire surveys (n=880), and spatial analysis to determine noise hotspots in the city centre. and their relationship to household satisfaction. The findings were compared to national (50 dBA) and worldwide (55 dBA) standards by the WHO. The findings revealed that noise from places of worship and road noise were highly rated, with about 75% of respondents reporting that environmental noise has a negative influence on their quality of life. The study recommended a synergistic approach to built environment design, design quality of residential buildings, and interventions by architects and other built environment experts to combat urban environmental pollution in residential settings. The study contributes to urban policy through its recommendations for noise mitigation measures and urban design frameworks that encourage healthier living conditions.

1. Introduction

Urbanisation promotes economic development while also introducing environmental issues, including noise pollution. Urban noise poses significant hazards to public health and urban

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sustainability, acting as an environmental stressor that impairs quality of life, mental health, and overall well-being. According to the stress-diathesis concept, noise-induced stress causes a variety of psychological and physiological illnesses [1-3]. Environmental noise has been linked to tinnitus, which can induce insomnia, irritation, and depression, as well as an increased risk of cardiovascular disease. While almost all human activities generate noise, exceeding certain thresholds can have a negative influence on health and well-being. According to the International Labour Organisation (ILO), noise exposure should be kept between 80 and 90 decibels to remain within an acceptable range, while levels above 90 decibels pose severe health risks [4].

Prolonged noise exposure has a subtle impact on physiological functioning, resulting in elevated blood pressure, heart rate variations, and hormonal changes, which can contribute to anxiety, tension, nausea, mood disorders, and other health concerns. Acute noise exposure causes physiological arousal by stimulating the endocrine and autonomic nerve systems, resulting in increased stress hormones such catecholamines and cortisol [5]. If exposure continues, prolonged activation of these responses might result in anxiety and sadness [6,7]. Furthermore, noise-induced psychological stress might show as displeasure, which may directly influence stress hormone release, worsening detrimental health outcomes.

Given that cities house more than half of the world's population, regulating noise pollution is critical for long-term urban growth as well as public health and well-being [8]. In Nigeria, rapid urbanisation and unchecked urban expansion have increased noise pollution, which is mostly caused by transportation, industrial activity, and commercial operations. As one of the most common environmental stressors, noise pollution has a substantial influence on public health and urban liveability, affecting millions across the country [9,10].

Concerns about its impact on well-being, mental health, and quality of life have prompted the creation of regulation frameworks such as the WHO Community Noise Guidelines. These standards propose that background noise levels in outdoor living areas throughout the day and evening do not exceed 50 dB LAeq for more than 16 hours, while nighttime bedroom noise should be kept below 30 dB LAeq for eight hours. However, inadequate implementation of these restrictions has allowed urban noise to remain a serious public health concern, contributing to cardiovascular disease and chronic discomfort.

Noise pollution is a common irritation in residential settings, with studies correlating excessive urban noise to lower life satisfaction [11,12]. Noise pollution, unlike other environmental pollutants, is unseen, therefore its adverse impacts are less obvious. However, its gradual impact on human health emerges as deficits in auditory, physiological, psychological, and cognitive performance [13]. Despite its growing prevalence, noise pollution is typically overshadowed by worries about air pollution in both developed and developing countries [14,15]. Given that more than half of Nigeria's population currently lives in cities, reducing noise pollution is critical for promoting sustainable and healthy living conditions.

1.1 Gap in Knowledge

There is a significant scarcity of empirical studies on noise pollution in Nigerian urban settings, with the majority of published research lacking detailed assessments of noise levels and their direct influence on people' well-being. Furthermore, past research has mostly relied on self-reported noise complaints, with insufficient use of spatial analysis to map noise hotspots, which is critical for targeted interventions. Hence, the need for studies integrating spatial analysis and residents' subjective experiences. Additionally, urban noise mitigation measures in Nigeria are mostly theoretical, with few practical, context-specific strategies tailored to local urban dynamics. Finally,

there is a lack of study on how built environment design interventions, such as spatial planning, landscape buffers, and building orientation, might effectively reduce noise pollution.

1.2 Significance of the Research

The significance of this study is multifaceted as it addresses the following such as (i) looking at how urban environmental policies and regulations might be improved. As a result, it provides data-driven insights that may be used to inform urban noise pollution laws, ensuring that environmental restrictions are in line with national and international noise requirements. (ii) The significance of enhancing urban planning and built environment design is highlighted since the findings can help architects, urban planners, and policymakers create residential spaces that reduce noise intrusion, hence increasing overall quality of life. (iii) By providing empirical data for public health and well-being, the study evaluated noise levels and their psychological and physical impacts, potentially adding to the expanding body of knowledge on environmental determinants of health in Nigerian urban environments. Furthermore, the study provides a platform for encouraging context-specific noise mitigation strategies by emphasising the need for tailored interventions, such as zoning laws, soundproof building materials, and strategic green buffer zones, to effectively combat noise pollution. Finally, the study promotes and supports sustainable urban development goals (SDGs) by reducing noise pollution, which is consistent with SDG 3 (Good Health and Well-being) and SDG 11 (Sustainable Cities and Communities), resulting in healthier and more livable urban settings.

The aim of this study is to examine environmental risks associated with noise pollution and its impact on residents' quality of life in Nigerian cities. The objectives are (i) to investigate the effects of noise pollution on residents' well-being (ii) to determine the impact of noise pollution on residents who live in the high-level noisy area (iii) to determine the extent of the effect of noise pollution on residents who stated that noise pollution has an influence on their well-being (iv) to identify residential areas for noise management in the study area. This study aims to answer the following main questions, which are consistent with the research's focus on environmental risks, noise effects on well-being, and the role of built-environment interventions in mitigating urban noise pollution.

i. How does noise pollution affect residents' quality of life and well-being in Nigerian urban areas?
ii. How do socio-demographic factors influence citizens' perceptions and experiences with noise pollution in Nigerian cities?
iii. What built environment design interventions can reduce noise pollution in Nigerian urban residential areas?
iv. What policies and urban planning techniques can address noise pollution in Nigerian cities?

2. Literature Review

Environmental noise pollution is defined as undesirable or damaging sounds generated by human activities that interfere with typical activities such as sleeping, working, or communicating. According to Clark & Paunovic [16], environmental noise levels that exceed 55 decibels during the day and 40 decibels at night can have a harmful influence on human health. Noise pollution has been connected to a variety of health problems, including cardiovascular illness, stress, sleep difficulties, cognitive impairments, and decreased workplace productivity [17]. It also has an impact on social interactions and contributes to lower community cohesion in urban neighbourhoods.

2.1 Theoretical Framework

This study is based on two theories that support this work. The theories are called Environmental Stress Theory (EST) and Urban Sustainability Theory (UST). While the EST posits that excessive environmental stimuli, such as noise, can cause stress-related illnesses and a lower quality of life [18], the UST advocates for sustainable urban development that minimises negative environmental externalities, such as noise pollution [19].

2.1.1 Environmental stress theory and its relevance to urban environmental risks

The Environmental Stress Theory (EST) is a psychological and ecological theory that explains how environmental problems like noise pollution, overcrowding, and poor housing conditions lead to stress and, as a result, affect human health and well-being [20]. It shows that excessive environmental stimulation, such as noise, might cause stress-related disorders and a lower quality of life [18]. According to the idea, environmental cues operate as stressors, challenging individuals' coping skills and eliciting physiological, psychological, and behavioural reactions [21]. Noise pollution, air pollution, inadequate housing, and poor sanitation are major stressors in urban areas [22,23]. These pressures not only jeopardise inhabitants' well-being, but also create vulnerability in low-income communities.

Noise pollution is a major environmental stressor in Nigerian cities, and it is especially prevalent in low-income urban settlements where regulatory enforcement is weak. Given Nigeria's growing urbanisation and associated environmental challenges, the EST is an effective tool for analysing how urban environmental risks affect citizens' quality of life. According to Yadav *et al.,* [24], quality of life (QoL) includes physical health, psychological well-being, social interactions, and environmental factors. Prolonged exposure to noise pollution has a negative impact on residents' quality of life in a variety of ways, including: (i) Health consequences, which have been linked to hypertension, hearing impairment, and increased stress hormone levels [25,26]. (ii) Psychological Well-Being which arises as a result of noise disturbance to sleep patterns, resulting in mood disorders, anxiety, and worse overall life satisfaction [27]. (iii) Social and Cognitive Effects in which noise interference impairs concentration, workplace productivity, and academic performance, especially among youngsters [28]. Thus, the EST provides a framework for proposing various ways to alleviate the impacts of noise stress, such as behavioural adaptations, environmental changes, and policy interventions [29].

2.2 Urban Sustainability Theory

Urban sustainability theory (UST) promotes sustainable urban development that reduces negative environmental externalities, such as noise pollution [19]. It provides a valuable framework for analysing the relationship between environmental dangers like noise pollution and inhabitants' quality of life. metropolitan sustainability is widely regarded as a critical paradigm for solving environmental and social challenges in metropolitan areas. The philosophy of urban sustainability seeks to create urban environments that are ecologically viable, socially inclusive, and economically robust [30].

In the context of Nigerian urban environments, where rapid urbanisation has resulted in significant environmental degradation, the Urban Sustainability Theory provides valuable insights into the interaction between environmental risks and residents' health and well-being, particularly in terms of noise pollution. According to the notion, sustainable urban settings must incorporate environmental, economic, and social considerations in order to improve inhabitants' quality of life

while also preserving the long-term viability of urban spaces [31]. However, environmental threats such as air pollution, water contamination, waste mismanagement, and noise pollution jeopardise the viability of urban living environments. For example, increased industrialisation and the expansion of transport networks in Nigerian cities such as Lagos, Abuja, and Kano have exacerbated environmental concerns, thereby jeopardising public health.

Byaello [32] identified noise pollution as a significant environmental issue in metropolitan Nigeria, caused by traffic, construction, and industrial activity. It is recognised as a significant environmental stressor that has an impact on inhabitants' physical health and psychological well-being, and the UST helps to contextualise these effects within the larger goals of building resilient, healthy, and inclusive metropolitan communities. Residents in high-density metropolitan areas in Nigeria are disproportionately harmed by this pollution because infrastructural progress frequently neglect noise reduction. The UST emphasises the necessity for policies and measures to decrease environmental concerns such as noise in order to improve urban liveability.

According to a study by Abel [26], chronic noise pollution in Nigerian cities reduces citizens' quality of life by lowering sleep quality, increasing stress levels, and contributing to mental health disorders. This paper contends that incorporating noise control techniques into urban design methods is critical for promoting environmental sustainability and public health. The link between noise pollution and well-being is intricate and multidimensional. Several researchers have found that noise harms not just physical health, but also social interactions and psychological well-being [33]. Noise pollution exacerbates emotions of anxiety and insecurity in Nigerian urban environments, where socioeconomic stressors are compounded by environmental risks.

A study conducted in Lagos by Akindejoye *et al.,* [34] discovered that extended exposure to excessive noise levels led in higher complaints of stress and dissatisfaction among inhabitants, particularly low-income households residing near major roads and industrial zones. Furthermore, the health consequences of noise in Nigerian cities are exacerbated by a lack of noise controls and ineffective urban planning techniques. While noise pollution is acknowledged in urban planning frameworks, its management remains inadequate, particularly in residential areas. This oversight has a direct impact on the social sustainability of Nigerian urban areas, increasing inhabitants' vulnerability to health concerns.

2.2.1 The role of urban sustainability theory in mitigating noise pollution

In this study, the Urban Sustainability Theory emphasises the significance of including environmental protection into urban planning regulations in order to reduce the negative effects of noise on inhabitants' health and well-being. It promotes sustainable practices including mixed-use zoning, green areas, traffic management, and building insulation to mitigate environmental risks [30]. In Nigerian urban areas, these concepts could be used through initiatives such as increasing public transport to minimise traffic noise, enforcing tougher construction noise rules, and promoting green spaces as noise buffers. By focussing on these environmental and social factors, urban sustainability practices can limit inhabitants' exposure to noise and its related health hazards, hence enhancing overall quality of life. Thus, by tackling noise pollution through sustainable urban planning and policy development, urban planners and policymakers can reduce the negative consequences of environmental risks on the well-being of city dwellers.

2.3 Empirical Studies on Environmental Noise Pollution

Environmental noise pollution has been identified and defined as undesirable or hazardous outdoor sound produced by human activity, presents considerable difficulties to residential surroundings, affecting inhabitants' health and well-being [35,36]. Several studies have published extensive assessments on this topic, highlighting the varied health repercussions of noise exposure. For example, previous research by Williams and McCrae [37], Tang and Tong [38], and Thorsson *et al.* [39] investigated the impacts of noise pollution on urban populations. Although these studies proposed corrective measures, they were mostly focused on noise exposure and its impact on work performance [40,41]; work/market spaces [42-44]; and strategic locations within urban centres [45].

Other research has investigated the influence of noise pollution from various sources using subjective and objective outcome markers. For example, Kroesen *et al.,* [46] used a structural equation model to investigate the effect of aircraft noise exposure in residential areas within a 25-kilometer radius in the Netherlands, utilising both objective (high blood pressure, anxiety, depression) and subjective studies (annoyance, quality of life). The subjective outcome demonstrated that noise annoyance characteristics reduce residential contentment, whereas the objective outcome, which quantifies aircraft noise exposure, was found to be a significant predictor of residential satisfaction.

In a subsequent study by Weinhold [47], the health effects of residential noise were examined using a longitudinal survey of over 5000 adults in the Netherlands between 2007 and 2013. The impact of neighbourhood noise on perceived health outcomes included cardio-vascular symptoms, joint and bone disease, and headache, all of which contributed to a variety of health disorders. As a result, noise pollution has been connected to a variety of health problems, including cardiovascular disease, stress, sleep difficulties, cognitive impairments, and decreased workplace productivity [17]. It also has an impact on social interactions and contributes to lower community cohesion in urban neighbourhoods. Despite the International Labour Organisation (ILO), the allowable maximum of noise exposure for human well-being in a setting should be between 80 and 90 decibels (dBA), with 90 decibels and above designated as the hazard limit with probable risk [4]; research undertaken in Nigeria has indicated that average noise levels in major metropolitan centres surpass both national and WHO standards, which has a significant impact on the population's health and well-being [48-49].

Noise pollution according to research conducted in Nigerian cities is mostly caused by faulty urban design, population growth, and increased motorisation. Research has found main contributors, including road traffic, religious centres, industrial operations, and recreational activities, that exceed regulation noise levels [35,36,50]. For example, Chukumah *et al.,* [51] discovered that health conditions such as ear discomfort, headaches, weariness, and tinnitus are more prevalent among inhabitants exposed to noise from portable generators in an institutional setting in Nigeria.

A study by Awosusi and Akindutire [52], examined perceived health awareness related with noise pollution in Nigeria. Occupants had a good understanding of the level of health consequences caused by noise pollution, and a strong association was found between location and reported health effects. Other studies by Olamijulo *et al.,* [50] found that continuous exposure to environmental noise causes greater stress and lower life satisfaction among urban residents. As noise continues to be an environmental stressor and nuisance, its impact on human existence as a disruption of a conducive environment may result in health problems [51]. While the deleterious impacts of noise pollution are extensive, affecting both health and society, proper control methods are required.

While the majority of these research studied focused on areas with high levels of noise pollution, there is little literature on locations of living. As urbanisation continues, there is a greater need for

empirical understanding of the impact of noise in residential settings. The empirical understanding of the potential consequences of noise pollution would thus provide a foundation for managing urban space and integrating the health-environment nexus in an urbanising era towards a calm and livable environment fit for human welfare. This study aims to contribute to the literature on the impact of neighbourhood noise on inhabitants' health and well-being. The goal is to examine the impact of noise exposure levels on urban areas in Nigeria.

3. Materials and Methods

3.1 Study Design

A cross-sectional questionnaire survey was carried out in residential city regions of Minna metropolis, Nigeria. The empirical field studies were designed with great care, and the various study sites were carefully selected. The latter was based on a variety of criteria, including equivalent noise exposures, no other dominant noise source than road traffic, and similar dwellings in terms of height and kind.

3.2. Study Sites, Selection and Sample Size

The investigation was carried out in Niger state, Nigeria which lies between latitudes 8°20'N and 11°30'N, and longitudes 3°30'E and 7°20'E. The state is one of Nigeria's 36 states, with a population of approximately 3,950,249. Minna, the state capital, is located between latitude 8°20'N and longitude 60°33'N. Minna town is almost entirely linear, with a main road passing through it. This study examines environmental risks and the effects of noise on residents' quality of life and well-being in Nigerian urban residential environments. However, the scope is limited to residential environments in Minna Township. Baba and Jinadu [53] divided Minna town into different residential zones. The zones were divided into three categories depending on population density: low density (LD) areas, medium density (MD) areas, and high density (HD) residential neighbourhoods, with 1LD, 5MD, and 6HD correspondingly. Five (5) percent of the dwellings in each residential neighbourhood type were randomly chosen, and participants were sampled. In total, 880 residents were surveyed (73 for LD, 367 for MD, and 440 for HD). This study was carried out in three stages: (i) Noise Level Measurement by using noise measurement equipment in both exposed and non-exposed sections of the Minna metropolis; (ii) Survey Questionnaire was used for doing health investigations in all residential environment zones; and (iii) Spatial Analysis through the application of Geographic Information System (GIS) tools to map noise hotspots in the city center.

3.3 Study Instruments

(i) Data was collected from residents at every tenth house using a well-structured questionnaire based on the defined benchmark for a specific location in each residential environment. It gathered helpful data and information to better understand citizens' perspectives on noise pollution in their community and how it has affected them. A systematic use of questionnaire approach similar to the one used in this study was employed in a comparable noise study conducted by Mishra *et al.,* [54].

(ii) A sound level meter was used to collect noise readings and levels at selected places in the LD, MD and HD residential areas over a range of low and high measuring points. The noise levels were measured on a weighted decibel scale (dB). This strategy was utilised in a comparable noise investigation by Kapp *et al.,* [55] and Abbaspour *et al.,* [56]. Extech 407730 proved to be useful in this

project. The model has an accuracy of ±2dB, A and C weighting, and a measurement range of 40 to 130dB.

(iii) The locations of places with recorded noise levels were obtained using a handheld Global Positioning System (GPS) for Geographic Information Systems (GIS) data collection and processing. The sampling locations were captured using a GPS to aid in the creation of GIS database for spatial modelling of noise levels. The GIS is particularly beneficial for geographic editing, data processing, interpolation, and visualisation, which were all absent in most models. The notion of GIS investigates the spatial distribution and interactions between geographic objects or phenomena; for example, noise is a location-specific event. GIS has been used in similar studies [57-59] to monitor and anticipate noise pollution patterns in several nations throughout the world. GIS could be a valuable tool for noise analysis and management, particularly in developing nations like Nigeria. In addition to its robust skills in spatial database building, spatial data processing, management, and modelling includes visualisation and map-making tools for efficiently presenting the spatial variability of noise intensity. Hence, this provides the rationale for its application in this study.

3.4 Data Collection

The sound level meter was placed at several sample sites at specified times of day: 8:00-8:15 AM, 12:00-12:15 PM, 4:00-4:15 PM, and 6:00-6:15 PM. These durations were chosen to capture important everyday events in Minna, such as commuting to work in the morning (8:00 AM), active work hours (12:00 PM), the end of school and some work shifts (4:00 PM), and the end of daily activities (6:00 PM). Noise maps were created to evaluate road traffic noise exposure in each site. These maps identify places with certain noise levels, measured in decibels (dB), and use isophone lines to depict similar rating levels throughout defined time periods. A land use map and actual field observations were used to determine the association between noise levels and various land uses in Minna. These strategies assisted in determining which places had the highest and lowest noise levels based on ongoing activity. In addition to this, the questionnaires were sent to elicit respondents' perspectives on noise pollution sources, followed by a field study to confirm these reasons.

To designate priority sites for noise management in Minna, noise maps from the initial assessment were analysed to identify locations that exceeded the National Environmental Standards and Regulations Enforcement Agency (NESREA [60]) noise levels. A stratified random sampling approach was used, with 30 sampling points needed for noise level assessments. The city map was stratified using the fishnet ArcGIS approach (Figure 1), which yielded 20 initial noise measurement locations. These spots were later plotted on Google Maps for precise identification and evaluation. This study used ArcGIS 10.1 for data processing, with purposive sampling—also known as judgement or selected sampling—to pick 20 noise measurement sites. Initially, 20 sampling locations were chosen using the fishnet approach in ArcGIS 10.1. A cross-sectional survey was done to determine how urban inhabitants perceive and respond to noise.

The study involved participants aged 16 and up who volunteered to complete a questionnaire. Participants were given instructional booklets outlining the study's aims and scope. The structured questionnaire developed by the researchers were distributed to the residents in the selected residential environments through the use of research assistants to collect important data on noise pollution from households in the study area. The questionnaire was distributed to adults (i.e. those aged 16 and up) to ensure a more comprehensive knowledge of community experiences with noise pollution. Although questionnaire is a useful way of data collection, the limitation of this method is also obvious because it is highly dependent on the willingness and cooperation of the respondent in completing it [61]. Besides that, time is also one of the key factors to consider when developing

questionnaires [61]. Despite its shortcomings, the questionnaire was employed in this study because of its advantage of rapidly reaching a broad range of study participants. [62].

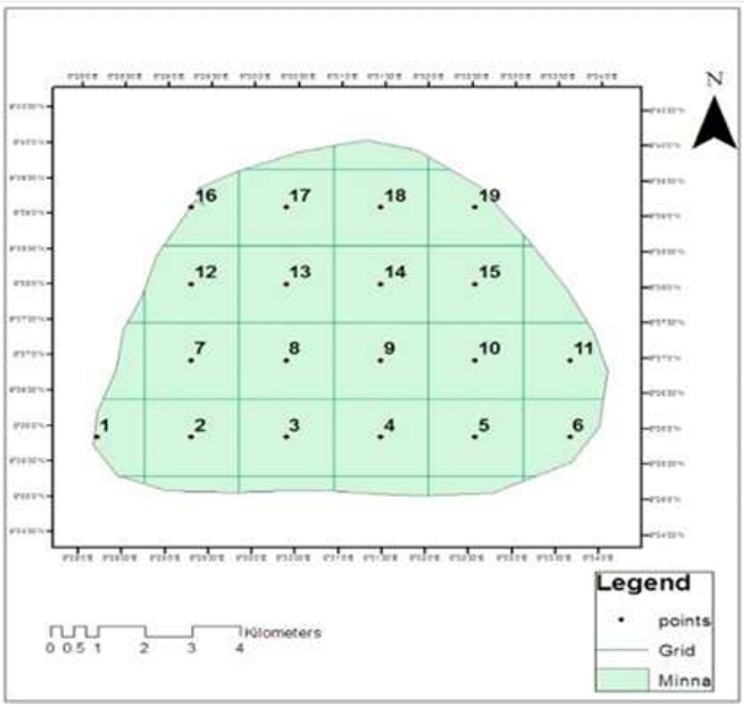

Fig. 1. Random points for noise reading using fishnet ArcGIS

3.5 Data Analysis and Procedure

A demographic profile of the population was produced using a descriptive analysis, considering their views of noise sources, environmental concerns, and the impacts of urban noise exposure. The Chi-square test was used to investigate the link between the duration of noise pollution exposure and its effects on well-being. Descriptive data analysis was used to evaluate the obtained data, and noise levels were mapped to show the temporal distribution and intensity of noise over the study area. To handle temporal noise data, the inverse distance weighting (IDW) interpolation approach was used. IDW, a deterministic approach for multivariate interpolation, guesses unknown values by taking the weighted average of known data points.

A classed noise map was used to identify the priority areas for noise management in Minna, which were then compared to the permitted noise limitations for various land uses set by NESREA [60]. This classed map was then superimposed onto Minna's land use map to investigate the noise levels associated with different land uses. Areas that exceeded the NESREA [60] noise level regulation of 59 decibels were prioritised for noise management solutions. The structured questionnaire results gave insight into noise pollution sources in various areas, allowing for the development of appropriate noise control strategies. The demographic data was analysed to better understand how various groups perceive noise and how it affects their well-being. Furthermore, the Chi-square test was employed to investigate the relationship between exposure length and perceptions of noise sources in residential settings. To guarantee data dependability, reliability statistics were done on the questionnaire items, providing a Cronbach's alpha value of 0.5, which is within an acceptable range and indicates that the findings are reliable.

4. Results and Discussions

According to the findings, the majority of respondents are men (65.1%), with women accounting for 34.9%. The largest age group is 25-34 years (36.8%), followed by 16-24 years (35.9%), indicating that young people make up a sizable proportion of the study population. Educational backgrounds vary, with 32.4% having O-level qualifications, 27.8% holding graduate or HND degrees, and 8.3% pursuing postgraduate studies. The respondents are mostly students (41%), traders (25.5%), and civil servants (21.8%), reflecting the diverse socioeconomic structure of Minna's metropolitan environment. The spatio-temporal noise distribution map (Figures 2 and 3) shows that particular neighbourhoods are subjected to high noise exposure, with levels reaching up to 94 decibels in the morning. This substantially exceeds the NESREA-recommended limit of 59 decibels for residential areas, exposing individuals to stress-related health hazards such as cardiovascular disease, sleep difficulties, and poor cognitive performance. According to the Environmental Stress Theory, this prolonged exposure to environmental stressors like noise pollution can have a deleterious influence on psychological and physiological well-being [20].

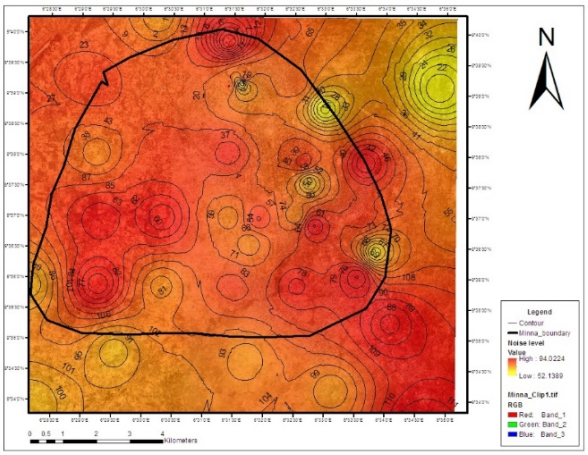

Fig. 2. Noise map for morning time (8:00am)

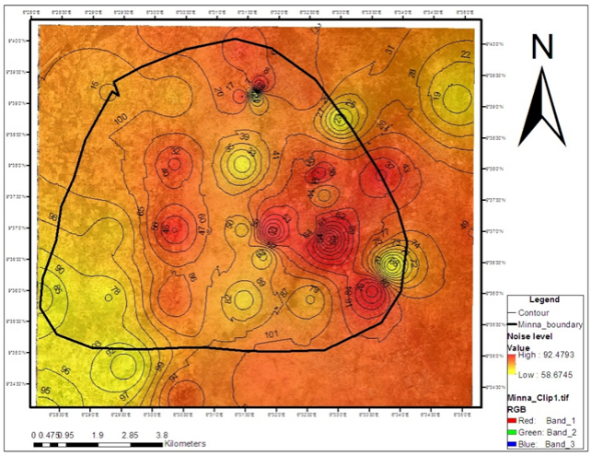

Fig. 3. Noise map for midday (12:00 noon)

The various noise levels, represented by different colour intensities on the noise map, demonstrate the uneven distribution of noise pollution throughout Minna, implying that certain neighbourhoods are more sensitive than others. The demographic profile, with a major proportion of young people and students, suggests that a large number of residents who goes to school may suffer academic and cognitive consequences from continuous exposure to excessive noise levels. This supports the assertion of Evans & Cohen [29]. In addition to this, the aim of the Urban Sustainability Theory is defeated which emphasises the importance of making cities livable, environmentally responsible, and socially inclusive as posited by Campbell [63]. This is because the excessive noise levels measured in Minna make it difficult to achieve sustainable urban development goals.

According to Wang *et al.,* [8] noise pollution disturbs daily activities, reduces residential quality of life, and adds to environmental degradation. The findings indicate that locations with higher noise pollution, notably commercial and transportation hubs, require strategic interventions such as enhanced urban planning, noise regulation enforcement, and the development of green buffers to alleviate the impact of noise. The findings highlight the critical need for noise management solutions in Minna. The reported high noise levels are consistent with Environmental Stress Theory, implying

that noise pollution is a significant environmental stressor harming urban people' health and well-being.

From an urban sustainability standpoint, controlling noise pollution is critical to developing a healthier and more livable city. Urban planning strategies should include noise control measures, stricter enforcement of NESREA [60] noise laws, and sustainable urban design to reduce the impact of environmental noise on people. Further investigation of noise pollution in Minna reveals considerable fluctuations in noise levels at different times of day and in different sections of the city. The maximum noise levels were observed in the morning and evening (Figures 4 & 5), reaching up to 96 decibels, while the lowest levels were about 56 decibels. The spatial distribution of noise suggests that highly inhabited and high-activity areas are subjected to increased noise pollution, notably in Minna's centre regions. The findings also suggest a temporal shift in noise pollution, with high levels in the morning migrating to business areas around noon and then spreading out again in the evening.

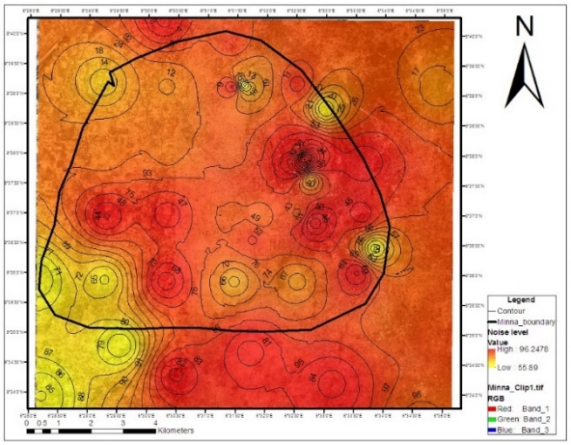

Fig. 4. Noise map for evening time (6:00pm)

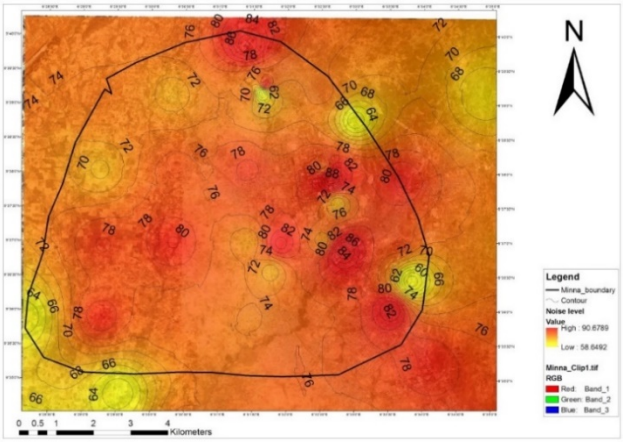

Fig. 5. Noise map for overall mean noise level

This pattern is congruent with the findings of Oyedepo *et al.,* [64], who discovered that noise pollution varies with time and location, with peak levels occurring during periods of heavy human activity. The noise maps' compacted contour lines represent places with high noise concentration, whilst scattered contours reflect noise dispersion. The data also indicate that land use and human activities are important factors of noise pollution, since regions with heavy commercial and transportation activity had greater noise levels than residential areas. According to Environmental Stress Theory, chronic exposure to environmental stressors such as noise pollution can have deleterious psychological and physiological consequences [20]. The high noise levels seen in Minna's densely populated areas suggest that individuals in these locations are at a higher risk of stress-related health conditions such as sleep difficulties, anxiety, and cardiovascular disease [65]. The rise in noise levels in the morning and evening, which coincides with peak commuting and business hours, suggests that people who commute through or live in these regions are more vulnerable to chronic stress and lower quality of life [29]. The altering nature of noise pollution, as evidenced by comparisons of noise maps over time, lends credence to the notion that urban noise is a dynamic stressor.

The transient fall in noise levels in some regions at midday implies that individuals may sense relief on occasion, but overall, the high levels of exposure continue to be a problem for public health and urban liveability. The concentration of noise pollution in specific regions emphasises the importance of focused urban planning initiatives to reduce the negative effects of environmental

stress on people. When seen through the lens of Urban Sustainability Theory, the outcome emphasises the importance of cities being environmentally sustainable, economically successful, and socially inclusive [63]. The findings show that noise pollution in Minna poses a substantial obstacle to sustainable urban life. High noise levels in commercial hubs and transport corridors stress the need for better urban design and implementation of noise regulations. The fluctuating nature of noise pollution indicates that Minna's urban form does not successfully segregate residential and business areas, resulting in increased noise exposure for people.

The findings emphasise the need of incorporating noise-reduction methods into urban planning initiatives. Measures such as green buffers, noise zoning enforcement, and investments in quieter transit infrastructure can all help to reduce the impact of noise pollution on people. Furthermore, future sustainable urban development should consider locating residential areas away from high-noise zones in order to provide residents with a higher quality of life. The findings shed light on the regional and temporal distribution of noise pollution in Minna, emphasising the importance of human activities and land use in determining noise exposure patterns. The interpretation of these findings using Environmental Stress Theory emphasises the possible health hazards associated with chronic noise exposure, meanwhile, in relation to Urban Sustainability Theory, it emphasise the need for improved urban planning and noise control techniques. Addressing noise pollution through targeted regulations can help to create a healthier and more livable urban environment in Minna.

Table 1 indicates the maximum allowed noise level for the general environment from day to night and vice versa, as determined by NESREA [60] for various land uses.

Table 1
Maximum permissible noise level for general environment

Facility	Noise limits dB (A)	
	Day 6:00a.m to 10: 00p.m	Night 10:00p.m to 6.00a.m
Institutes for learning, offices etc.	45	35
Residential areas	50	35
Mixed residential (with some commercial and entertainment)	55	45
Residential + industry	60	50
Industrial	70	60

Source: NESREA (2009)

The data in the table were used to calculate the allowable level of noise recorded in the city for land uses. To investigate the effects of noise pollution on residents' well-being, residential areas near noise measurement sites were identified. The noise level recorded was calculated and compared to the standard noise limit, as indicated in Table 1. Figure 6 depicts the residential neighbourhood of Minna and its various noise levels. The attained results include the minimum, maximum, and mean noise levels for the entire neighbourhood. A comparison was done between the reference parameters, 50 dB(A) (Table 1) according to NESREA [60] and the World Health Organization's recommended level of 55 dB(A) for residential areas. This comparison demonstrated that the urban noise levels in the residential neighbourhood were too loud for acoustic comfort. Figure 6 shows that all values exceeded the standard noise limit for residential zones. This demonstrates that these locations, as well as the living environment in them, are subjected to extremely loud noises that might be hazardous to one's health. In addition, responses obtained from the respondents through the questionnaire suggest that noises from places of worship and road noise were the most pronounced, and thus scored higher than other sources of noise. This finding is consistent with that of Abbaspour *et al.,* [56] who conducted a hierarchical assessment of noise pollution in urban regions of Tehran

Metropolitan City. They demonstrated that, in addition to traffic noise, additional factors aggravating noise pollution in urban areas included land use kinds, population distribution, and passage type, all of which had varying degrees of impact. Unfortunately, this has received little attention in noise pollution assessment research.

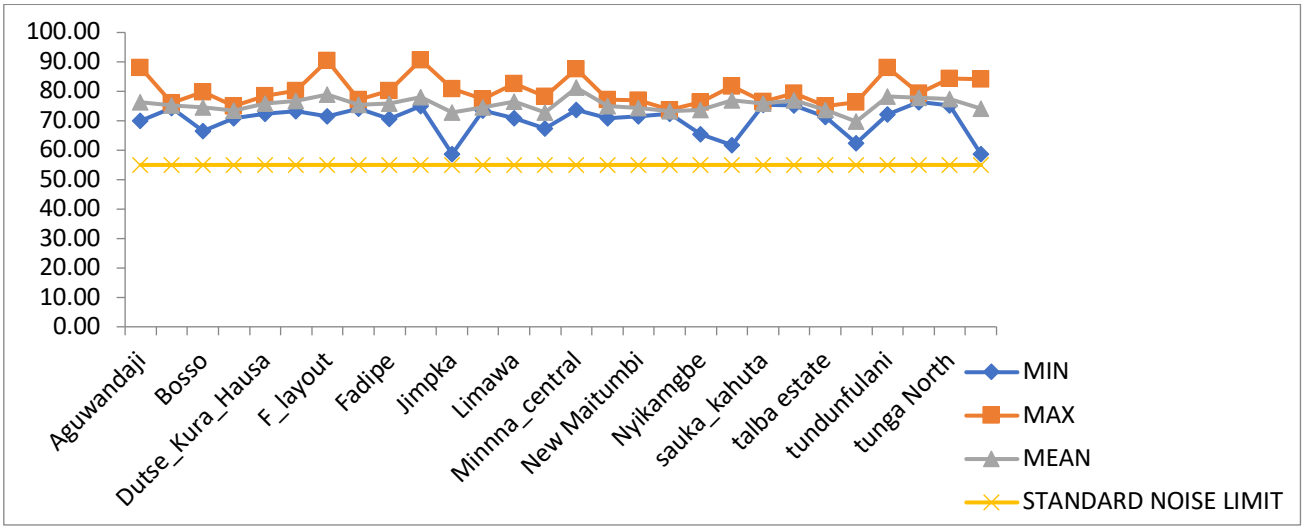

Fig. 6. Minna residential neighborhoods and their noise level

In addition to the findings above, to determine the impact of noise pollution on residents who live in the high-level noisy area depicted in Figure 6, residents were asked in the questionnaire to select from a list of possible effects of noise pollution on their wellbeing. According to the questionnaire responses shown in Table 2, 79% of respondents believe noise pollution has an impact on their well-being. Approximately one-third (31.1%) reported that noise pollution produces general disturbance (irritation) for them. This was followed by 24.4 percent reporting that it gives them headaches. Other respondents (10.1%) report that noise pollution causes them to lose sleep or sleeplessness, while others (7.5%) report that it creates stress. These findings are comparable to those obtained by Mead [66], Martins *et al.* [67], and Paneto *et al.* [68], who investigated the "relationship between urban noise and the health of users of public spaces." Similar to this study, Paneto *et al.* [68] distributed a questionnaire to 375 persons, and the primary responses to noise exposure were as follows: irritation (58%), trouble concentrating (42%), sleeping disturbances (20%), and headaches (20%). Meanwhile, Martins *et al.* [67] found that persons who are exposed to lengthy periods of noise are more likely to have headaches than those who are not exposed to long periods of noise.

Table 2
Implications of noise pollution on the respondents' well-being

How would you describe the effect of noise pollution on your wellbeing		Frequency	Percent	Rank
Valid	No disturbance (can tolerate)	185	21.0	3
	General Disturbance (irritation)	274	31.1	1
	Headache	215	24.4	2
	Hypertension	24	2.7	6
	Loss of Sleep/Insomnia	89	10.1	4
	Stress	66	7.5	5
	Hearing loss due to continuous noise	10	1.1	8
	Physically and mentally affected	17	1.9	7
	Total	880	100.0	

To determine the extent of the effect of noise pollution on residents who stated that noise pollution has an influence on their well-being, the length of time respondents spent in the residential environment was explored. The respondents were asked how long they have lived in the environment. A cross-tabulation was undertaken to determine whether the respondents' length of stay in the residential setting is related to the effect of noise pollution on them. Table 3 reveals that the responses to the questionnaires revealed that the majority of the population in this study is aware of the detrimental consequences of noise exposure, and this level of knowledge is deemed high, at 79%. As a result, the cross-tabulation results illustrate how respondents' wellbeing is affected by noise pollution based on their length of stay in the residential setting.

Table 3
Length of stay in the environment and the effect of noise pollution on respondents' health

		How long have you lived in your current neighbourhood (in years)					Total
		1-5	6-10	11-15	16-20	20+	
How would you describe the effect of noise pollution on your wellbeing	No disturbance (can tolerate)	83	51	20	14	17	185
	General Disturbance (irritation)	132	68	26	17	31	274
	Headache	80	51	36	19	29	215
	Hypertension	2	10	6	5	1	24
	Loss of Sleep/Insomnia	46	20	10	10	3	89
	Stress	9	29	9	12	7	66
	Hearing loss due to continuous noise	3	1	0	3	3	10
	Physically and mentally affected	7	3	0	0	7	17
Total		362	233	107	80	98	880

According to Table 4, 363 respondents who had been in the environment for 1-5 years reported irritation, headache, hypertension, loss of sleep, stress, and hearing loss, while 98 respondents who had been in the environment for more than 20 years reported irritation, headache, hypertension, loss of sleep, stress, hearing loss, and physical and mental effects from noise pollution. As the length of time spent in the environment increased, each of the respondents experienced one or more effects of noise pollution. To corroborate these findings, the relationship between respondents' length of stay in the environment and the impact of noise pollution on their well-being was investigated further using the following hypothesis:

H0: There is no relationship between the respondent's length of stay and the impact of noise pollution on their health.

H1: There is a relationship between the respondent's length of stay and the impact of noise pollution on their health.

Table 4 displays the results of the Chi-Square tests that were used to determine whether the association is significant.

Table 4
Chi-Square Tests to determine whether there is a significant association between the respondent's length of stay in the environment and the influence of noise pollution on their well-being

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	94.916[a]	28	.000
Likelihood Ratio	96.212	28	.000
Linear-by-Linear Association	11.176	1	.001
N of Valid Cases	880		

a. 12 cells (30.0%) have expected count less than 5. The minimum expected count is .91.

There is a significant and positive link between the length of stay in the environment and the influence of noise pollution on responder well-being, as the significant value is less than 0.05. As a result, as respondents' length of stay increases, so does the impact of noise pollution on their health. Further research was conducted to evaluate the relationship between occupants' educational level, occupation, and perception of noise pollution. 28.3% of respondents rated noise as very significant, 25.3% as moderately important, and 18.9% as slightly important, with only 21.8% dismissing noise pollution as a concern. 57.2% of respondents identified a problem with noise pollution in their region, while only 32% did not. Kendall's tau_b analysis was used to assess whether there is a relationship between educational qualification and respondents' perceptions of noise pollution, as outlined in the hypothesis below:

H0: There is no association between educational qualification and the perception of noise pollution.
H1: There is a relationship between educational qualification and the sense of noise pollution.

Table 5 displays the findings of Kendall's tau_b analysis to examine the association between educational qualification and respondents' perceptions of noise pollution. The findings indicate that there is a substantial association between educational degrees and how residents describe their understanding of noise pollution. As the critical value is less than 0.05, we reject the null hypothesis. The connection appears to be modest and positive, with pho at 0.242. This means that an educated individual is more likely to be aware of the effects of noise pollution on their well-being than a less educated response. It was also revealed that educational qualification has a substantial association with how important noise pollution is to the respondent individually. The connection is shown to be weak and positive, with pho at 0.179. This means that a well-educated person will take noise pollution more seriously than a less educated person, possibly because they are aware of the implications for their well-being. To provide urban noise management techniques for residential locations in order to reduce its negative impact on the urban population.

Table 5
Relationship between educational qualification and the respondents' perception of noise pollution

			Educational Qualification
Kendall's tau_b	How would you describe your knowledge about noise pollution	Correlation Coefficient	.242**
		Sig. (2-tailed)	.000
		N	880
	How important is the issue of noise pollution to you personally?	Correlation Coefficient	.179**
		Sig. (2-tailed)	.000
		N	880
	Do you perceive any problem of noise pollution in your neighbour?	Correlation Coefficient	-.150**
		Sig. (2-tailed)	.000
		N	880
	Does any particular noise annoy you on a daily basis?	Correlation Coefficient	-.020
		Sig. (2-tailed)	.495
		N	880
		N	880

The study looked into residential areas for noise management in Minna and its surroundings. Figure 7 depicts the findings of the investigation, which identify the priority residential environment for noise management in the Minna metropolitan. The areas subjected to investigation are Anguwandaji, Dutse_Kura_Hausa, Dutsen_Kura_Gwari, F_layout, Gbeganu, Fadipe, GRA Jimpka, Kpakungu, Limawa, Maitumbi, Minnna_central, Nasarawa, New Maitumbi, New GRA, Nyikamgbe**,**

Sabon gari, Sauka_kahuta, Shango, Talba estate, Tayi_Village, Tundunfulani, Tunga low-cost, and Tunga North.

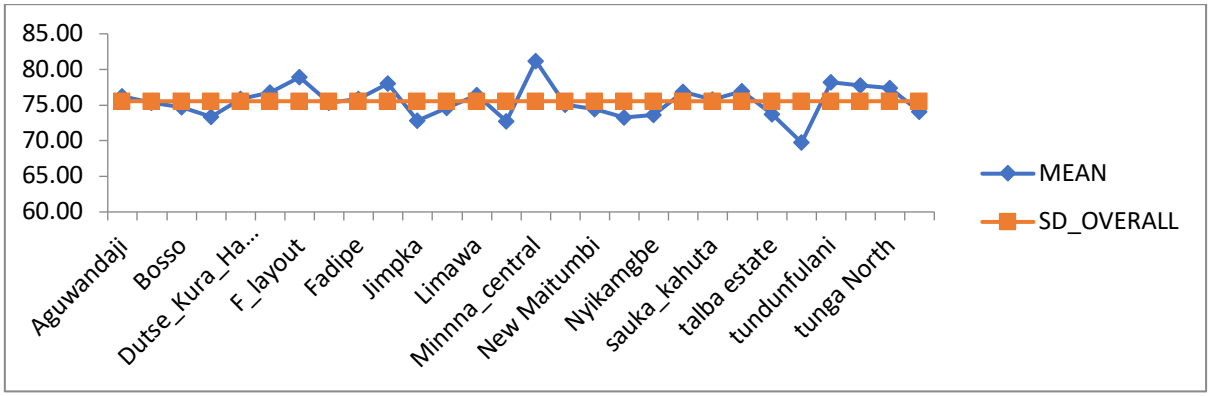

Fig. 7. Residential neighborhood most prone noise for noise management

As a result, we can conclude that certain residential areas are acoustically contaminated. The areas with points listed below did not surpass the standard deviation. As a result, sound levels measured in residential areas that fall below the standard deviation are considered desirable and acoustically managed. As a result, their characteristics might serve as reference points for subsequent assessments. Meanwhile, regions exceeding the standard deviation can be designated as acoustically contaminated, making them the top priority for noise management in Minna. Table 6 shows how respondents rate the nuisance of noise to them.

Table 6
Degree of annoyance of noise to you Crosstabulation

		Rate the degree of annoyance of noise to you							Total
		Very low	Low	Neither low or high	High	Extremely high	Total for high & extremely high	Rank	
Location	Angwandaji Minna	6	11	20	42	0	42	1	79
	Bosso	11	26	6	8	7	15	11	58
	Democratic Garden	2	2	5	6	3	09	14	18
	Dutse Kura	4	27	25	26	8	34	2	90
	F Layout	0	16	20	10	5	15	11	51
	Fadekpe	8	23	13	11	7	18	9	62
	Garima Junction	13	15	19	3	4	07	15	54
	Gudugudu Maitunbi	5	15	7	24	3	27	4	54
	Jikpon	0	19	28	27	6	33	3	80
	Limawa	2	9	22	25	1	26	5	59
	Mobil/Old Airport Road	1	6	6	11	1	12	13	25
	Mobile Park	10	9	6	4	0	04	16	29
	Nikangbe	4	8	24	22	2	24	6	60
	Talba Estate	7	21	16	14	2	16	10	60
	Tundun Fulani	1	12	23	20	4	24	6	60
	Tunga North	11	7	4	14	5	19	8	41
Total		85	226	244	267	58			880

The rate of noise irritation varies around Minna city. For example, in Angwandaji, 53% (42 out of 79 respondents) found noise to be a significant source of aggravation. In Bosso, 26% (eight deemed it high, seven considered it extremely high). In the Dutse Kura area, 29% (26 of 90 respondents rated it as high). In the Gudugudu Maitunbi region, 44% (24 out of 54 respondents rated the irritation of

noise as high). In the Jikpon area, 34% (27 of 80 respondents rated the level of noise disturbance as high). In the Limawa neighbourhood, 42% (25 of 59 respondents rated noise discomfort as high). In Nikangbe region, 37% of 60 respondents, 22 evaluated the degree of annoyance of noise to be high. Tundun Fulani: 33% out of 60 responders, 20 regarded it high. The rate of aggravation caused by environmental noise was cross-tabulated with the respondents' residential location. The total number of people who evaluated their level of aggravation as high or extremely high was determined and ranked. The findings suggest that Angwandaji ranked first, followed by Dutse Kura in second, Jikpon in third, Gudugudu Maitunbi in fourth, and Limawa in fifth. This finding was supported by the measured mean sound pressure levels, which showed the greatest noise level of 90 dBA and the lowest noise level of 58 dBA in the residential neighbourhood. All of these residential areas verified the before discussed results because their calculated noise level was higher than the mean standard deviation obtained. This study shows that these residential zones are the most susceptible to noise pollution in the Minna metropolitan and should be prioritised for noise management.

5. Implications of The Study for Design Practice

The findings of this study demonstrate the importance of effective urban planning, including noise zoning and buffer zones between residential and commercial/industrial districts. The design interventions should result in the integration of noise-reducing building materials and increased insulation in residential structures. In addition, green infrastructure should be prioritized by expanding the use of vegetation barriers and urban green spaces for sound absorption. Finally, smart city efforts must be implemented through the use of smart noise monitoring systems that collect real-time data and enforce policies.

6. Contribution to Knowledge

This study makes a significant contribution to knowledge by providing empirical evidence on the association between noise pollution and urban well-being in Nigeria's cities. It makes a methodological contribution by combining environmental monitoring with sociological research, providing a comprehensive view of urban noise management. The study's findings inform policy recommendations for more sustainable urban design and better quality of life.

7. Limitations of the Study

This study has limitations in some ways such as (i) its geographical scope, which is limited to specific urban regions and may not reflect national patterns. (ii) Time limits, as it might be claimed that noise pollution is dynamic, and longer-term research would produce more thorough results. (ii) Instrumentation limitations are not uncommon in a study of this sort, as variations in sound pressure level meter sensitivity may impair accuracy.

8. Application of Findings to Similar or other Contexts, and Future Research Considerations

The study's findings on geographical differences in noise annoyance across Minna's neighbourhoods highlight the context-dependent character of noise pollution in urban areas. The differences in residents' perceptions, ranked levels of noise disturbance, and measured noise pressure levels indicate that land use patterns, population density, socioeconomic activities, and built environment characteristics all contribute to varying noise pollution levels across residential areas.

Given these findings, future research should include a comparative analysis of different Nigerian cities to see if comparable noise pollution patterns and aggravation levels exist. For example, a comparative examination of cities such as Lagos, Abuja, Kano, and Port Harcourt, which differ in urban density, economic activity, and planning laws, could reveal whether the tendencies observed in Minna are consistent across Nigeria.

Such a study could evaluate: (i) Variations in noise sources. While informal economic activities and traffic in Minna may contribute to noise pollution, cities with greater industrial zones (such as Lagos and Port Harcourt) may have unique dominant noise sources. (ii) Socioeconomic Factors Affecting Noise Perception - Income, housing conditions, and education on environmental noise consequences can all impact residents' noise tolerance and perception. (iii) Testing the Effectiveness of Spatial Analysis in Noise Studies - Spatial mapping of noise hotspots in different cities can reveal how well geographic variations in noise levels correspond with inhabitants' subjective perceptions. (iv) Policy and Mitigation Strategies - Comparing cities can reveal if existing noise control policies and built environment interventions (e.g., zoning, green buffers, and building orientation) effectively reduce noise in different circumstances. By expanding this research to different metropolitan contexts, policymakers and urban planners may build context-specific noise management methods, ensuring that actions are not just data-driven but also suited to the particular urban dynamics of each city.

9. Conclusion and Recommendations

This study focusses on the environmental concerns of noise pollution in Nigerian urban residential areas, as well as the negative consequences it has on inhabitants' quality of life and health. The findings highlight the critical need for noise management solutions in Minnesota. The reported high noise levels are consistent with Environmental Stress Theory, implying that noise pollution is a significant environmental stressor harming urban people' health and well-being. Similarly, from an urban sustainability standpoint, controlling noise pollution is critical to developing a healthier and more livable city. Urban planning strategies should include noise control measures, tighter enforcement of noise rules, and sustainable urban design to reduce the impact of environmental noise on people. Finally, reducing noise pollution and promoting sustainable urban living requires a multifaceted approach that includes urban planning, architectural design, regulatory frameworks, and public awareness. The following recommendations are suggested to address environmental noise risks on residents' health and well-being to create more livable, healthier, and noise-conscious urban residential environments in Nigeria.

i. Develop improved urban planning and zoning regulations
   This can be achieved by (i) enforcing zoning laws that separate high-noise-generating activities (e.g., commercial hubs, places of worship, industrial zones) from residential areas. (ii) creating buffer zones such as green belts, water bodies, and open spaces between noise-sensitive residential areas and noise sources. (iii) by combining mixed-use zoning and noise-reducing urban design to balance residential, commercial, and industrial development.
ii. Incorporate strategic architectural and building design innovations
   This can be achieved by (i) improve building envelope design by using soundproofing materials like insulated windows, acoustic panels, and noise-absorbing walls to limit indoor noise intrusion. (ii) encourage and integrate the use of courtyard and cluster house design to reduce exposure to external noise. (iii) consider specifying and installing double-glazing windows and sound-absorbing facades in residential building design and implementing it on

buildings near noisy areas. (iv) incorporate strategic building orientation such as (i) shielding residential spaces from significant noise sources such as roadways and business hubs and (ii) design residential house layouts with green barriers, including trees and landscaped buffers, to reduce noise pollution.

iii. Develop and device transportation and traffic noise control
This can be implemented by (i) encouraging low-noise road surfaces, such as rubberised asphalt, to reduce traffic noise. (ii) enforcing speed reduction zones and vehicle noise laws in residential areas. (iii) promoting electric and hybrid vehicles with policy incentives to reduce engine noise. (iv) implementing dedicated public transportation corridors to reduce noise from congestion in residential areas.

iv. Develop noise mitigation strategies for public places
This could take the form of (i) requiring acoustic impact assessments for worship, markets, and entertainment facilities before approval. (ii) enforcing laws for public speech systems and loudspeakers, especially in highly populated residential areas. (iii) encouraging silence zones near schools, hospitals, and residential areas.

v. Outline different policy and regulatory measures
This could be possible through (i) aligning national noise pollution regulations with WHO standards (55 dBA for residential areas). (ii) developing noise monitoring frameworks for routine assessments and enforcement of noise control measures. (iii) establishing urban noise mapping programs to manage noise pollution in Nigerian cities. (iv) implementing community noise reporting mechanisms for residents to report excessive noise levels.

vi. Recommendations for Conducting Longitudinal Studies to observe the long-term effects of on Chronic Noise Exposure and Urban Planning Interventions
Given the findings on noise irritation levels in Minna's residential zones, longitudinal studies are needed to examine the long-term impacts of chronic noise exposure and determine how urban design initiatives can ameliorate these effects over time. The recommendations below describe major areas for future investigation. (i) Setting up long-term noise monitoring networks. This could be accomplished by installing continuous noise monitoring sensors in heavily impacted regions such as Angwandaji, Dutse Kura, and Jikpon to detect fluctuations in noise levels over time.

Geospatial analysis could be used to map noise trends and determine how seasonal variations, economic activity, and infrastructure improvements affect noise levels over time. (ii) Evaluate the Long-Term Health and Well-Being Impacts. Cohort studies of inhabitants in noise-prone locations could be done to assess the cumulative health impacts of chronic noise exposure, such as stress, sleep disruptions, cardiovascular illness, and cognitive impairments. Self-reported data on inhabitants' quality of life, psychological well-being, and productivity might also be collected, and the results compared to measured noise levels. (iii) Assessing the efficacy of urban planning interventions. Urban planning initiatives such as green buffers, noise barriers, enhanced zoning restrictions, and traffic management measures should be implemented and monitored to determine their long-term noise reduction impact.

Noise levels and resident perceptions can be compared before and after interventions to discover the most successful solutions. (iv) Conducting socioeconomic and behavioural analyses. This could look into how socioeconomic factors affect residents' ability to adapt to or minimise noise pollution (for example, access to soundproofing, relocation choices, or noise tolerance levels). Furthermore, changes in community behaviour over time, such as alterations in noise complaints, regulatory enforcement, and public knowledge of the effects of noise pollution, could be investigated. (v) Policy

proposals and implementation techniques should include the establishment of evidence-based policies that use long-term noise data to support context-specific noise mitigation legislation in Nigerian cities. Local governments, urban planners, and environmental health experts should collaborate to incorporate research findings into city design and noise control measures. Thus, by undertaking longitudinal research, policymakers and urban planners can gain a better understanding of the long-term effects of noise pollution and develop intervention measures to produce quieter, healthier urban settings in Minna and elsewhere.

vii. Policy Implementation Strategies for Noise Pollution Mitigation in Minna

Based on the noise annoyance levels discovered in Minna's residential districts, the following policy implementation options are proposed to give a clear framework for urban planners and policymakers to transform this research into meaningful noise management techniques:

- develop Noise Zoning Regulations, which should include (i) implementing land use planning strategies that segregate high-noise-generating activities (e.g., markets, transit centres, industrial zones) from residential neighbourhoods. (ii) Creating urban noise zoning maps based on observed noise levels, with high-noise regions including Angwandaji, Dutse Kura, and Jikpon receiving tougher noise control measures. (iii) Enforcing permitted noise levels in various urban zones in compliance with World Health Organisation (WHO) guidelines and Nigeria's National Environmental regulations and Regulations Enforcement Agency (NESREA) noise regulations.
- strengthening noise monitoring and enforcement mechanisms, such as (i) installing permanent noise monitoring stations in high-noise locations to continually track noise pollution levels and assure regulatory compliance. (ii) creating a municipal noise control task force to conduct frequent inspections, resolve public complaints, and enforce noise reduction policies in noisy neighbourhoods. (iii) establishing penalties and fines for noncompliance by enterprises, transportation operators, and other noise-generating entities.
- providing infrastructure and urban design interventions, which should include (i) implementing noise-reducing infrastructure, such as green buffers and vegetative barriers along roads and between residential and commercial areas; noise barriers in high-traffic areas to protect residential neighbourhoods; Proper road design and maintenance to reduce noise from vehicular movements; promote building design innovations, such as encouraging soundproofing materials in home and public building construction; and designing setback policies for major roads to reduce direct noise impact on residential areas.
- increasing community knowledge and stakeholder engagement, which might include (i) launching public awareness campaigns about the health effects of noise pollution and preventive measures, particularly in high-risk neighbourhoods. (ii) Including neighbourhood associations in decision-making processes and encouraging resident participation in noise reporting and mitigation techniques. (iii) Working with transportation unions, market leaders, and local companies to create voluntary noise reduction pledges.
- integration into broader urban and environmental policies, such as (i) incorporating noise pollution control into Minna's current urban master plans to ensure long-term sustainability. (ii) Aligning noise restrictions with environmental sustainability and health regulations, as well as tying them to air quality and overall urban living standards. (iii) Creating data-driven policy frameworks that rely on ongoing research, such as longitudinal noise effect studies and GIS-based geographical analysis, to improve noise reduction techniques.

Urban planners and policymakers can use these policy implementation measures to reduce noise pollution, improve residential quality of life, and promote long-term urban development in Minna and other Nigerian cities.

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References

[1] Tomei, Gianfranco, F. Tecchio, F. Zappasodi, M. Ercolani, F. Moffa, P. Chiovenda, and Manuela Ciarrocca. "Exposure to traffic noise and effects on attention." *Annali di igiene: medicina preventiva e di comunita* 18, no. 6 (2006): 507-519.

[2] Chiovenda, Paola, Patrizio Pasqualetti, Filippo Zappasodi, Matilde Ercolani, Daniele Milazzo, Gianfranco Tomei, Assuntina Capozzella, Francesco Tomei, Paolo M. Rossini, and Franca Tecchio. "Environmental noise-exposed workers: Event-related potentials, neuropsychological and mood assessment." *International journal of psychophysiology* 65, no. 3 (2007): 228-237. https://doi.org/10.1016/j.ijpsycho.2007.04.009

[3] Pedersen, Eja, and Kerstin Persson Waye. "Wind turbine noise, annoyance and self-reported health and well-being in different living environments." *Occupational and environmental medicine* 64, no. 7 (2007): 480-486. https://doi.org/10.1136/oem.2006.031039

[4] Oviasogie, A. C., and A. Ikudayisi. "Implication of noise pollution on residents' wellbeing in Benin City, Nigeria." *International Journal of Humanities and Social Sciences* 24, no. 12 (2019): 17-23.

[5] Guite, Hilary F., Charlotte Clark, and Gill Ackrill. "The impact of the physical and urban environment on mental well-being." *Public health* 120, no. 12 (2006): 1117-1126. https://doi.org/10.1016/j.puhe.2006.10.005

[6] Persson, Roger, Jonas Björk, Jonas Ardö, Maria Albin, and Kristina Jakobsson. "Trait anxiety and modeled exposure as determinants of self-reported annoyance to sound, air pollution and other environmental factors in the home." *International archives of occupational and environmental health* 81 (2007): 179-191. https://doi.org/10.1007/s00420-007-0204-1

[7] Prashanth, KV Mahendra, and V. Sridhar. "The relationship between noise frequency components and physical, physiological and psychological effects of industrial workers." *Noise and Health* 10, no. 40 (2008): 90-98. https://doi.org/10.4103/1463-1741.44347

[8] Wang, Jie, Xuejian Wang, Minmin Yuan, Wenlin Hu, Xuhong Hu, and Kexin Lu. "Deep learning-based road traffic noise annoyance assessment." *International Journal of Environmental Research and Public Health* 20, no. 6 (2023): 5199. https://doi.org/10.3390/ijerph20065199

[9] Haruna, Lumi Zamani, Julius O. Fasakin, and Adebayo Adewunmi Emmanuel. "Analysis of Traffic Noise Levels on Land Use in Jos Metropolis, Nigeria." *International Journal of Advanced Research* 6, no. 1 (2023): 88-101. https://doi.org/10.37284/ijar.6.1.1337

[10] Auwalu, Faisal Koko, and Muhammed Bello. "Exploring the contemporary challenges of urbanization and the role of sustainable urban development: a study of Lagos City, Nigeria." *Journal of Contemporary Urban Affairs* 7, no. 1 (2023): 175-188. https://doi.org/10.25034/ijcua.2023.v7n1-12

[11] Weinhold, Diana. "Sick of noise: the health effects of loud neighbours and urban din." *Grantham Research Institute on Climate Change and the Environment, Working Paper* 213 (2015).

[12] Amurtha, P. P., M. Sravani, K. M. Ashok, P. Sowmya, and S. P. Naga. "Noise pollution and its impact on human health and social behavior using system approach-A case study in Kurnool city, India." *Civil Environ. Res* 8, no. 7 (2016): 70-80.

[13] Pal, Debasish, and Debasish Bhattacharya. "Effect of road traffic noise pollution on human work efficiency in government offices, private organizations, and commercial business centres in Agartala City using fuzzy expert system: A case study." *Advances in Fuzzy Systems* 2012, no. 1 (2012): 828593. https://doi.org/10.1155/2012/828593

[14] Akande, T. M., and F. E. Ologe. "Awareness of commercial grinding machine operators in Ilorin to noise induced hearing loss." *The Tropical Journal of Health Sciences* 8 (2001): 28-31.

[15] Aluko, Esther O., and Victor Nna. "Impact of noise pollution on human cardiovascular system." *International Journal of Tropical Disease & Health* 6, no. 2 (2015): 35-43. https://doi.org/10.9734/IJTDH/2015/13791

[16] Clark, Charlotte, and Katarina Paunovic. "WHO environmental noise guidelines for the European region: a systematic review on environmental noise and quality of life, wellbeing and mental health." *International journal of environmental research and public health* 15, no. 11 (2018): 2400. https://doi.org/10.3390/ijerph15112400

[17] Ubuoh, E. A., S. M. O. Akhionbare, O. Onifade, and S. Ogbuji. "Perception of Health-Impacts of Environmental Noise in an Ambient Noise Context in Owerri-Urban, Imo State, Nigeria." *International Journal of Advances in Applied Sciences* 1, no. 3 (2012): 101-107. https://doi.org/10.11591/ijaas.v1i3.782
[18] Lazarus, Richard S. *Stress and emotion: A new synthesis*. Springer publishing company, 2006.
[19] Newman, Peter, and Jeffrey Kenworthy. "Sustainability and cities: overcoming automobile dependence." (1998).
[20] Lazarus, Richard S. *Stress, appraisal, and coping*. Vol. 464. Springer, 1984.
[21] Park, Giyoung, and Gary W. Evans. "Environmental stressors, urban design and planning: implications for human behaviour and health." *Journal of Urban Design* 21, no. 4 (2016): 453-470. https://doi.org/10.1080/13574809.2016.1194189
[22] Lanrewaju, Amao Funmilayo. "Urbanization, housing quality and environmental degeneration in Nigeria." *Journal of Geography and Regional planning* 5, no. 16 (2012): 422-429. https://doi.org/10.5897/JGRP12.060
[23] AKANDE, Oluwafemi Kehinde, Oluseun Olukemi OLUBAJO, and Yusuf IBRAHEEM. "Quality and Perception of Public Housing Provision in Nigeria and Implications for Low-Income Earners." *Journal of Salutogenic Architecture* 3, no. 1 (2024): 164-181. https://doi.org/10.38027/jsalutogenic_vol3no1_13
[24] Yadav, Deepshikha, Naveen Garg, Chitra Gautam, Ravinder Agarwal, and Sanjay Yadav. "Noise Pollution: The Silent Intruder to Health and Well-Being." In *Handbook of Vibroacoustics, Noise and Harshness*, pp. 1185-1203. Singapore: Springer Nature Singapore, 2024. https://doi.org/10.1007/978-981-97-8100-3_63
[25] Oloruntoba, E. O., R. A. Ademola, M. K. C. Sridhar, S. A. Agbola, F. O. Omokhodion, G. R. E. E. Ana, and R. T. Alabi. "Urban environmental noise pollution and perceived health effects in Ibadan, Nigeria." *African Journal of Biomedical Research* 15, no. 2 (2012): 77-84.
[26] Abel, Abotutu Ahi. "Urban noise pollution in Nigerian cities: Imperatives for abatement." *British Journal of Applied Science & Technology* 10, no. 6 (2015): 1-9. https://doi.org/10.9734/BJAST/2015/18466
[27] Basner, Mathias, and Sarah McGuire. "WHO environmental noise guidelines for the European region: a systematic review on environmental noise and effects on sleep." *International journal of environmental research and public health* 15, no. 3 (2018): 519. https://doi.org/10.3390/ijerph15030519
[28] Abdullah, Samsuri, Muhamad Firdaus Ahmad Fuad, Nazri Che Dom, Ali Najah Ahmed, Ku Mohd Kalkausar Ku Yusof, Mohamad Fakhratul Ridwan Zulkifli, Amalina Abu Mansor, Nur Nazmi Liyana Mohd Napi, and Marzuki Ismail. "Effects of Environmental Noise Pollution Towards School Children." *Malaysian Journal of Medicine & Health Sciences* 17, no. 3 (2021).
[29] Cohen, Sheldon, Gary W. Evans, Daniel Stokols, and David S. Krantz. *Behavior, health, and environmental stress*. Springer Science & Business Media, 2013..
[30] Barton, Hugh, Marcus Grant, and Richard Guise. *Shaping neighbourhoods: for local health and global sustainability*. Routledge, 2021. https://doi.org/10.4324/9780429321245
[31] Haughton, Graham, and Colin Hunter. *Sustainable cities*. Routledge, 2004. https://doi.org/10.4324/9780203645567
[32] Byaello, Kilowau. "Impact of Noise Pollution on Community Health and Well-Being in Lagos, Nigeria." *Journal Wetenskap Health* 4, no. 4 (2023): 15-21. https://doi.org/10.48173/jwh.v4i4.203
[33] Ajibade, Ibijade Olabisi, Patrick Ngozi Ojogwu, and Samuel Olufemi Ajayi. "A Survey of Common Socio-Environmental Factors as a Determinant of Hearing Loss Among University Undergraduates Students in South West Nigeria." *Journal Of Issues* 12, no. 2 (2013): 103.
[34] Akindejoye, Funmi, Uchenna Ezedinma, and Nnenna Ike. "A case study of urban design for wellbeing and mental health in Lagos, Nigeria." *Journal of Urban Design and Mental Health, 7* 10 (2021).
[35] Akande, O. K., A. A. Adenle, L. C. Emechebe, J. J. Lembi, S. Ahmed, C. J. Eze, and M. R. Ajayi. "Implications of residential housing exposure to urban environmental noise on resident's wellbeing in Minna, Nigeria." *Khulna University Studies* (2022): 154-166. https://doi.org/10.53808/KUS.2022.19.02.2242-se
[36] Akande, Oluwafemi Kehinde, and Abdullahi Yusuf. "Environmental noise in residential environments: the case for quality of life in Minna, Nigeria." *Environment-Behaviour Proceedings Journal* 7, no. 22 (2022): 117-125. https://doi.org/10.21834/ebpj.v7i22.4161
[37] Williams, I. D., and I. S. McCrae. "Road traffic nuisance in residential and commercial areas." *Science of the total environment* 169, no. 1-3 (1995): 75-82. https://doi.org/10.1016/0048-9697(95)04635-E
[38] Tang, Shiu Keung, and K. K. Tong. "Estimating traffic noise for inclined roads with freely flowing traffic." *Applied acoustics* 65, no. 2 (2004): 171-181. https://doi.org/10.1016/j.apacoust.2003.08.001
[39] Thorsson, Pontus J., Mikael Ögren, and Wolfgang Kropp. "Noise levels on the shielded side in cities using a flat city model." *Applied Acoustics* 65, no. 4 (2004): 313-323. https://doi.org/10.1016/j.apacoust.2003.11.005
[40] Rabinowitz, Peter M., Deron Galusha, Sharon R. Kirsche, Mark R. Cullen, Martin D. Slade, and Christine Dixon-Ernst. "Effect of daily noise exposure monitoring on annual rates of hearing loss in industrial workers." *Occupational and Environmental Medicine* 68, no. 6 (2011): 414-418. https://doi.org/10.1136/oem.2010.055905

[41] Sirajus Salehin, Sirajus Salehin, K. M. N. Islam, Mohammad Shafiul Alam Mohammad Shafiul Alam, and Mohammad Mosharraf Hossain Mohammad Mosharraf Hossain. "Industrial noise levels in Bangladesh; is worker health at risk?." (2014): 1719-1726.
[42] Bisong, S. A., A. N. Umana, V. Onoyom-Ita, and E. E. Osim. "Hearing acuity loss of operators of food grinding machines in Calabar, Nigeria." *Nigerian Journal of Physiological Sciences* 19, no. 1 (2004): 20-26. https://doi.org/10.4314/njps.v19i1.32631
[43] Ighoroje, A. D. A., C. Marchie, and E. D. Nwobodo. "Noise-induced hearing impairment as an occupational risk factor among Nigerian traders." *Nigerian journal of physiological sciences* 19, no. 1 (2004): 14-19. https://doi.org/10.4314/njps.v19i1.32630
[44] Yesufu, A. L., and G. R. E. E. Ana. "Electric generator characteristics, pattern of use and non auditory health effects experienced by commercial workers in Agbowo and Ajibode Areas of Ibadan, Nigeria." *Review of Global Medicine and Healthcare Research* 3, no. 2 (2012): 159-171.
[45] Ogunseye, T. T., N. N. Jibiri, and V. K. Akanni. "Noise exposure levels and health implications on daily road side petty traders at some major roundabouts in Ibadan, Nigeria." *International Journal of Physical Sciences* 13, no. 19 (2018): 257-264. https://doi.org/10.5897/IJPS2018.4775
[46] Kroesen, Maarten, Eric JE Molin, Henk ME Miedema, Henk Vos, Sabine A. Janssen, and Bert Van Wee. "Estimation of the effects of aircraft noise on residential satisfaction." *Transportation research part D: Transport and environment* 15, no. 3 (2010): 144-153. https://doi.org/10.1016/j.trd.2009.12.005
[47] Fan, Yi, and Diana M. Weinhold. "Urban noise, sleep disruption and health." *Applied Economics* 54, no. 50 (2022): 5782-5799. https://doi.org/10.1080/00036846.2022.2053054
[48] Haruna, L. Z., and J. O. Fasakin. "Assessment of Road Traffic Noise Differentials in the Land Uses of Jos, Nigeria." *Am. J. Environ. Clim* 2, no. 2 (2023): 33-40. https://doi.org/10.54536/ajec.v2i2.1873
[49] Orikpete, Ochuko Felix, and Daniel Ewim. "A review of noise management practice in Nigeria." *Environmental Science & Sustainable Development* 8, no. 1 (2023): 31-42. https://doi.org/10.21625/essd.v8i1.931
[50] Olamijulo, John Oluseye, Godson Rowland Ana, and Oyewale Mayowa Morakinyo. "Noise from portable electric power generators in an institutional setting: A neglected risk factor." *International Journal of Environmental Monitoring and Analysis* 4, no. 4 (2016): 115-120. https://doi.org/10.11648/j.ijema.20160404.11
[51] Chukumah, Charity O., Gabriel CC Ndinwa, and Solomon A. Akpafun. "Evaluation of perceived effects from exposure to occupational noise pollution on hearing loss among cement factory workers." (2020).
[52] Awosusi, A. O., and I. O. Akindutire. "Perceived health effects of environmental noise pollution on the inhabitants of Ado-Ekiti Metropolis. Ekiti State, Nigeria." *Journal of Biology, Agriculture and Healthcare* 4, no. 26 (2014): 106-113.
[53] Baba, J.M. and Jinadu, A.M. "Analysis of spatial variation in the occurrence of Housing Environment -Related Diseases in Minna Metropolis", Being a research submitted to the university Board of research, Federal University of Technology Minna (2000).
[54] Mishra, R. K., Manoranjan Parida, and S. Rangnekar. "Evaluation and analysis of traffic noise along bus rapid transit system corridor." *International Journal of Environmental Science & Technology* 7 (2010): 737-750. https://doi.org/10.1007/BF03326183
[55] Kapp, Andrew F., Joseph M. Passmore, and Anika H. Schneider. "Noise Pollution? What's the solution?: Understanding Traffic Noise Pollution in Gettysburg, Pennsylvania." (2014).
[56] Abbaspour, Majid, Elham Karimi, Parvin Nassiri, Mohammad Reza Monazzam, and Lobat Taghavi. "Hierarchal assessment of noise pollution in urban areas–A case study." *Transportation Research Part D: Transport and Environment* 34 (2015): 95-103. https://doi.org/10.1016/j.trd.2014.10.002
[57] Mehdi, Mohammed Raza, M. H. Arsalan, and J. H. Kazmi. "Spotting noise risk zones in Karachi, Pakistan: A GIS perspective." *Proceedings GISDECO: Governance and the use of GIS in developing countries. ITC Enschede, the Netherlands* (2002).
[58] Kucas, A., J. Hoej, and R. Frederiksen. "Efficient Noise Mapping using ArcGIS and detailed Noise Propagation Simulation." In *ESRI European User Conference*. 2017.
[59] Wawa, Enock Abe, and Galcano Canny Mulaku. "Noise pollution mapping using GIS in Nairobi, Kenya." *Journal of Geographic Information System* 7, no. 5 (2015): 486-493. https://doi.org/10.4236/jgis.2015.75039
[60] NESREA (National Environmental Standards and Regulations Enforcement Agency). Review of NESREA Act 2007 and Regulation: Av New Dawn in Environmental Compliance and Enforcement in Nigeria (2009).
[61] Talib, Rozilah, Nik Norzahariah Ashikin N. Mohamed, Nafisah Ya'cob, Ng Jia Jian, and Mazura Mahdzir. "Sustainable Construction Method: Key Issues of BIM Implementation in Malaysia." *Journal of Advanced Research in Technology and Innovation Management* 8, no. 1 (2023): 1-15.
[62] Akande, Oluwafemi Kehinde, Adegbenga Adewale Oshineye, Igbayemi Daniel Akeremale, Gambo Aisha Haruna, Emmanuel Moses Anikor, Charles Yakubu Makun, and Ebere Donatus Okonta. "Towards Sustainable Redesign of

Academic Library Buildings in Nigeria: Case for Remodelling Higher Institution Library Buildings to Meet 21st Century Users' Expectations." *Semarak International Journal of Design, Built Environment and Sustainability* 1, no. 1 (2024): 40-71. https://doi.org/10.37934/sijdbes.1.1.4071

[63] Campbell, Scott. "Green cities, growing cities, just cities? Urban planning and the contradictions of sustainable development." In *Classic readings in urban planning*, pp. 308-326. Routledge, 2018. https://doi.org/10.4324/9781351179522-25

[64] Oyedepo, Sunday Olayinka. "Development of noise map for Ilorin metropolis, Nigeria." *International journal of environmental studies* 70, no. 4 (2013): 503-514. https://doi.org/10.1080/00207233.2013.813716

[65] Babisch, Wolfgang. "Road traffic noise and cardiovascular risk." *Noise and Health* 10, no. 38 (2008): 27-33. https://doi.org/10.4103/1463-1741.39005

[66] Mead, M. Nathaniel. "Noise pollution: the sound behind heart effects." (2007): A536-A537. https://doi.org/10.1289/ehp.115-a536b

[67] Martins Pereira, Gonçalo, José Brito, Maria João Oliveira, and Pedro Oliveira. "Urban noise exposure and cardiometabolic diseases: an exploratory cross-sectional study in Lisbon." *Portuguese Journal of Public Health* 39, no. 2 (2021): 95-102. https://doi.org/10.1159/000520263

[68] Paneto, Greicikelly Gaburro, Cristina Engel de Alvarez, and Paulo Henrique Trombetta Zannin. "Relationship between urban noise and the health of users of public spaces—A case study in Vitoria, ES, Brazil." *Journal of Building Construction and Planning Research* 5, no. 02 (2017): 45. https://doi.org/10.4236/jbcpr.2017.52004