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Evaluation of Occupational and Environmental Noise Pollution Exposure Levels in Selected Sawmills, Southern Nigeria

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Abstract: *This study presents the assessment and evaluation of noise levels in some selected sawmills within Warri and its environs. An MS6701 Digital Sound Level Meter of range 30-130 dBA, and a Geographical Positioning System (GPS) were employed to measure the noise level of strategic Sawmills locations and ascertain the location coordinates within the study area during the time of measurements. According to the analysis of the empirical results, the noise levels of the different sawmills ranged from 92.02 dB(A) to 96.5 dB (A) when operations were conducted. This is higher than the FMEnv and OSHA recommended standard of 90 dBA for eight hours per day (FEPA, 1991; OSHA, 1993), and lower than the recommended level when operations were not conducted, which ranged from 62.31dBA to 68.91dBA. Microsoft Excel was used to validate the results that were obtained. For both in-use and non-used equipment, the Noise Climate (NC), Traffic Noise Index (TNI), and n-percent exceedance level (L10 and L90) values were computed. All of the average values from these computed noise level parameters were over the 55 dBA threshold that the National Environmental Standards and Regulations Enforcement Agency (NESREA) and the World Health Organisation (WHO) prescribe for residential areas.*

Keywords*: Noise Levels, Sawmills, Noise Climate, Parameters, Evaluation.*

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1.0 Introduction

Noise pollution has become a significant environmental and occupational health challenge, particularly in industrial settings. It has been associated with adverse health outcomes such as hearing impairment, cardiovascular complications, sleep disturbance, and reduced productivity. Sawmill operations, due to the continuous cutting, sawing, and processing of wood, generate sustained high levels of noise that affect both workers and surrounding communities.

Several studies have reported elevated noise levels in sawmills across Nigeria and other countries. For instance, Aremu et al. (2024) reported background noise levels of 58.1–64.9 dB(A) and machine equivalent noise levels of up to 112.3 dB(A) in Ilorin sawmills, with 73% of the noise exceeding recommended limits, leading to tinnitus, headache, and hearing impairment among workers. Similarly,

Ugbebor & Yorkor (2015) found mean noise values exceeding the Federal Ministry of Environment (FMEnv) exposure limits in Port Harcourt sawmills, with a risk of excess exposure for both workers and nearby residents. More recently, Anekwe and Avwiri (2024) measured average noise pollution levels ranging from 96.13 to 101.23 dB in sawmills in Port Harcourt and environs, with Igwuruta recording the highest levels above FMEnv permissible standards. These findings are consistent with Rathipe and Raphela (2022), who documented noise levels above 85 dB(A) in South African timber factories, placing workers at high risk of noise-induced hearing loss (NIHL).

In addition to noise, other occupational hazards in sawmills have been documented. Eghomwanre & Ojoka (2025) demonstrated that particulate matter (PM2.5 and PM10) in Benin City sawmills exceeded WHO limits, with toxicity linked to respiratory health problems among workers. These studies collectively highlight the wide range of occupational hazards associated with sawmill operations in Nigeria and beyond.

Despite these reports, there is limited documentation that simultaneously evaluates occupational and environmental noise exposure in sawmills within Southern Nigeria. Previous research has mostly focused on isolated urban centers (e.g., Ilorin, Port Harcourt, Benin City) without providing region-wide evidence that links worker exposure with community environmental impacts. This constitutes a significant knowledge gap.

The aim of this study is therefore to evaluate occupational and environmental noise pollution exposure levels in selected sawmills in Southern Nigeria, with emphasis on comparing the results with national (FMEnv, NESREA, 2009; LASEPA, 2019) and international (WHO, 1995; OSHA, 2012) standards.

The significance of this research lies in its potential to provide reliable evidence for policymaking, occupational health regulation, and community protection. The findings will support the design of effective noise control strategies, strengthen compliance with environmental standards, and contribute to safeguarding the health of sawmill workers and nearby residents.

2.0 Materials and Methods

2.1 Study Area

With coordinates between 5°41′E and 5°48′E and latitudes 5°30′N and 5°36′N, Warri city in Delta State is well-known for its commercial, industrial, and socioeconomic activities in Nigeria (Fig. 1).

]The city serves as a transit and conference hub due to its advantageous location at the boundary between eastern and western Nigeria. The central location of Warri sawmills makes the area a commercial hub for wood supply to the city and its surrounding communities, as there are several wood markets, some of which lack sawmill equipment. The city's dense population is partly attributed to the presence of numerous wood furniture stores, as well as the strategic presence of military facilities, including an army barracks and a naval base. According to the 2006 National Population Census and subsequent demographic projections, Warri and its environs have a population of several hundred thousand, making it one of the fastest-growing urban centers in southern Nigeria. *This study was conducted in* July 2019 during the peak of the wet season.

2.2 Data Collection

A total of twenty-one (21) sawmill factories were selected for this study. Noise measurements were conducted using an MS6701 Digital Sound Level Meter with an accuracy of ±1.5 dB and a

measurement range of 30–130 dBA. To prevent contamination, the instrument was positioned at a height of one metre above ground level and at least two metres away from reflective surfaces. The exact location of each sampling point was determined using a Global Positioning System (GPS).

To ensure accuracy, the sound level meters were calibrated before use in line with the manufacturer's instructions, and their tolerance was confirmed to be within acceptable limits. Noise

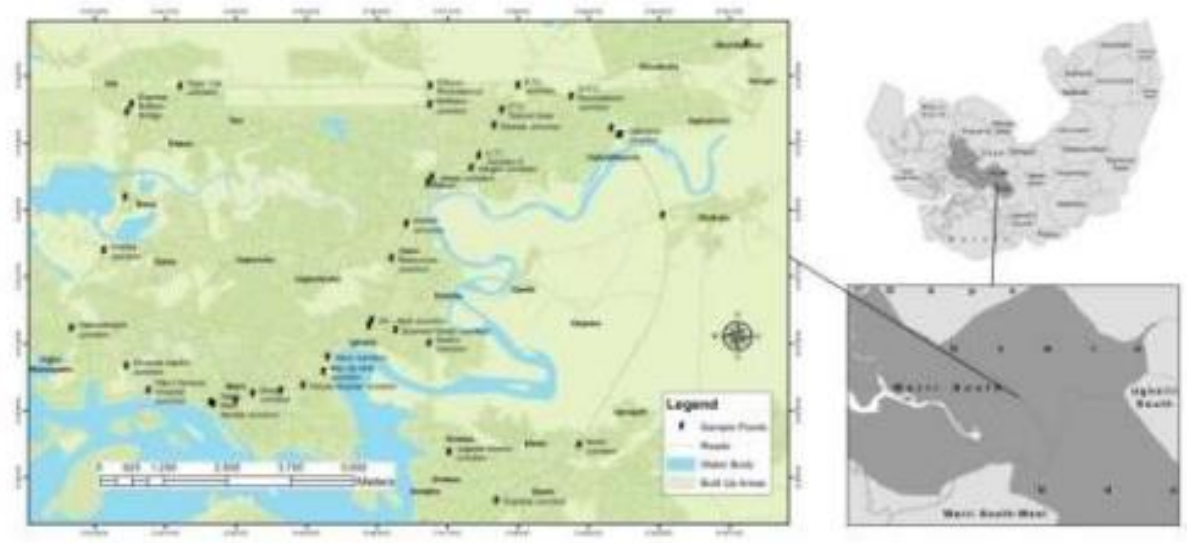

Fig. 1: Map of the study area

levels at each sawmill were measured during machine operation (*peak period measurements*) and when machines were not in operation (background measurements*). In accordance with the* New South Wales Environmental Protection Authority (NSW EPA, 2000) noise measurement procedure, measurements were taken at one-metre height, repeated three times at each location, and the mean values were computed. Each measurement lasted for a period of 5 minutes, capturing both instantaneous and equivalent continuous sound pressure levels (Leq). *The average results were used to calculate the rating and mean noise levels for each monitoring* location. As shown in Table 1, the sampling locations were grouped into their respective Local Government Areas (LGAs).

Table 1. List of Sawmills (21) grouped into their various Local Government Areas

Uvwie lga	Warri South & North lga	Udu & Ughelli South lga
Jakpa Road	Kpesu market 1	Mofe Junction
Uti Road 1	Kpesu market 2	Otokutu Bridge
Uti Road 2	Kpesu market 3	Beside Udu Bridge 1
Uti Road 3	Kpesu market 4	Beside Udu Bridge 2
Uti Road 4	Kpesu market 5	Beside Udu Bridge 3
Uti Road 5		Beside Udu Bridge 4
		Udu Road 1

3.0 Results and Discussion

3.1 Results

3.1 Noise Levels During Machine Operation

Table 2 presents the equivalent noise levels (Leq) at the various sawmills when machines were in use. The observed values ranged from

86.9 dBA at Uti Road 3 to 103.2 dBA at Kpesu Market 5, indicating substantial variability across locations. The highest average noise level was consistently observed at Kpesu Market, which can be attributed to the clustering of sawmills, intense vehicular movement, and dense commercial activities in the area. Generally, the majority of the sawmills recorded Leq values above 95 dBA, suggesting that workers in these environments are regularly exposed to noise levels that are not only hazardous but also exceed both occupational and environmental safety limits.

Table 2 Average Noise Levels of the different Sawmills when the machines were in Used.

Location	Location GPS	Mean	Standard Deviation	Rating
Otokutu bridge	N05º33.239' E 005º49.485'	96.6	3.10	extremely high
Mofo junction	N05º30.211' E 005º48.362'	95.3	3.01	extremely high
Udu road 1	N05º30.704' E 005º47.069'	92.1	2.91	extremely high
Kpesu market 1	N05º30.594' E 005º44.933'	90.4	2.87	extremely high
Kpesu market 2	N05º30.528' E 005º44.970'	92.3	2.82	extremely high
Kpesu market 3	N05º30.429' E 005º45.082'	92.8	2.90	extremely high
Kpesu market 4	N05º30.400' E 005º45.123'	92.7	2.88	extremely high
Uti road 1	N05º33.564' E 005º47.615'	93.0	2.94	extremely high
Uti road 2	N05º33.590' E 005º47.601'	91.8	2.87	extremely high
Uti road 3	N05º33.555' E 005º47.580'	86.9	2.56	very high
Uti road 4	N05º33.564' E 005º47.593'	90.0	2.82	extremely high
Beside Udu bridge 1	N05º30.909' E 005º47.105'	93.5	2.94	extremely high
Kpesu market 5	N05º30.465' E 005º45.004'	92.4	2.86	extremely high
Beside Udubridge 2	N05º30.909' E 005º47.169'	91.2	2.85	extremely high
Beside Udu bridge 3	N05º30.922' E 005º47.255'	90.6	2.80	extremely high
Beside Udu bridge 4	N05º30.930' E 005º47.299'	89.7	2.59	extremely high
Uti road 5	N05º33.558'	94.1	3.00	extremely high

	E 005º47.634'			
Udu road 2	N05º30.788'	94.2	3.10	extremely high
	E 005º47.090'			
Jakpa road	N05º33.749'	92.3	2.86	extremely high
	E 005º45.959'			
Kpesu market 5	N05º30.542'	92.1	2.84	extremely high
	E 005º44.970'			
Udu road 3	N05º30.706'	94.2	3.10	extremely high
	E 005º47.059'			

These values far exceed the permissible exposure limit of 90 dBA set by the Occupational Safety and Health Administration (OSHA, 2002) and the 90 dBA threshold established by the Nigerian Federal Ministry of Environment (FMEnv) and National Environmental Standards and Regulations Enforcement Agency (NESREA, 2009). For instance, the measurement at Kpesu Mar, 2009ket 5 (103.2 dBA) surpasses the OSHA standard by more than 13 dBA, which, on a logarithmic scale of sound intensity, represents a several-fold increase in acoustic energy. This implies that prolonged exposure in such locations could result in accelerated hearing damage within shorter durations of work shifts.

Noise levels recorded in Uti Road sawmills, although relatively lower (86.9–92.5 dBA), were still within a range that exceeds acceptable limits for continuous occupational exposure, highlighting that even less crowded sawmills in Warri contribute significantly to noise hazards. The variation in noise levels across different sites reflects the combined influence of machine type, operational intensity, wood load, and environmental setting. Sawmills located along busy transport corridors such as Jakpa Road and Udu Road tended to produce higher readings due to the additive effect of road traffic and ancillary commercial activities (Zollinger *et al*., .2020). These findings demonstrate that noise from sawmill operations in Warri is not an isolated concern but a widespread occupational and environmental issue that demands immediate regulatory attention.

3.1.1 Noise Levels Without Machine Operation

When machines were not in operation (Table 3), noise levels ranged from 63.3 dBA to 85.3 dBA. Even in the absence of active sawing, the background noise in several sawmills exceeded the FMEnv and NESREA limits for residential and commercial areas (55–70 dBA). This finding underscores the contribution of traffic, human activity, and neighboring industrial operations to persistent noise pollution.

Notably, the maximum background level of 85.3 dBA recorded at Kpesu Market is only marginally lower than the Leq values obtained during machine operation, suggesting that this location experiences a near-continuous high-noise environment irrespective of sawing activities.

Similarly, sites such as Jakpa Road and Udu Road recorded background noise levels between 75 dBA and 80 dBA, which are substantially above the upper permissible limit of 70 dBA for mixed commercial–residential areas. This indicates that even during periods when machines are switched off, residents and workers remain exposed to noise levels capable of causing annoyance, sleep disturbance, and long-term health effects.

On the other hand, relatively lower values (63.3–68 dBA) were observed at certain Uti Road sawmills. Although these fall closer to

the regulatory threshold, they still exceed the 55 dBA limit recommended for residential neighbourhoods, implying that no site within the study area can be classified as noise-safe.

The persistence of elevated background noise levels across all sawmills highlights the synergistic effect of environmental factors such as vehicular movement, human congregation, and the close proximity of multiple industrial facilities. This continuous exposure environment greatly reduces the opportunity for auditory recovery and exacerbates the cumulative risks of occupational and community noise pollution.

Table 3 Average Noise Levels of the different Sawmills when the machines were not in Used.

Location	Location GPS	Mean	Standard deviation	Rating
Otokutu bridge	N05º33.239' E 005º49.485'	65.9	1.99	VERY HIGH
Mofo junction	N05º30.211' E 005º48.362'	73.6	2.34	VERY HIGH
Udu road 1	N05º30.704' E 005º47.069'	65.8	1.91	VERY HIGH
Kpesu market 1	N05º30.594' E 005º44.933'	76.1	2.41	VERY HIGH
Kpesu market 2	N05º30.528' E 005º44.970'	74.2	2.39	VERY HIGH
Kpesu market 3	N05º30.429' E 005º45.082'	68.6	2.42	VERY HIGH
Kpesu market 4	N05º30.400' E 005º45.123'	72.7	2.88	VERY HIGH
Uti road 1	N05º33.564' E 005º47.615'	66.0	1.87	VERY HIGH
UTI ROAD 2	N05º33.590' E 005º47.601'	69.8	1.96	VERY HIGH
UTI ROAD 3	N05º33.555' E 005º47.580'	65.0	1.89	VERY HIGH
UTI ROAD 4	N05º33.564' E 005º47.593'	64.9	1.86	VERY HIGH

3.1.2 Noise Indices

The calculated noise indices, including L10, L90, Noise Climate (NC), and Traffic Noise Index (TNI), are presented in Tables 4 and 5. L10 values consistently surpassed 95 dBA at several sites, confirming frequent peaks in noise exposure. The NC values indicated a highly fluctuating noise environment, with Kpesu Market exhibiting the highest variability. TNI values were also significantly elevated, further highlighting the potential for adverse health and environmental impacts.

Specifically, the L10 values during machine operation exceeded 95 dBA at sites such as Otokutu Bridge, Mofo Junction, and Uti Road 3, suggesting that workers are subjected to recurrent noise bursts above the recommended safe limit. These frequent peaks are of particular concern because transient high-intensity noise is more damaging to hearing than steady-state exposure at the same average level.

Table 4: L_{10} and L_{90} Exceedance Levels, Traffic Noise Index (TNI), Noise Climate (NC) calculated when the machines were in use.

Location	L_{10} (dBA)	L_{90} (dBA)	Noise Climate (NC) (dBA)	Traffic Noise Index (TNI) (dBA)
Otokutu bridge	97.9	94.9	3.0	76.9
Mofo junction	97.8	90.0	7.8	91.2
Udu road 1	92.5	90.1	2.4	69.7
Kpesu market 1	91.2	89.9	1.3	65.1
Kpesu market 2	93.1	90.8	2.3	70.0
Kpesu market 3	94.8	90.4	4.4	78.0
Kpesu market 4	94.7	90.9	3.8	76.1
Uti road 1	94.3	91.5	2.8	72.7
Uti road 2	92.7	90.8	1.9	68.4
Uti road 3	95.9	77.9	18	119.9
Uti road 4	90.1	89.9	0.2	60.7
Beside Udu bridge 1	96.8	91.1	5.7	83.9
Kpesu market 5	93.1	91.3	1.8	68.5
Beside Ududbridge 2	96.5	87.7	8.8	80.5
Beside Udu bridge 3	91.4	89.7	1.7	66.5
Beside Udu bridge 4	90.2	88.1	2.1	64.9
Uti road 5	95.8	92.7	3.1	75.1
Udu road 2	96.6	92.6	4.0	78.6
Jakpa road	93.4	91.3	2.1	69.7
Kpesu market 5	94.1	90.2	3.9	75.8
Udu road 3	95.9	92.6	3.3	75.8

Table 5 L_{10} and L_{90} Exceedance Levels, Traffic Noise Index (TNI), Noise Climate (NC) calculated when the machines were not in used

Location	L10 (dBA)	L90 (dBA)	Noise Climate (NC) (dBA)	Traffic Noise Index (TNI) (dBA)
Otokutu Bridge	66.9	65.2	1.7	42.0
Mofo Junction	73.9	73.1	0.8	46.3
Udu Road 1	66.0	65.6	0.6	38.0
Kpesu Market 1	77.5	74.2	3.3	57.4
Kpesu Market 2	76.7	72.4	4.3	59.6
Kpesu Market 3	70.4	67.3	3.1	49.7
Kpesu Market 4	74.0	71.9	2.1	50.3
Uti Road 1	66.6	65.7	0.9	37.3
Uti Road 2	71.0	68.9	2.1	47.3
Uti Road 3	66.8	63.6	3.2	46.4
Uti Road 4	66.9	63.9	3.0	45.9

The L90 values, which represent the baseline background noise, ranged between 88–92 dBA across most sites, underscoring the persistence of elevated noise even during quieter intervals. This finding confirms that the noise environment in these sawmills does not provide relief from exposure, thereby increasing cumulative auditory strain.

Noise Climate (NC) values varied considerably, with Uti Road 3 showing the highest fluctuation (18 dBA) and Uti Road 4 recording the lowest (0.2 dBA). The wide differences in NC reflect the influence of operational intensity, machine conditions, and the surrounding traffic environment. High NC values are typically associated with unpredictable and irregular noise events, which contribute to psychological stress, communication difficulties, and decreased worker productivity.

Similarly, the Traffic Noise Index (TNI) ranged from 60.7 dBA at Uti Road 4 to 119.9 dBA at Uti Road 3 during machine operation. The extreme TNI recorded at Uti Road 3 is indicative of severe variability and intense background activity, reinforcing its status as one of the noisiest and most hazardous sites in the study area. Even in the absence of machine activity, TNI values remained elevated (37.3–59.6 dBA), suggesting that traffic and other anthropogenic activities alone contribute substantially to noise pollution.

Taken together, the high L10 and L90 levels, coupled with large NC and TNI values, demonstrate that the noise environment within the Warri sawmills is both persistently elevated and highly variable. This dual burden of continuous exposure and frequent peaks increases the risk of occupational hearing loss, cardiovascular stress, and reduced quality of life for workers and nearby residents.

Figs. 2 and 3 illustrate the comparative analysis of noise levels across the surveyed sawmills. The spatial distribution patterns clearly indicate that sawmills located near major transportation corridors—such as Jakpa Road, Udu Road, and Otokutu Bridge, recorded higher Leq values compared to those in relatively secluded or residential zones (e.g., Uti Road sites). This finding underscores the significant contribution of vehicular traffic, roadside commercial activity, and continuous timber transport to elevated noise levels.

Moreover, the influence of urban density and land-use type becomes evident in the distributional trends. For instance, sawmills within densely populated business districts, particularly at Kpesu Market and Mofo Junction, consistently showed higher noise indices, reflecting both machine activity and the cumulative effect of human and vehicular congestion**.**

Fig. 4 further demonstrates the average noise levels aggregated by Local Government Areas (LGAs). The results reveal that Warri South and Uvwie LGAs were the most impacted, exhibiting consistently elevated Leq values, while Udu and Ughelli South LGAs showed relatively lower averages. This spatial differentiation is likely a function of population density, proximity to major commercial routes, and the clustering of industrial activities in the Warri metropolitan area.

These spatial patterns highlight the uneven distribution of noise exposure risk within the study area. Workers and residents in Warri South and Uvwie are disproportionately affected, which raises important concerns for targeted policy interventions, urban planning, and enforcement of noise control regulations. The persistence of elevated levels across multiple LGAs also underscores that noise pollution is not confined to isolated sites but represents a broader environmental health challenge in Warri city.

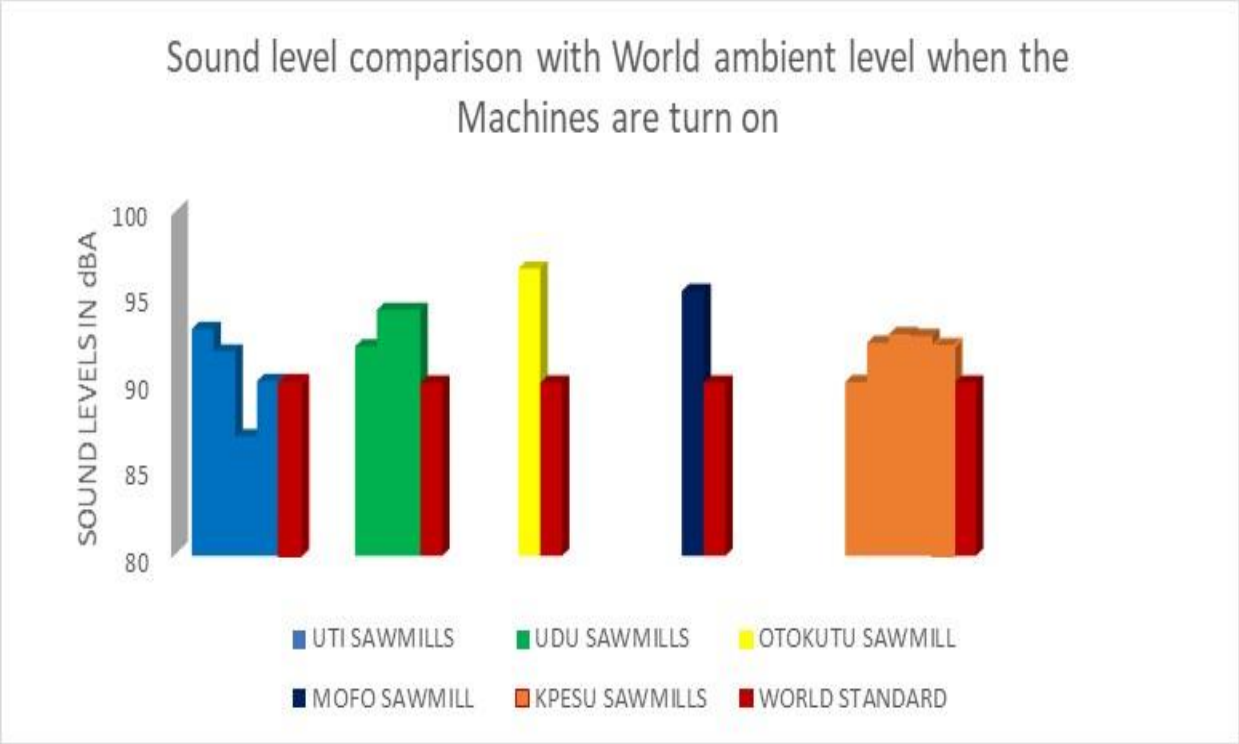

Fig 2: Comparison chart of the noise level of the different sawmills when the machines are in use with the ambient level

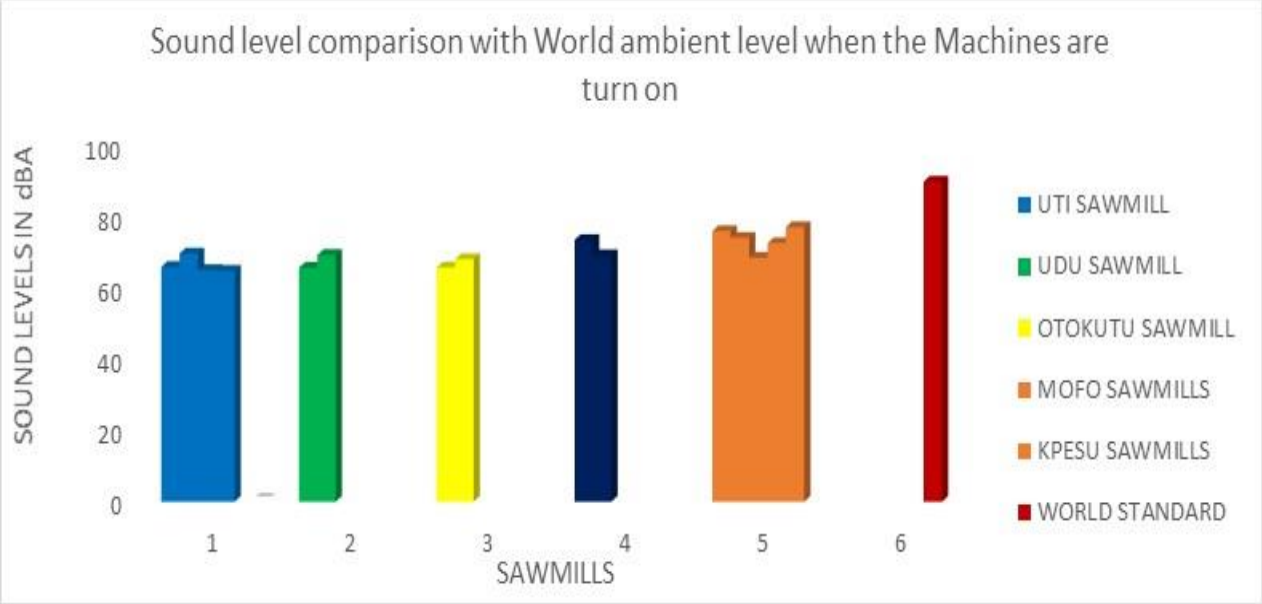

Fig 3: Comparison chart of the noise level of the different sawmills when the machines are not in use, with the ambient level

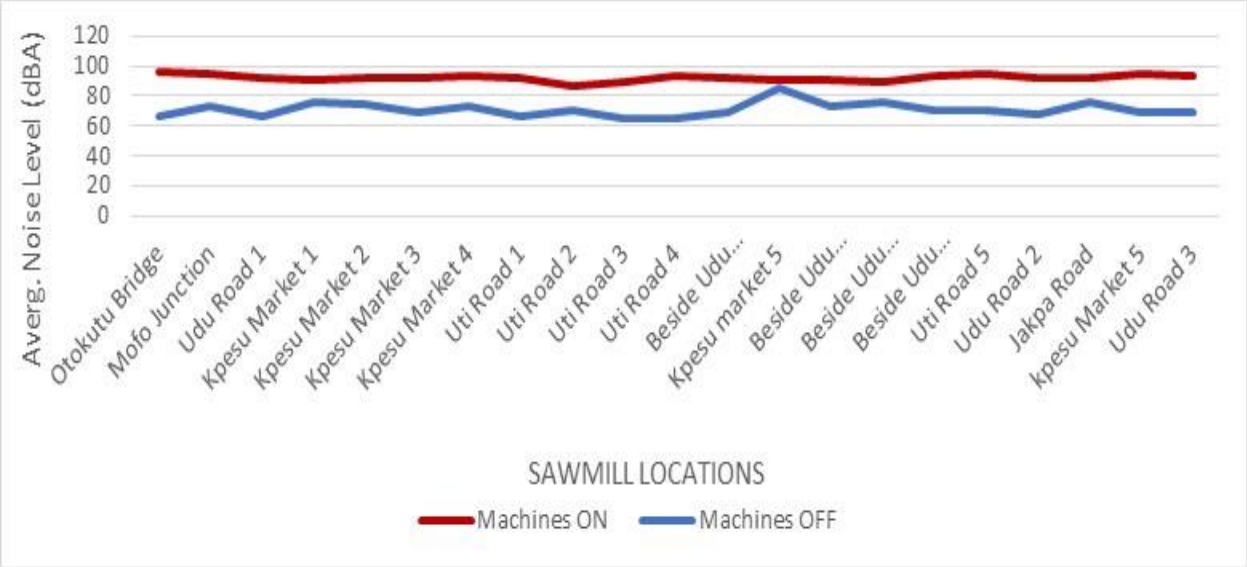

Fig 4: Variational analysis of the sawmills when the machines were in use and not in use

3.2 Discussion

The results clearly demonstrate that sawmill operations in Warri generate noise levels that substantially exceed both national and international standards. Sustained exposure to values above 90 dBA poses serious risks of temporary or permanent hearing loss,

heightened stress levels, and cardiovascular complications among workers and nearby residents (WHO, 2018). In occupational health terms, such continuous exposure surpasses the maximum permissible daily noise dose recommended by OSHA and NESREA, thereby placing both workers and the surrounding population in a high-risk category. The consistently high values at Kpesu Market can be linked not only to machine operation but also to cumulative environmental factors such as traffic congestion, proximity of multiple sawmills, and limited spatial planning. This clustering effect magnifies exposure intensity, creating a persistent noise hotspot within Warri's commercial core**.** This observation aligns with similar findings in studies reported in the literature. Also, concerning is the persistence of background noise levels above 70 dBA during periods of machine inactivity, which indicates that the noise environment in Warri is not intermittent but chronic. Such conditions restrict opportunities for auditory recovery, thereby compounding the risk of long-term auditory fatigue and non-auditory health effects such as hypertension and sleep disturbance**.** This is particularly critical for vulnerable groups such as children, the elderly, and patients in nearby health facilities who may have reduced tolerance to environmental stressors.

The noise indices (L10, L90, NC, and TNI) provide deeper insights into the intensity and variability of the noise environment. High L10 values confirm frequent and recurrent peaks that exceed safe limits, while elevated NC values highlight the unstable and fluctuating character of the noise environment. Such variability is known to exacerbate annoyance, reduce community tolerance, and impair cognitive performance (Onjefu et al., 2019*).* Similarly, elevated TNI values reinforce the conclusion that communities near sawmills are continuously exposed to disruptive, traffic-like

noise conditions, even in periods of reduced machine activity.

From a policy perspective, these findings point to the urgent need for the enforcement of environmental noise regulations in Nigeria. Practical interventions could include the mandatory provision and enforcement of personal protective equipment (PPE) for sawmill workers, installation of physical noise barriers, and spatial reorganization of sawmills to reduce clustering in densely populated areas. Periodic monitoring and compliance checks by environmental agencies such as NESREA are also essential. Equally important are community-based awareness campaigns and public health education programs to sensitize residents about the risks of prolonged noise exposure and encourage behavioural adaptations such as restricted exposure times and use of hearing protection.

4.0 Conclusion

This study investigated noise pollution in 21 selected sawmills across Warri, Delta State, and the findings revealed that equivalent noise levels (Leq) during machine operation ranged from 86.9 dBA to 103.2 dBA, values that far exceed the permissible exposure limits of OSHA (90 dBA) as well as the thresholds set by FMEnv and NESREA (90 dBA). Even when machines were not in operation, background noise levels remained elevated, ranging from 63.3 dBA to 85.3 dBA, which is above the regulatory thresholds for residential and commercial environments (55–70 dBA). The calculated noise indices (L10, L90, NC, and TNI) confirmed the prevalenceof frequent peaks, highly fluctuating noise environments, and elevated exposure risks, particularly at Kpesu Market and sawmills located near major roads. Spatial distribution analysis further indicated that Warri South and Uvwie LGAs were the most impacted zones.

The overall results demonstrate that sawmill operations in Warri contribute substantially to chronic noise pollution, consistently surpassing both national and international standards. The observed high noise levels pose significant occupational and public health concerns, including noise-induced hearing loss, elevated stress levels, cardiovascular complications, disturbed sleep patterns, and reduced community well-being. Particularly concerning is the persistence of high background noise, which remains above acceptable limits even during machine inactivity, thereby highlighting a chronic exposure condition that prevents adequate auditory recovery. Without adequate interventions, both workers and surrounding communities face increasing risks of long-term adverse health outcomes and declining environmental quality.

To mitigate these risks, there is an urgent need for strict enforcement of environmental noise regulations by FMEnv and NESREA, coupled with regular monitoring of sawmill operations. The mandatory use of personal protective equipment (PPE), such as earmuffs and earplugs, should be ensured for all sawmill workers, while strategic urban planning is required to prevent further clustering of sawmills near roads and residential settlements. In addition, installation of noise barriers, adoption of noise-reducing technologies, and the relocation of sawmills to designated non-residential zones waould significantly reduce exposure levels. Equally important are public health awareness campaigns and sensitization programs for both workers and residents, which would help to increase understanding of the risks associated with long-term noise exposure and encourage preventive practices.

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Consent for publication

Not Applicable

Availability of data and materials

The publisher has the right to make the data public

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Not applicable

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EOE conceived and designed the study, supervised data collection, and contributed to manuscript drafting. AOT performed instrumental measurements and data validation. OD assisted in field sampling, noise data computation, and statistical analysis. AOE provided technical guidance, reviewed literature, and critically revised the manuscript. All authors discussed the results and approved the final version for publication.