Occupational Exposure to Noise and Electromagnetic Fields in Industrial Workplaces: Health Implications, Safety Practices, and Mitigation Strategies in Kebbi State

[1*]Samaila B., [1]Ifeoluwa M. A, [1]Maidamma B., [1]Garba I.I.
[1]Department of Physics with Electronics,
Federal University Birnin Kebbi
[1*]Corresponding Author: buhari.samaila@fubk.edu.ng
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Abstract
*Industrialization has significantly increased occupational exposure to both noise and electromagnetic fields (EMFs), creating complex health and safety challenges. This study assessed the patterns, intensity, and health impacts of noise and EMF exposure among workers across selected industries in Northwestern Nigeria. Data were analysed from ten structured variables, including exposure sources, intensity levels, health effects, protective practices, training, and policy implementation. The findings revealed that machinery and generators were the dominant exposure sources, accounting for over 60% of total risk frequency. Exposure intensity ranged from moderate to very high, with power and rice-processing industries showing the highest prevalence. Commonly reported health effects included headache (60.6%), sleep disturbances (37.4%), and stress (35.4%), while auditory effects such as hearing loss (13.1%) and tinnitus (2%) were less frequent. Only 24% of industries had implemented protection or training programs, and 75.8% of respondents lacked access to any form of personal protective equipment (PPE). About 74.7% of workers never wore noise protection, and only two industries had done formal exposure assessments. The most proposed mitigation strategies included workplace improvement (50.5%) and PPE provision (47.5%). The study concludes that poor occupational safety culture, lack of training, and inadequate regulatory enforcement are major contributors to the observed health outcomes. For long-term workplace safety, it is important to strengthen industrial health policies, make regular exposure monitoring mandatory, and use both engineering and administrative controls. These findings align with the recommendations of the World Health Organization (2020), the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2020), **and** the International Labour Organization (ILO, 2021) on workplace environmental safety standards.*

Keywords: *Noise exposure, electromagnetic fields, industrial health, occupational safety, protective equipment, Nigeria.*

Introduction

Industrialization has enhanced economic productivity but has also increased exposure to physical occupational hazards, noise and electromagnetic fields (EMFs). Power generators, heavy machinery, and electrical devices commonly found in industrial workplaces generate these hazards (WHO, 2020; ICNIRP, 2020). Noise levels above 85 dB(A) can cause noise-induced hearing loss (NIHL), tinnitus, stress, hypertension, and cognitive impairment (Lee et al., 2023; Sliwinska-Kowalska & Zaborowski, 2017), while prolonged exposure to EMFs may induce oxidative stress, neurobehavioral disorders, and sleep disturbances (Khurana, & Kundi, 2021; Huss & Joseph, 2021; Samaila et al., 2023; Samaila et al., 2020). Both hazards frequently

co-occur in industrial settings, yet most studies assess them independently, overlooking their synergistic health impacts (Adeola, & Ibrahim, 2022).

In developing nations such as Nigeria, inadequate safety regulations, heavy dependence on generators, and poor enforcement of occupational health policies exacerbate these exposures (ILO, 2021). Research indicates that while awareness of noise hazards is relatively high (93%), the consistent utilization of protective devices among Nigerian industrial workers remains low (27%) (Adekoya, & Oyeniyi, 2018). Moreover, EMF intensities in some transmission facilities exceed the ICNIRP limits of 5 kV/m for electric fields and 0.1 mT for magnetic fields (ICNIRP, 2020). Such conditions contribute to widespread headache, stress, fatigue, and auditory dysfunction among workers (Ogungbe & Amosu, 2017; Oyeme & Ayo, 2017). These hazards persist despite efforts to mitigate them Deficient training programs, limited access to personal protective equipment (PPE), and absence of periodic exposure monitoring largely contribute to the persistence of these hazards (Allam, & Khider, 2024). Chronic exposure to both agents can amplify oxidative and neuroendocrine stress responses, thereby worsen health outcomes and reduce productivity (Basner et al., 2014; Huss et al., 2021). As emphasized by the World Health Organization (WHO) and the International Labour Organization (ILO), integrated occupational safety frameworks are essential for minimizing the dual burden of noise and EMF exposure (ILO, 2021; WHO, 2020).

This study therefore evaluates exposure patterns, health effects, safety practices, and mitigation strategies among industrial workers in Northwestern Nigeria. It seeks to provide empirical evidence to guide national policy development and align Nigeria's occupational safety standards with international benchmarks. By linking exposure sources, environmental intensity, worker behaviour, and institutional safety culture, the research advances understanding of how technical and behavioral interventions can sustainably reduce occupational hazards and improve worker well-being.

Materials and methods

Study Area Description

The study was conducted in Kebbi State, Northwestern Nigeria, located between latitudes 10°8′N and 13°15′N and longitudes 3°30′E and 6°02′E. To the east, it shares a border with Sokoto and Zamfara States; to the south, it shares a border with Niger State; and to the west, it shares a border with the Republic of Benin. Kebbi State has an estimated population of about 4.4 million people (National Bureau of Statistics [NBS], 2023). Agriculture and agro-industries, such as rice milling (Labana Rice, Rayhan Rice), welding and fabrication (Adam Welding), energy transmission (TCN, Kaduna Electric), and broadcasting (Rayhan Radio), make up most of the state's economy. These industrial activities expose workers to varying degrees of noise and electromagnetic fields (EMFs), making the area suitable for occupational exposure studies (Kebbi State Ministry of Commerce and Industry, 2024).

Study Design and Setting

A cross-sectional, questionnaire-based study was conducted in ten industrial facilities across Kebbi State between August and September 2025. These facilities were selected to represent the diversity of industrial activities in the state. A total of 99 participants were recruited, with 10-15 respondents from each facility. Data collection focused on exposure sources, workplace safety practices, and health effects.

Study Population and Sampling

The study population consisted of full-time industrial workers aged 18 years and above who had worked for at least six months. Stratified random sampling ensured equal representation across industries. Participants were randomly chosen from staff rosters where available or

systematically selected otherwise. Temporary or short-term workers were excluded from the study. In total, 100 participants were enrolled.

Instrument Development and Validation

Data were collected using a structured questionnaire adapted from WHO (2020) and ICNIRP (2020) guidelines. The instrument covered sociodemographic information, exposure duration, safety practices, and perceived health effects. Experts in occupational health and medical physics validated the instrument for clarity and relevance. A pilot test involving 10 workers confirmed the reliability (Cronbach's $\alpha \geq 0.70$) (Cronbach, 1951).

Data Collection and Analysis

Data collection was performed by trained research assistants under the supervision of the principal investigator. Participants received information on the study's objectives and provided written consent before participation. Questionnaires were administered in English and also based on participants' preference, and data were verified daily for completeness. All the participants responded in the English version. Data were entered into Microsoft Excel, and the frequency percentage response for each item in the questionnaire was analysed.

Ethical Considerations

Ethical approval was obtained from the Institutional Review Board of Federal University Birnin Kebbi. The research adhered to the principles of the Declaration of Helsinki (World Medical Association, 2013). Confidentiality was maintained, and participants were free to withdraw at any time without consequence.

Results and discussions

Primary Sources of Exposure to Noise and Electromagnetic Fields

Industrial environments are major sources of both **occupational noise** and **electromagnetic fields (EMFs)**, often resulting in concurrent exposure. High noise levels typically originate from **mechanical operations** such as rotating machinery (turbines, compressors, pumps, and motors), **metal fabrication** (grinding, welding, and hammering), and **construction and transport equipment** (excavators, trucks, and jackhammers). Figure 1 illustrates that machinery and generators represent the most prevalent sources of industrial exposure to both noise and EMFs. Industries such as TCN (12.1%), Ganou (11.1%), and Rayhan Rice (11.1%) show the highest exposure frequencies, indicating extensive dependence on heavy-duty equipment and continuous power generation for production. These findings are consistent with reports by Ademola and Oyebanjo (2023) and WHO (2020), which attribute high occupational exposure to poorly maintained machinery, uninsulated electric systems, and prolonged generator use, especially in regions with unstable electricity supply.

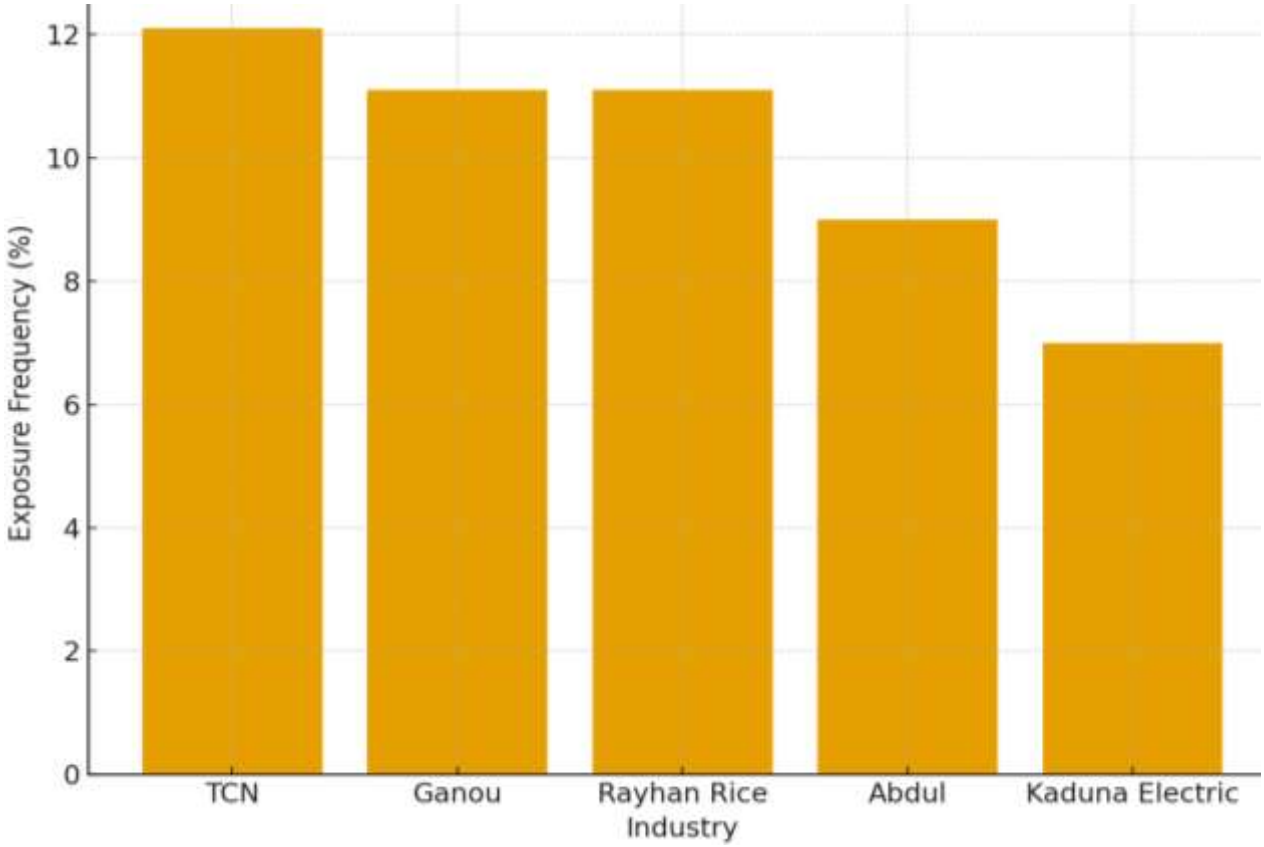

Figure 1: Primary Source of exposure to Noise and EMFs

The pattern observed highlights the occupational risk hierarchy, where energy, manufacturing, and agro-processing industries experience the most significant combined exposure to EMFs and noise. The dominance of mechanical and generator-related exposure reflects infrastructural limitations in developing industrial environments. Mitigation requires upgrading to low-noise, energy-efficient machines and implementing scheduled equipment maintenance programs (ILO, 2021).

Levels of Noise and Electromagnetic Field Exposure

Figure 2 reveals variable intensity levels across industries, ranging from moderate to very high. The Transmission Company of Nigeria (TCN) recorded the highest moderate exposure (15.2%), while Mubadala (5%), Ganou (4%), and Labana Rice (8%) experienced high to very high exposure levels. Such disparities reflect the operational nature of each industry—electric power and rice processing plants typically involve simultaneous noise and EMF emissions from both electrical transformers and large rotating machinery.

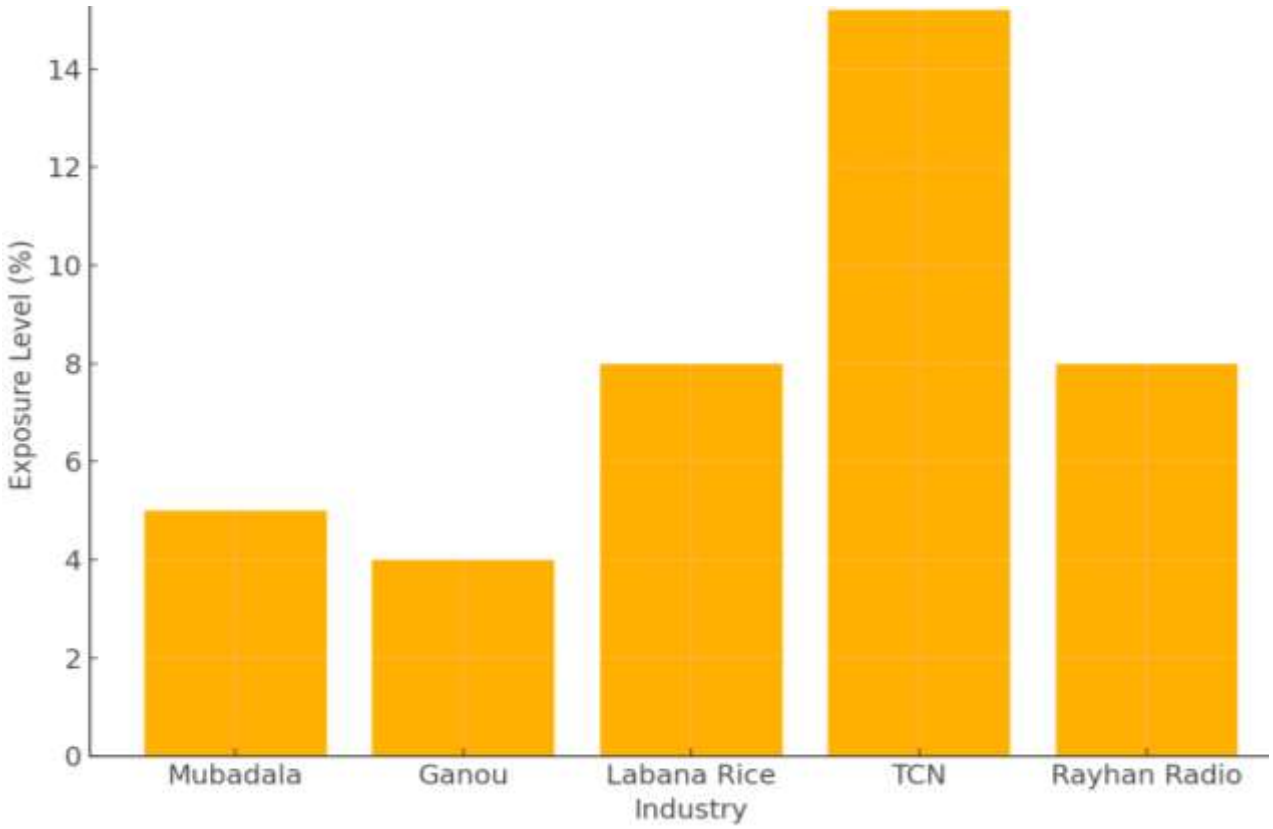

Figure 2: illustrates the levels of noise and EMF exposure.

This distribution corroborates findings by Lee et al. (2023), who demonstrated that combined exposure to sound pressure levels above 85 dB(A) and EMFs exceeding occupational thresholds can induce physiological stress and fatigue. The result points out the importance of environmental engineering controls, such as acoustic insulation, EMF shielding, and periodic exposure audits in industrial facilities.

Health Effects of Exposure

Prolonged exposure to such noise levels has been linked to **noise-induced hearing loss**, **tinnitus**, and **cardiovascular stress** (Basner et al., 2014; NIOSH, 2019). In parallel, industrial operations generate EMFs across a broad frequency range: **extremely low-frequency (ELF) fields** from power transmission and electric motors, **intermediate-frequency fields** from induction heating and welding systems, and **radiofrequency (RF) fields** from microwave dryers, communication antennas, and RF sealers (ICNIRP, 2020; Rianne et al., 2021). Chronic or high-level exposure to EMFs has raised concerns over **neurophysiological**, **thermal**, and **behavioral effects**, with guidelines emphasizing the need to control induced currents and prevent interference with medical devices (ICNIRP, 2020). Emerging studies further indicate that **co-exposure to noise and EMFs** may exacerbate physiological stress and cognitive strain, highlighting the necessity for integrated exposure assessment, engineering controls, and adherence to occupational exposure limits (Golmohammadi et al., 2020).

As shown in Figure 3, headache (60.6%), sleep disturbance (37.4%), and stress (35.4%) are the most common symptoms among workers exposed to noise and EMFs, while hearing loss (13.1%) and tinnitus (2%) were less frequent. These results indicate a dominance of non-auditory effects, aligning with the global trend where neurological and psychological symptoms precede measurable hearing impairment (Khurana et al., 2021; ICNIRP, 2020).

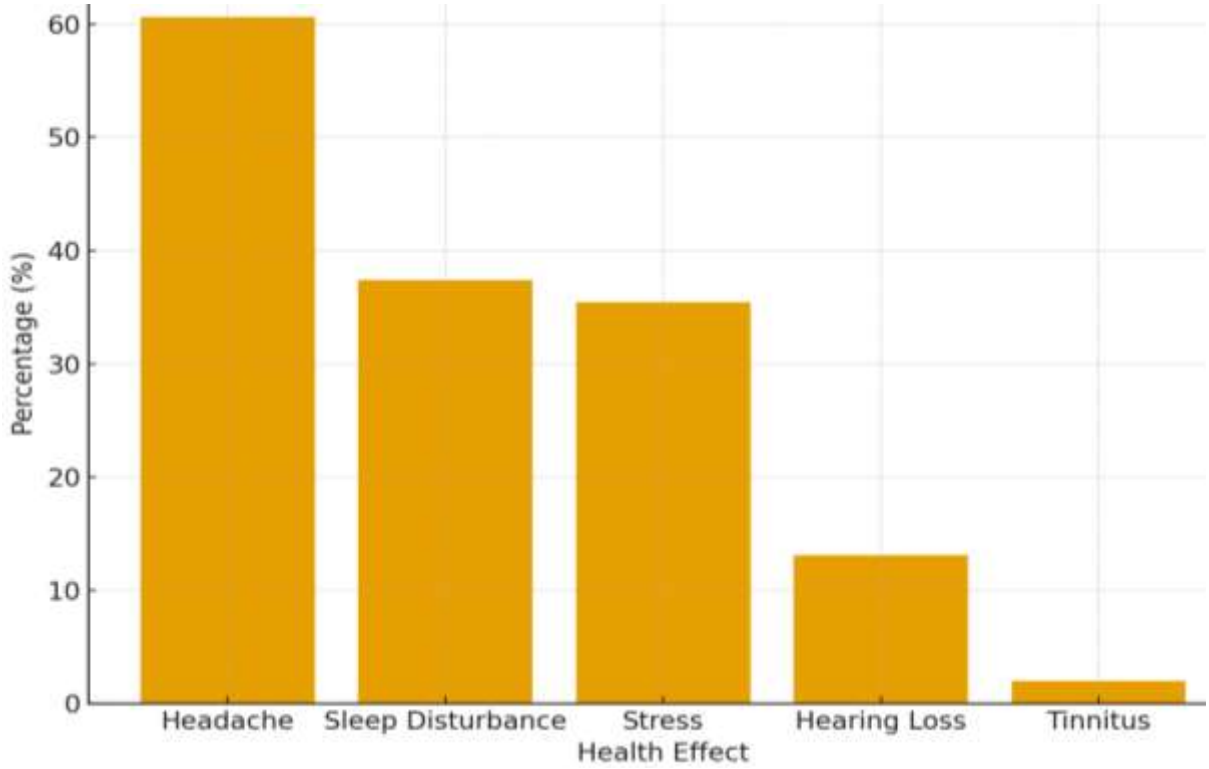

Figure 3: Health Effects of Exposure

Prolonged exposure to EMFs and high-intensity noise has been shown to disrupt neuronal transmission and increase oxidative stress levels, potentially leading to neurobehavioral alterations and sleep disorders (Sliwinska-Kowalska & Zaborowski, 2017). The observed prevalence of headache and fatigue among respondents supports the hypothesis that industrial EMF exposure contributes to central nervous system (CNS) dysregulation, particularly when combined with chronic acoustic overstimulation.

The total frequency of reported symptoms compares across industries, with TCN (26 cases), Rayhan Rice (22), and Labana (17) recording the highest prevalence. These results mirror their exposure intensity, indicating a direct link between operational noise/EMF levels and symptom manifestation. The concentration of effects in power and agro-industries suggests cumulative exposure, often exacerbated by long working hours and insufficient rest periods. The findings reinforce earlier conclusions by Adeola et al. (2022), who observed that unmonitored industrial noise and radiation exposure contribute to higher stress, reduced productivity, and impaired cognitive function among workers. This evidence underscores the need for integrated occupational health surveillance programs in these sectors to ensure early detection and management of exposure-related disorders.

Mitigation Strategies

Protection Measures and Training

Figure 4 illustrates the limited availability of protective measures and formal training across industries, with only TCN (15.1%) and Rayhan Radio (8%) demonstrating meaningful compliance. Most industries lack occupational safety policies or structured training programs addressing EMF and noise hazards. This deficiency highlights systemic neglect of workplace safety and the absence of national-level regulatory enforcement in many developing regions (Allam et al., 2024).

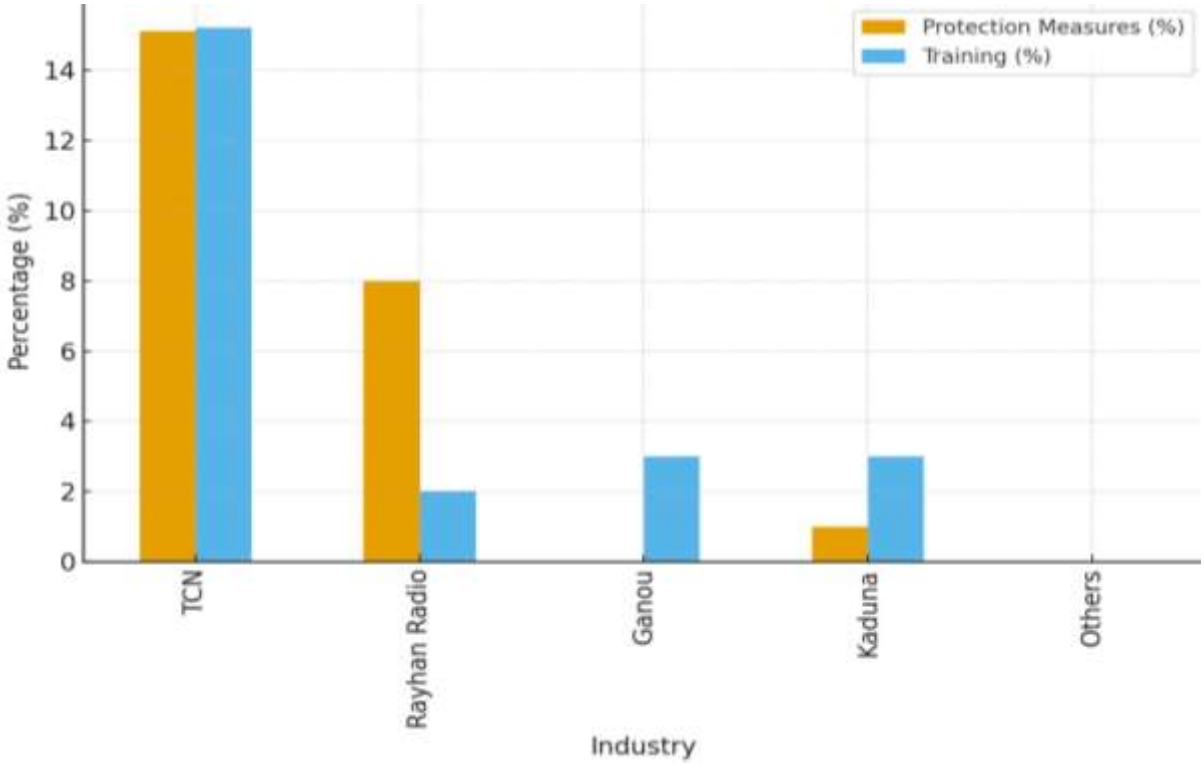

Figure 4: Protection Measures and Training

The strong link between industries that provide safety training and those with lower exposure levels shows that educational programs can help reduce workplace risks. Continuous professional education and institutional safety culture, as recommended by NIOSH (2022), can significantly reduce the incidence of exposure-related health issues and improve risk perception among industrial workers.

Protective Equipment Availability

Figure 6 shows a critical shortage of protective equipment, with 75.8% of respondents indicating no protective gear. Only 20.2% reported access to earplugs, while earmuffs (1%) and noise barriers (8%) were extremely rare. This deficiency reveals a gap between knowledge of occupational hazards and actual implementation of safety practices. The situation contravenes ILO (2021) recommendations mandating PPE provision in all high-risk industries.

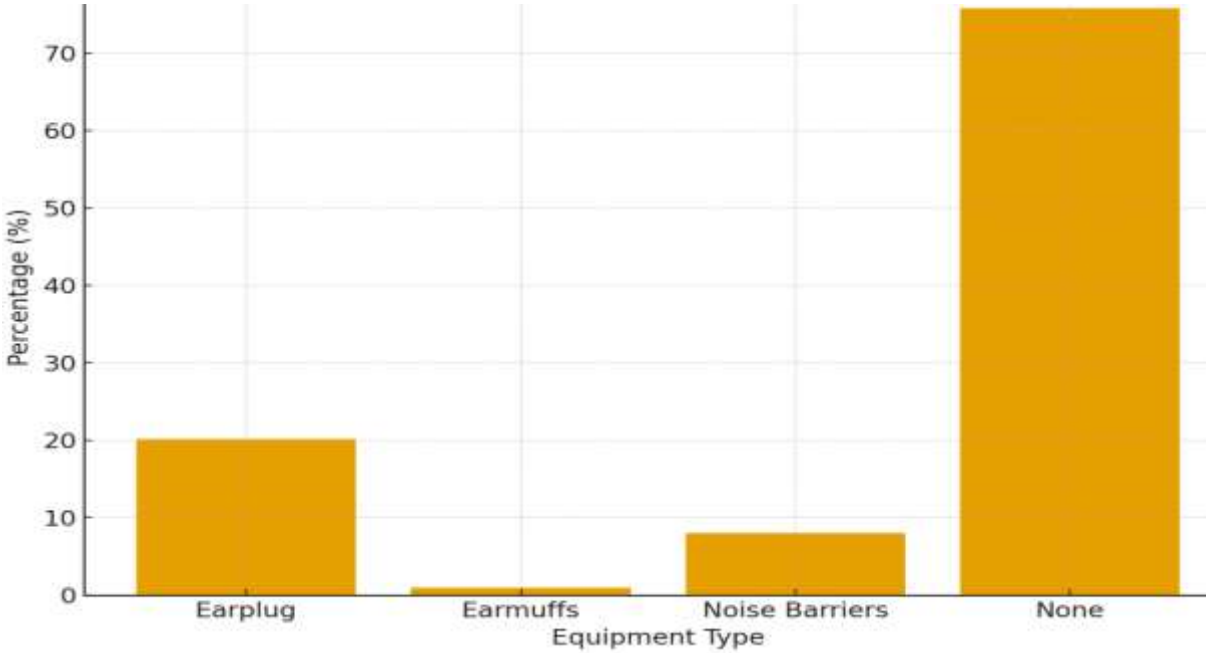

Figure 5: Protective Equipment

The absence of PPE correlates strongly with the high prevalence of auditory and non-auditory health effects reported. The introduction of inexpensive, durable hearing protection devices and EMF-insulated clothing could drastically reduce occupational burden. This highlights the importance of employer accountability in enforcing health and safety compliance measures.

Frequency of Noise Protection Usage

Figure 6 depicts the frequency of noise protection usage, showing that 74.7% of respondents never used any protective devices, while only 11.1% reported consistent usage. This pattern signifies behavioral negligence compounded by institutional non-availability of PPE. Occasional and inconsistent usage further limits the potential effectiveness of available protective measures.

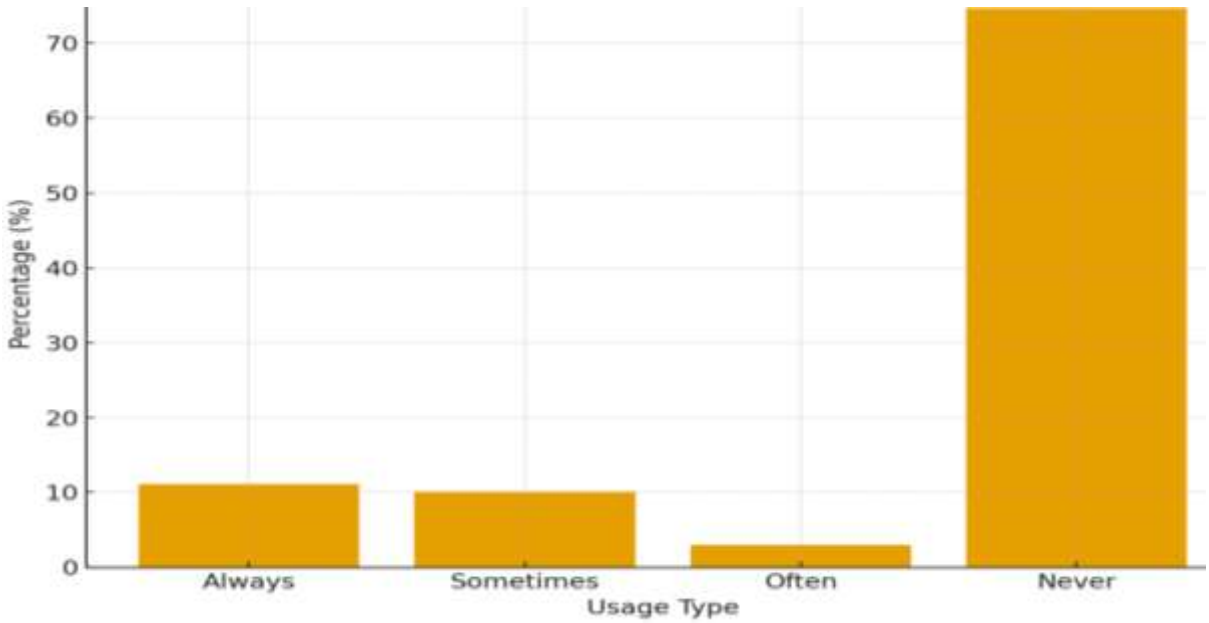

Figure 7: Frequency of Noise Protection Usage

As supported by NIOSH (2022) and Chauhan et al. (2020), consistent PPE use is influenced by comfort, accessibility, and management supervision. The lack of habitual use observed here indicates the need for behavioral change campaigns, managerial monitoring, and incentive-based safety programs to enhance compliance among industrial workers.

EMF and noise exposure assessments are conducted.

According to Figure 8, formal EMF and noise exposure assessments were rarely conducted—only Kaduna (1%) and Rayhan Radio (1%) reported compliance. This demonstrates a serious gap in environmental monitoring capacity. Without routine assessments, industries cannot quantify exposure or implement evidence-based interventions, leaving workers vulnerable to cumulative hazards (Adeola et al., 2022).

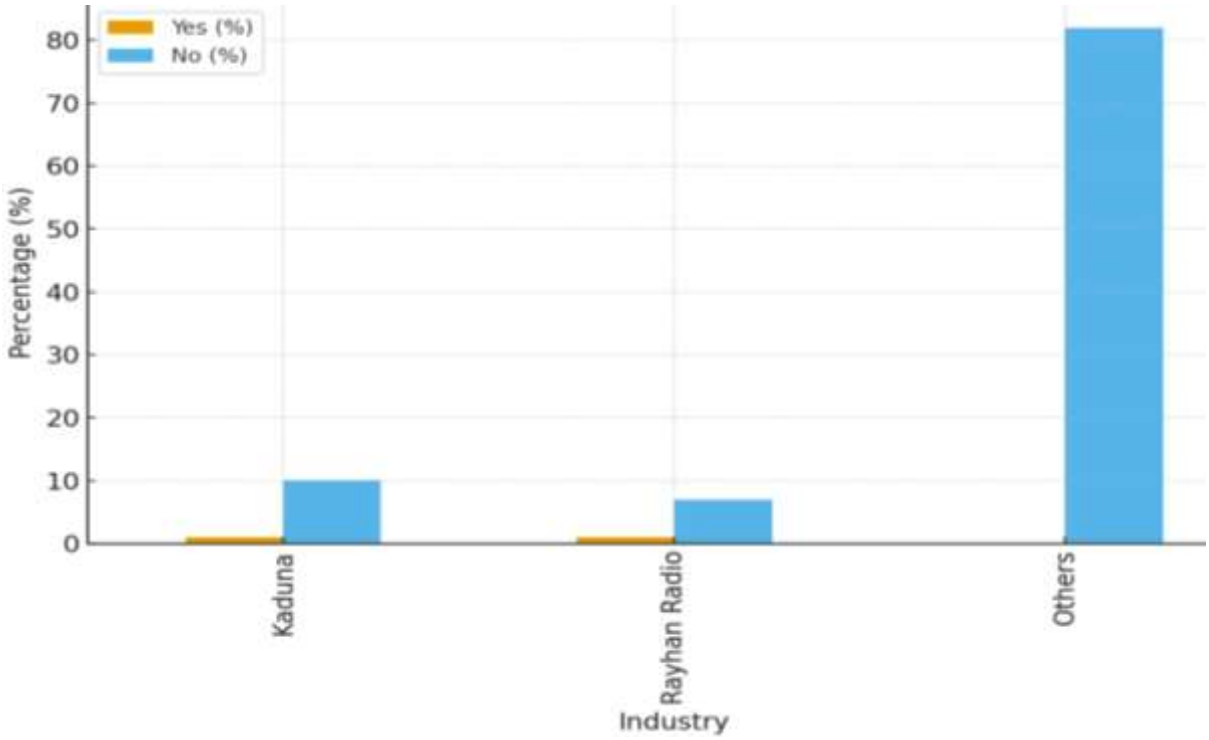

Figure 8: EMF and Noise Exposure Assessment Conducted

Institutionalizing mandatory exposure audits and adopting international monitoring protocols (such as ISO 1999:2013 and ICNIRP guidelines) can improve compliance. Establishing partnerships between regulatory bodies and academic institutions can enhance technical capacity for environmental and radiation assessments across industrial sectors.

Training on EMF and Noise Safety

Figure 9 shows that only 23% of industries provided safety training. TCN (15.2%) was the most common, followed by Ganou (3%), Kaduna (3%), and Rayhan Radio (2%). The majority had no awareness or skill-development initiatives related to EMF or noise safety. This lack of structured education limits workers' ability to recognize hazards and adopt preventive practices.

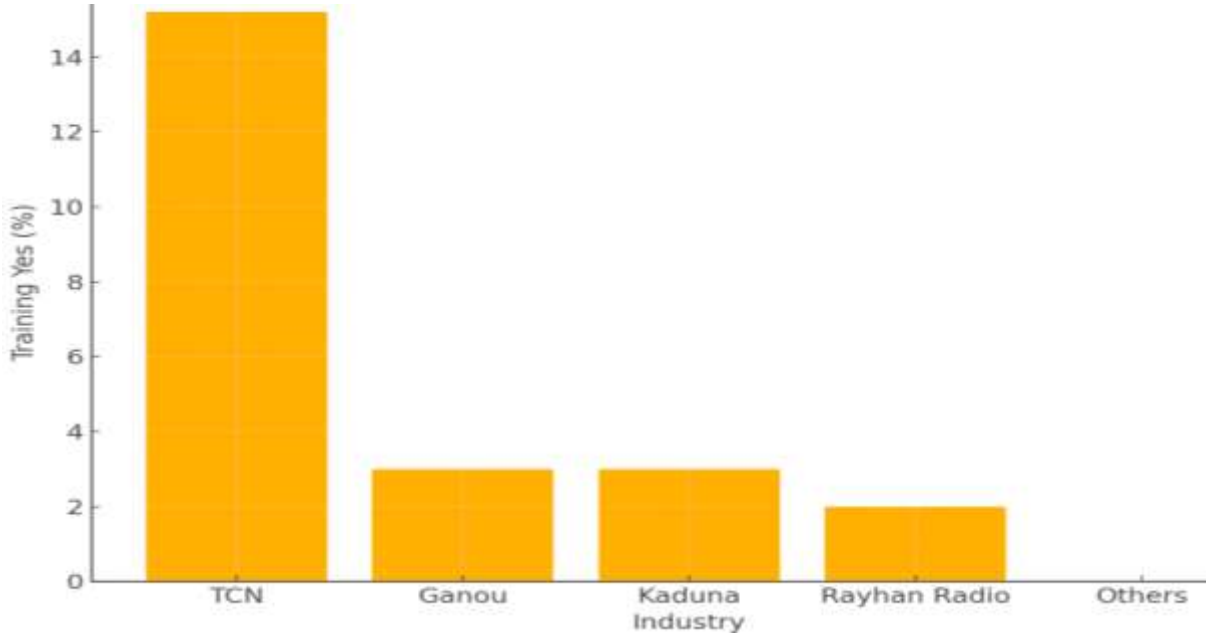

Figure 9: Training on EMF and Noise Safety

This trend mirrors findings by Allam et al. (2024), who identified inadequate professional training as a significant barrier to occupational safety compliance. Regular, standardized training programs enhance situational awareness, foster safe work behavior, and strengthen the institutional safety culture necessary for sustainable exposure control.

Measures to Reduce Exposure

Figure 10 summarizes proposed mitigation strategies, with workplace improvement (50.5%) and provision of protective equipment (47.5%) ranked highest, while regular monitoring and training were each cited by 9% of respondents. These preferences reflect an understanding of both engineering and administrative control measures, which align with best practices in occupational risk reduction (ISO 45001).

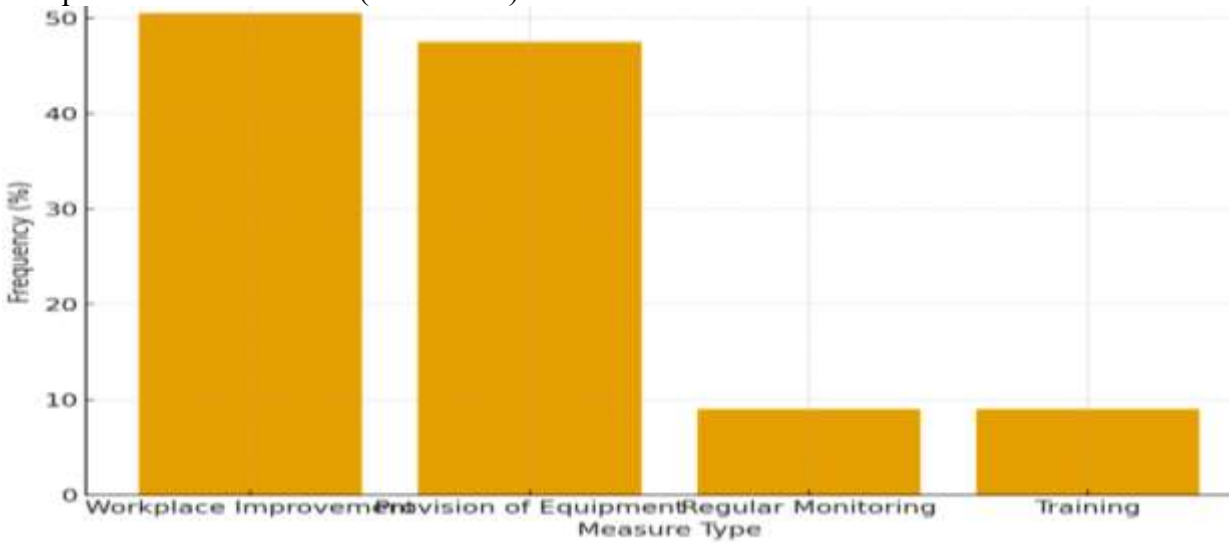

Figure 10: Measures to Reduce Exposure

However, the low percentage advocating for continuous monitoring and training suggests limited long-term safety planning. Implementing holistic risk management strategies combining engineering controls, PPE provision, and behavioral reinforcement is essential for achieving sustainable industrial safety outcomes (WHO, 2020). To keep up with compliance

and worker protection standards, there should be regular policy reviews and ongoing assessments.

Conclusion

This study reveals that industrial workers in Northwestern Nigeria face significant exposure to both noise and electromagnetic fields, predominantly from machinery and power-generating equipment. The prevalence of headaches, stress, and sleep disturbances highlights the physiological burden of chronic exposure. The findings further expose a critical gap in the availability of protective measures, professional training, and formal exposure assessment. A comprehensive strategy combining engineering control, PPE provision, regulatory enforcement, and continuous training is essential to mitigate these hazards. Institutionalizing a safety-first culture and integrating occupational health surveillance into industrial management will not only safeguard workers but also enhance productivity and sustainability. These results contribute valuable baseline data for developing regional occupational exposure guidelines and point to the urgent need for multidisciplinary collaboration among policymakers, health scientists, and industrial engineers.

Recommendations

1. **Implementation of National Exposure Standards:** Regulatory agencies should establish and enforce permissible limits for occupational noise and EMF exposure, following international standards such as **ICNIRP (2020)** and **NIOSH (2022)** guidelines.
2. **Engineering and Administrative Controls:** Industries should adopt noise-dampening materials, EMF shielding technologies, and improved ventilation systems. Administrative controls—such as rotation of workers and reduced exposure time—should complement engineering measures.
3. **Mandatory Periodic Exposure Assessments:** Every industrial facility should conduct quarterly noise and EMF assessments using calibrated dosimeters and field meters. Data should be documented and reported to a national occupational safety database.
4. **Provision and Enforcement of Personal Protective Equipment (PPE):** Employers must provide earplugs, earmuffs, and EMF-insulated clothing for all high-risk workers. Compliance audits should be mandated under occupational safety regulations.
5. **Continuous Professional Training and Awareness Programs:** Regular training sessions should be organized to educate workers on exposure risks, proper PPE use, and early symptom recognition. Awareness campaigns can reduce behavioral resistance to safety measures.
6. **Integration of Occupational Health Surveillance:** Workers should undergo periodic medical check-ups focusing on auditory, cardiovascular, and neurological assessments. Early detection of exposure-related disorders can minimize long-term disability.
7. **Institutionalization of Workplace Safety Culture:** Industries should establish internal safety committees, develop EMF/noise risk registers, and promote leadership-driven safety culture emphasizing worker welfare.

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