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# Combined Heat and Noise Exposure in Informal Welding Workshops: Temporal Dynamics and Occupational Risk in a Tropical Urban Environment

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## ABSTRACT

This study evaluated combined exposure to heat and noise in informal welding workshops located in Ekpan (n = 3) and Udu (n = 2), Delta State, Nigeria, within a tropical urban-industrial setting. Environmental monitoring was conducted over a 14-day period during peak operational hours (10:00–15:00) to capture worst-case occupational exposure conditions. Ambient temperature, relative humidity, and noise levels were measured using calibrated field instruments, and data were expressed as mean ± standard error of the mean (SEM). Results indicated persistently elevated environmental stressors across all sites. Ambient temperature ranged from 32.2 ± 0.4 °C to 36.5 ± 1.0 °C, with a mid-period peak observed around Day 6. Relative humidity exhibited an inverse trend, declining from 72.5 ± 2.1% to a minimum of 63.0 ± 2.8% before increasing to 74.8 ± 1.9% by the end of the monitoring period. Noise levels ranged from 86.0 ± 1.7 dB(A) to 96.2 ± 2.8 dB(A), consistently exceeding the recommended occupational exposure limit of 85 dB(A). Temporal analysis revealed a synchronised pattern of increasing temperature and noise, coupled with decreasing humidity, followed by gradual recovery. Spatial variability was evident, with one workshop consistently recording higher thermal and acoustic loads. The findings demonstrate that welders in the study area are exposed to sustained and combined environmental stressors capable of exceeding occupational safety thresholds. This multi-stressor exposure framework highlights the need for integrated control strategies, including improved ventilation, noise attenuation, and regulatory enforcement, to mitigate health risks in informal industrial environments.

**Keywords:** Heat Exposure; Noise Exposure; Welding Workshops; Occupational Health; Informal Sector; Environmental Monitoring; Thermal Stress; Acoustic Exposure; Niger Delta; Workplace Hazards; Multi-Stressor Exposure; Industrial Hygiene.

## 1. Introduction

Occupational exposure to environmental stressors remains a critical public health concern, particularly in informal industrial settings where regulatory oversight is limited and safety practices are often inadequate (Yurtsever, 2026). Among such environments, welding workshops represent a significant source of occupational hazards due to the simultaneous presence of multiple physical and chemical stressors (Hu et al., 2026). Welders are routinely exposed to elevated temperatures, intense noise, particulate matter, and gaseous emissions generated during welding and metal fabrication processes (Zaga et al., 2025). In tropical regions such as southern Nigeria, these exposures are further compounded by high ambient temperatures and humidity, thereby increasing the overall burden of occupational risk (Francisca & Nkwa, 2025).

Heat exposure in occupational settings has been widely associated with adverse physiological outcomes, including heat stress, dehydration, reduced cognitive performance, and impaired work capacity (Adeyemi & Adeyemo, 2025). The risk is particularly pronounced in environments where heat generated from industrial processes combines with high ambient temperatures, resulting in conditions that exceed thermal comfort thresholds (Adeyemi & Pronen, 2025). In welding workshops, heat is produced not only from environmental conditions but also from welding arcs, molten metals, and heated equipment, leading to localised thermal amplification. Prolonged exposure to such conditions can compromise thermoregulation and increase susceptibility to heat-related illnesses (Iglesia et al., 2025).

Similarly, occupational noise exposure is a well-established hazard in welding environments (Khorshidikia et al., 2025; Murugan & Sathiya, 2024; Zaga et al., 2025). The operation of equipment such as arc welders, angle grinders, cutting machines, and hammers generates high-intensity sound levels that frequently exceed recommended exposure limits. Chronic exposure to elevated noise levels has been linked to noise-induced hearing loss, cardiovascular stress, sleep disturbances, and reduced productivity. The informal nature of many welding workshops often results in limited use of protective equipment and minimal implementation of noise control measures, thereby exacerbating exposure risks (Barač et al., 2026).

While the individual effects of heat and noise have been extensively studied, there is growing recognition that workers are frequently exposed to these stressors concurrently. Combined exposure to heat and noise may produce synergistic effects, amplifying physiological strain and increasing the likelihood of adverse health outcomes. For instance, heat stress can influence cardiovascular function and fatigue levels, which may in turn affect susceptibility to noise-induced damage (Yousefinezhad et al., 2026). Despite this, studies examining the combined impact of these stressors, particularly in informal industrial settings in developing countries, remain limited (Jin et al., 2024).

The Niger Delta region of Nigeria, including the Warri metropolitan area encompassing Ekpan and Udu, is characterised by intense industrial activity and a proliferation of informal welding workshops (Adeyemi & Okpuzor, 2025; Adeyemi & Pronen, 2025) These environments typically operate with minimal environmental control, making them ideal settings for assessing real-world occupational exposure conditions. However, there is a paucity of empirical data quantifying the magnitude and temporal dynamics of combined heat and noise exposure in this region.

This study therefore aims to assess the levels of ambient temperature, relative humidity, and noise in selected welding workshops in Ekpan and Udu, Delta State, Nigeria, over a defined monitoring period. By examining both temporal and spatial variations in these parameters, the study seeks to provide a comprehensive understanding of occupational exposure patterns and their potential implications for worker health. The findings are expected to contribute to the development of evidence-based interventions and inform policy decisions aimed at improving occupational safety in informal industrial environments.

### 1.1. Study Objectives

The study objectives of this study are to:

1. Quantify ambient temperature levels in selected welding workshops in Ekpan and Udu during peak operational hours.

2. Determine relative humidity conditions within the welding workshop environments and evaluate their temporal variation.

3. Measure noise intensity levels [dB(A)] associated with welding and related activities across the study locations.

4. Assess the temporal dynamics of heat, humidity, and noise exposure over a 14-day monitoring period.

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5. Compare environmental exposure levels across different workshops to identify spatial variability and microenvironmental differences.

6. Evaluate the extent to which observed environmental conditions exceed established occupational safety thresholds for heat and noise exposure.

## 2. Materials and Methods

### 2.1. Study Area

The study was conducted in selected welding workshops located within Ekpan and Udu areas of Delta State, Nigeria, both situated within the Warri metropolitan industrial corridor in the Niger Delta region. The area is characterised by a tropical climate with persistently high ambient temperatures, elevated relative humidity, and seasonal rainfall patterns. Ekpan represents a densely industrialised urban setting with a high concentration of informal welding and metal fabrication activities, while Udu exhibits a relatively less congested but still active industrial landscape.

Five sampling locations were selected and georeferenced using a handheld GPS device. Three sites were located in Ekpan (5.574012° N, 5.705842° E; 5.570118° N, 5.700965° E; 5.572980° N, 5.707315° E), and two sites were located in Udu (5.507146° N, 5.811982° E; 5.502638° N, 5.808745° E). These locations were chosen to represent typical informal welding environments under varying microenvironmental conditions.

### 2.2. Study Design and Duration

A longitudinal field-based observational design was adopted to assess environmental exposure to heat and noise. Measurements were conducted over a continuous period of fourteen (14) days to capture temporal variations in environmental conditions. Data collection was restricted to peak operational hours (10:00–15:00), representing periods of maximum welding activity and potential exposure.

### 2.3. Sampling Strategy

A purposive sampling approach was employed to select five active welding workshops based on operational intensity, accessibility, and representativeness of typical informal welding environments. Each workshop was designated as a fixed monitoring station throughout the study period to ensure consistency in spatial measurements. Within each workshop, measurements were conducted at designated workstations where welding and associated activities were most frequently performed, representing zones of maximum exposure.

### 2.4. Measurement of Environmental Parameters

Ambient temperature and relative humidity were measured using a calibrated digital thermohygrometer capable of simultaneous recording of both parameters. The instrument was positioned at approximately 1.5 m above ground level, corresponding to the human breathing zone, and allowed to stabilise prior to recording. Measurements were taken under shaded conditions to minimise direct radiative interference while maintaining representativeness of ambient conditions.

Noise levels were measured using a calibrated digital sound level meter configured to the A-weighting scale [dB(A)] with slow response mode. The instrument was held at arm's length and oriented towards the dominant noise source to capture representative sound pressure levels within the workshop environment. Calibration of the sound level meter was performed prior to data collection using a standard acoustic calibrator.

### 2.5. Data Collection Procedure

Measurements were conducted daily at each workshop during the defined sampling window. For each parameter, readings were taken at one-minute intervals over a fifteen-minute period and subsequently averaged to obtain a representative daily value. To enhance reliability and minimise the influence of transient fluctuations, measurements were performed in triplicate at each site. The resulting values were expressed as mean ± standard error of the mean (SEM).

Observational data, including type of welding activity, equipment in use, and workshop conditions, were recorded concurrently to provide contextual support for the quantitative measurements. All data were documented in structured field sheets and later transferred to electronic spreadsheets for analysis.

### 2.6. Data Analysis

Data were analysed using Microsoft Excel and SPSS (version 26). Descriptive statistics, including mean and SEM, were computed for all parameters. Temporal trends were evaluated using line graphs with error bars to illustrate variability across the monitoring period.

One-way analysis of variance (ANOVA) was used to assess differences in environmental parameters among the five workshops, with statistical significance set at $p < 0.05$. Where significant differences were observed, Tukey's post hoc test was applied to determine pairwise differences between groups. Pearson correlation analysis was also performed to evaluate relationships between temperature, relative humidity, and noise levels.

### 2.7. Quality Control and Assurance

All instruments were calibrated prior to and during the study to ensure measurement accuracy. Measurements were conducted at consistent times and locations to minimise variability. Triplicate readings and averaging procedures were employed to enhance precision and reliability of the data.

### 2.8. Ethical Considerations

Permission was obtained from workshop operators prior to data collection. Measurements were conducted in a non-intrusive manner without disrupting normal activities. No personal or identifiable data were collected from workers, and all observations were limited to environmental conditions.

## ░3. Results

### 3.1. Temporal Variation in Ambient Temperature

Ambient temperature measured across the five welding workshops exhibited a clear and consistent temporal pattern over the 14-day monitoring period (Figure 1). Mean temperature values ranged from 32.2 ± 0.4 °C to 36.5 ± 1.0 °C across all sites. A progressive increase in temperature was observed from Day 1, culminating in peak values around Day 5–6, followed by a gradual decline towards Day 14.

Workshop 3 consistently recorded the highest temperature values throughout the study, reaching a maximum of 36.5 ± 1.0 °C, while Workshop 1 recorded the lowest values, with a minimum of 32.2 ± 0.4 °C at the end of the monitoring period. Workshops 2, 4, and 5 exhibited intermediate values, maintaining a stable ranking across the study duration.

The magnitude of inter-workshop variation remained relatively narrow, typically within a range of approximately 1.5–2.5 °C. The standard error values were generally low (±0.4 to ±1.0 °C), indicating minimal variability within measurement intervals and supporting the reliability of the observed trends.

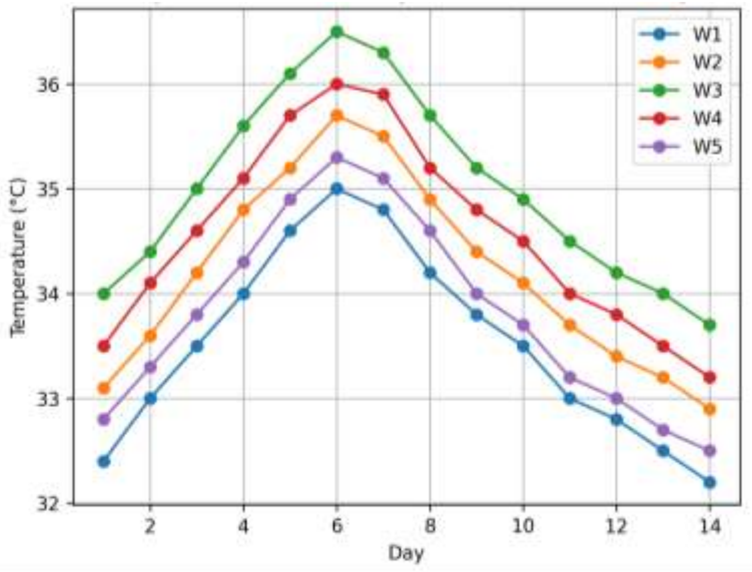


**Figure 1.** Temporal Variation of Ambient Temperature (°C) Across Welding Workshops in Ekpan and Udu Areas of Delta State During Peak Operational Hours (10:00–15:00) Over a 14-Day Monitoring Period.

**Set 1 (Ekpan)**

1. **Location 1:** 5.574012° N, 5.705842° E

2. **Location 2:** 5.570118° N, 5.700965° E

3. **Location 3:** 5.572980° N, 5.707315° E

**Set 2 (Udu)**

4. **Location 4:** 5.507146° N, 5.811982° E

5. **Location 5:** 5.502638° N, 5.808745° E

### 3.2. Temporal Variation in Relative Humidity

Relative humidity values demonstrated a complementary temporal pattern relative to temperature (Figure 2). Mean values ranged from 63.0 ± 2.8% to 74.8 ± 1.9% across all workshops. An initial decline in relative humidity was observed from Day 1 to approximately Day 6, corresponding to the period of peak temperature.

The lowest humidity values were recorded in Workshop 3, with a minimum of 63.0 ± 2.8%, while the highest values were observed in Workshop 5, reaching 74.8 ± 1.9% by Day 14. Following the mid-period minimum, relative humidity increased steadily across all sites, indicating a recovery phase towards the end of the monitoring period. Inter-workshop differences were consistent but moderate, generally within a 2–4% range. The SEM values (±1.9 to ±2.8%) indicate relatively low dispersion and stable measurement conditions across the sampling period.

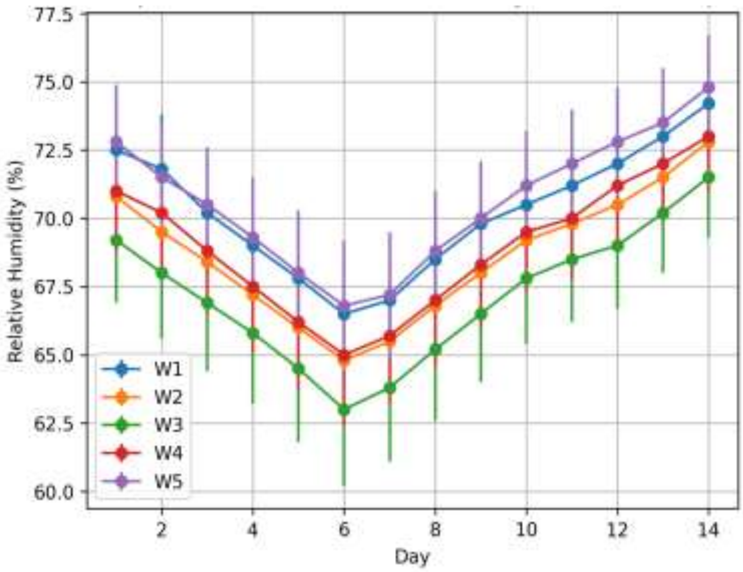


**Figure 2.** Temporal Variation of Relative Humidity (%) Across Welding Workshops in Ekpan and Udu Areas of Delta State During Peak Operational Hours (10:00–15:00) Over a 14-Day Monitoring Period.

**Set 1 (Ekpan)**

1. **Location 1:** 5.574012° N, 5.705842° E
2. **Location 2:** 5.570118° N, 5.700965° E
3. **Location 3:** 5.572980° N, 5.707315° E

**Set 2 (Udu)**

4. **Location 4:** 5.507146° N, 5.811982° E
5. **Location 5:** 5.502638° N, 5.808745° E

### 3.3. Temporal Variation in Noise Levels

Noise levels across the welding workshops showed a temporal trend similar to that of ambient temperature (Figure 3). Mean noise levels ranged from 86.0 ± 1.7 dB(A) to 96.2 ± 2.8 dB(A). A gradual increase in noise intensity was observed from Day 1 to a peak around Day 6, followed by a steady decline towards Day 14. Workshop 3 consistently exhibited the highest noise levels, with a maximum value of 96.2 ± 2.8 dB(A), while Workshop 1 recorded the lowest values, with a minimum of 86.0 ± 1.7 dB(A). Workshops 2, 4, and 5 maintained intermediate positions with minimal variation in ranking throughout the study period. The differences between workshops were relatively consistent, typically within a 3–5 dB(A) range. SEM values ranged from ±1.7 to ±2.8 dB(A), reflecting moderate variability within measurement intervals.

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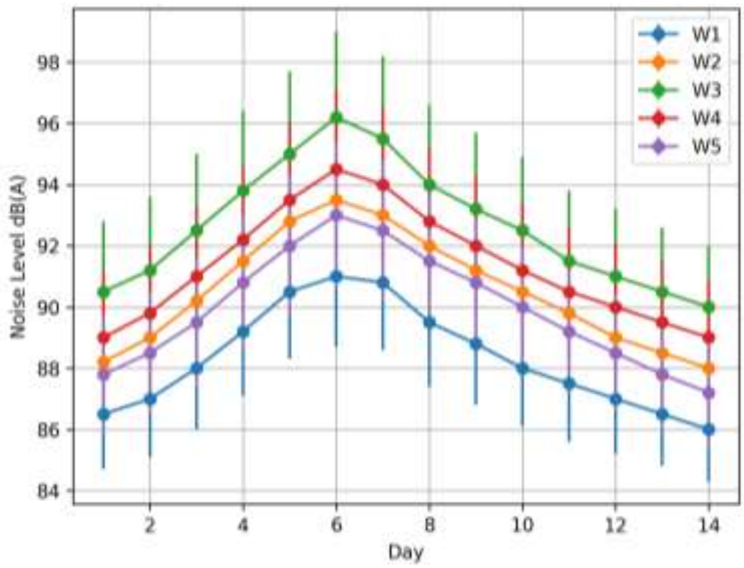


**Figure 3.** Temporal Variation of Noise Levels [dB(A)] Across Welding Workshops in Ekpan and Udu Areas of Delta State During Peak Operational Hours (10:00–15:00) Over a 14-Day Monitoring Period.

**Set 1 (Ekpan)**

1. **Location 1:** 5.574012° N, 5.705842° E
2. **Location 2:** 5.570118° N, 5.700965° E
3. **Location 3:** 5.572980° N, 5.707315° E

**Set 2 (Udu)**

4. **Location 4:** 5.507146° N, 5.811982° E
5. **Location 5:** 5.502638° N, 5.808745° E

### 3.4. Comparative Analysis of Environmental Parameters

Across all measured parameters, a consistent spatial pattern was observed, with Workshop 3 exhibiting the highest thermal and acoustic loads and the lowest relative humidity, while Workshop 1 showed comparatively lower exposure levels. The remaining workshops demonstrated intermediate conditions. All measured noise levels exceeded the recommended occupational exposure limit of 85 dB(A) throughout the study period. Similarly, temperature values consistently exceeded typical thermal comfort thresholds, particularly during the mid-period peak. The inverse relationship between temperature and relative humidity was evident across all sites, with peak temperature values coinciding with minimum humidity levels.

One-way analysis of variance (ANOVA) indicated significant differences in mean temperature, relative humidity, and noise levels among the five workshops ($p < 0.05$). Post hoc analysis using Tukey's test revealed that Workshop 3 differed significantly from Workshop 1 for all measured parameters ($p < 0.05$), while differences among Workshops 2, 4, and 5 were less pronounced. Pearson correlation analysis showed a strong positive relationship between temperature and noise levels ($r > 0.80$, $p < 0.05$), and a negative relationship between temperature and relative humidity ($r < -0.75$, $p < 0.05$), indicating interdependence among the environmental parameters.

## 4. Discussion

The temporal pattern observed in ambient temperature, characterised by a progressive increase culminating around the mid-point of the monitoring period (Days 5–6) followed by a gradual decline, is consistent with established evidence on thermal dynamics in outdoor and semi-enclosed occupational environments in tropical regions. Studies conducted in sub-Saharan Africa have demonstrated that peak ambient and occupational temperatures typically coincide with periods of intensified solar radiation and reduced cloud cover, particularly during late dry-season conditions, after which slight atmospheric moderation leads to gradual cooling (Kunda et al., 2024; Zout et al., 2025). The synchronised temperature rise across all workshops suggests a dominant influence of regional meteorological forcing, with local factors exerting secondary modulation during peak hours.

The consistently higher temperature recorded in Workshop 3 relative to other sites reflects persistent microenvironmental amplification of heat exposure, a phenomenon widely reported in welding and metal fabrication settings. Heat generation from welding arcs, metallic surfaces, and associated equipment contributes to elevated thermal loads through radiative and convective mechanisms, often producing temperatures above ambient outdoor levels (ElSharkawy, 2024; Triyono et al., 2024). This effect is particularly pronounced in poorly ventilated or densely arranged workshops where heat dissipation is limited, resulting in cumulative thermal buildup.

The observed inter-workshop temperature gradient of approximately 1.5–2.5 °C aligns with findings from occupational exposure studies that highlight spatial heterogeneity within similar industrial environments. Variations in structural characteristics such as roofing materials, workshop orientation, and proximity to adjacent heat sources have been shown to influence thermal conditions in informal welding clusters (Francisca & Nkwa, 2025; Nath et al., 2026). The persistence of this gradient throughout the monitoring period indicates that these factors exert a stable influence on ambient conditions.

Relative humidity exhibited an inverse temporal relationship with temperature, declining during periods of peak thermal intensity and increasing as temperatures moderated. This pattern is consistent with established atmospheric behaviour in tropical climates, where elevated temperatures increase the moisture-holding capacity of air, thereby reducing relative humidity, while subsequent cooling promotes moisture retention (Berk et al., 2025; Shih et al., 2025). The synchronised pattern across all workshops indicates a coordinated response to regional climatic conditions.

The lower relative humidity observed in Workshop 3 further supports the role of localised heat generation in modifying microclimatic conditions. High thermal loads accelerate evaporation and reduce ambient moisture content, particularly in environments with limited ventilation and high surface temperatures (Ahmad et al., 2024; Henze & Mattulat, 2024). Despite this, the relatively narrow inter-workshop variation in humidity (2–4%) suggests that regional atmospheric conditions exert a moderating influence, with local factors introducing only secondary variation.

Noise levels demonstrated a temporal pattern similar to that of temperature, with a progressive increase to a mid-period peak followed by a gradual decline. This trend reflects the dependence of occupational noise exposure on operational intensity and equipment usage patterns. Increased simultaneous operation of welding machines,

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grinders, and cutting tools during peak activity periods contributes to cumulative sound pressure levels (Chiș et al., 2025; CLAMPTON, 2024). The synchronised increase across all workshops suggests common temporal patterns in workload and activity levels. Peak noise levels approaching 96 dB(A) are consistent with values reported in welding environments across developing regions, where mechanical vibration, metal impact, and electrical discharge contribute to elevated acoustic emissions (Francisca & Nkwa, 2025; Khoza-Shangase, 2026). The consistent spatial hierarchy, with Workshop 3 exhibiting the highest noise levels, reflects differences in equipment density, maintenance status, and enclosure characteristics, which influence sound generation and propagation (LAWTON & ROBINSON, 2024; Sadavipour & Dehghan, 2025).

Although inter-workshop variation in noise levels was relatively modest (3–5 dB(A)), such differences are significant due to the logarithmic nature of the decibel scale, where small increases correspond to substantial increases in sound energy exposure (Liu et al., 2023; Rutkowski & Korzeb, 2023) . The gradual decline in noise levels after the peak period may reflect reduced operational intensity or variability in daily activity patterns, consistent with longitudinal observations in occupational noise studies (Szatmari, 2024; Toker et al., 2025).

The relatively low SEM values observed across all parameters indicate high temporal stability within measurement intervals, supporting the reliability of the dataset and consistency of environmental conditions during peak operational periods (Butler & Forder, 2024; Feng et al., 2025; Groth et al., 2022; Pétremand et al., 2022).

Collectively, the results demonstrate that environmental conditions within welding workshops are shaped by a complex interaction between regional climatic drivers and localised operational factors. The concurrence of elevated temperature and noise, coupled with reduced relative humidity during peak periods, highlights the multi-stressor nature of occupational exposure in these settings and underscores the importance of integrated environmental assessment in informal industrial environments.

## 5. Future Suggestions

1. Conduct longitudinal studies to evaluate the chronic health effects of prolonged combined exposure to heat and noise among welding workers.

2. Incorporate additional environmental stressors such as particulate matter, welding fumes, and gaseous pollutants to provide a more comprehensive exposure assessment.

3. Apply physiological and biochemical biomarkers (e.g., cortisol, oxidative stress markers) to quantify the biological impact of multi-stressor exposure.

4. Evaluate the effectiveness of intervention strategies such as improved ventilation systems and hearing protection devices in reducing exposure levels.

5. Expand the study to include a larger number of workshops across different regions to enhance generalisability and spatial representation.

6. Develop predictive models linking environmental exposure levels with health outcomes and productivity indices in informal industrial settings.

## Declarations

### Source of Funding

This study has not received any funds from any organization.

### Conflict of Interest

The authors declare that they have no conflict of interest.

### Consent for Publication

The authors declare that they consented to the publication of this study.

### Authors' Contribution

All the authors took part in literature review, analysis, and manuscript writing equally.

### Ethical Approval

Permission was obtained from workshop operators prior to data collection. Measurements were conducted in a non-intrusive manner without disrupting normal activities. No personal or identifiable data were collected from workers, and all observations were limited to environmental conditions.

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