ANALYSIS OF WORK ENVIRONMENT MEASUREMENTS AND SPATIAL MAPPING USING ARCGIS IN THE FURNITURE INDUSTRY

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ABSTRACT
Exposure to physical factors is one of the main problems in the implementation of industrial hygiene, especially in micro, small, and medium-sized furniture enterprises (MSMEs), which often have limited control over their working environments. This study aims to analyze occupational health risks associated with exposure to physical factors and to map the spatial distribution of these risks using a Health Risk Assessment (HRA) approach integrated with Geographic Information Systems (GIS). The study employed an analytical observational design with a mixed-methods approach, incorporating direct measurements of noise, vibration, thermal work climate, and lighting using calibrated industrial hygiene instruments, supported by field observations and interviews. The HRA results indicated that noise constituted the physical hazard with the highest risk level at several workstations, whereas vibration, thermal climate, and lighting were classified as low to moderate risk. Spatial mapping using ArcGIS showed that the highest concentration of risk was located in the wood-cutting area. This study contributes to the development of spatially based industrial hygiene evaluations as a foundation for more targeted and effective occupational safety and health (OSH) control strategies.
Keywords: Health Risk Assessment, Industrial Hygiene, Physical Factors, ArcGIS

1. INTRODUCTION

The work environment plays a crucial role in influencing worker performance, productivity, and health. It encompasses all facilities, physical conditions, and surrounding situations experienced by workers during daily work activities (Hanif et al., 2022). A well-managed work environment not only enhances efficiency and comfort but also serves as a preventive measure against occupational diseases. Consequently, work environment management constitutes an essential component of occupational safety and health (OSH) systems across industrial sectors.

Work environment management is closely related to industrial hygiene, a scientific discipline that focuses on the identification, evaluation, and control of workplace environmental factors that may cause adverse health effects among workers. According to Rizal (2015), industrial hygiene addresses hazards originating from physical, chemical, and biological factors. In this study, the focus is placed on physical hazards, including noise, vibration, heat, and lighting, as key elements of the physical work environment. These factors play an important role in determining both occupational comfort and safety.

Previous studies have shown that well-controlled physical work environments have a significant positive impact on worker health and performance. Compliance with industrial hygiene requirements can reduce subjective workload, minimize physical complaints, and increase productivity. In contrast, uncontrolled exposure to physical hazards may lead to fatigue, work-related stress, and long-term health disorders. This highlights the importance of applying industrial hygiene principles as part of OSH management systems (Sihaloho & Siregar, 2020).

The furniture industry is recognized as one of the sectors with a relatively high level of exposure to physical hazards, particularly among enterprises operating at the micro, small, and medium scale (MSMEs). This industry plays a strategic role in supporting local and national economic development by providing employment opportunities and increasing the value of wood-based products. In addition, the furniture sector contributes to the growth of the creative industry and national export activities. From a sustainable development perspective, the furniture industry also has considerable potential to promote green jobs, which emphasize not only productivity but also worker health and the long-term sustainability of the work environment (Lajaria & Utha, 2024).

Despite these contributions, occupational health risks remain a significant concern within the furniture industry, especially those related to exposure to physical hazards in the workplace. Production activities such as wood cutting, sanding, and assembly are associated with continuous noise from machinery, vibration from work equipment, heat accumulation in relatively enclosed workspaces, and uneven lighting conditions. One of the main challenges in the implementation of industrial hygiene in this sector is the continued reliance on conventional exposure assessment methods. Measurement results are typically presented in numerical values or tables, without illustrating how exposure is distributed spatially across the work area. This limitation reduces the ability to identify high-risk locations visually, resulting in hazard control measures that tend to be general and less effective.

Recent developments in geospatial technology, particularly Geographic Information Systems (GIS), provide an alternative approach for improving occupational risk management in industrial hygiene. GIS allows physical hazard measurement data to be integrated with spatial information, enabling exposure patterns to be visualized in map form. By using ArcGIS, the spatial distribution of noise, vibration, temperature, and lighting can be analyzed to identify high-risk zones or hotspots within the workplace. Therefore, the integration of industrial hygiene assessments with geospatial technology represents a relevant and necessary strategy for enhancing occupational health protection in the furniture industry (Baharuddin & Ali, 2025).

2. METHOD

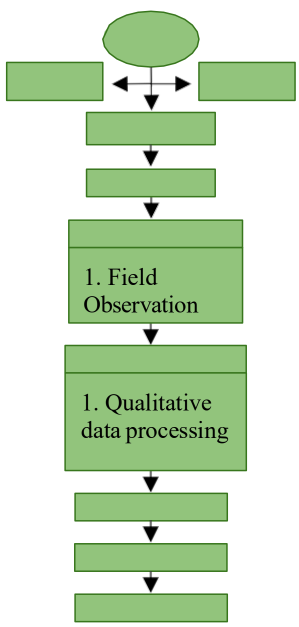

Fig 1. Research Flowchart

This study applied an analytical observational design using a field study approach that combines industrial hygiene principles with spatial analysis. This approach was used to identify, measure, and describe the distribution of physical hazard exposure in the work environment of a furniture industry, UD Jangkung Furniture, located in Ciracas District, East Jakarta. The research focused on physical hazards related to production activities, especially wood-cutting operations, which may result in exposure to noise, vibration, heat conditions in the workplace, and lighting

A mixed-methods research approach was applied, as described by Parjaman and Akhmad (2019). Mixed-methods research is a structured approach that integrates methods, techniques, perspectives, and conceptual frameworks from both quantitative and qualitative research within a single research process.

Qualitative data were descriptive and narrative in nature and were used to understand workplace conditions contextually and to describe work processes. These data were obtained through direct workplace observations and face-to-face interviews with workers and business owners or managers (Thabroni, 2022).

To improve the accuracy of exposure analysis, workers were grouped using the Similar Exposure Group (SEG) concept. A SEG refers to a group of workers who perform similar tasks, are exposed to similar hazard sources, have comparable exposure durations, and work under similar environmental conditions (Pratama & Tejamaya, 2025). Based on field observations and work process analysis at UD Jangkung Furniture in East Jakarta, one SEG was identified, consisting of workers in the wood-cutting section. The worker was directly exposed to physical hazards generated by the use of circular saw machines, including noise, vibration, thermal work climate, and lighting, with exposure occurring continuously during working hours.

In addition to the SEG group, two workers were classified into the Non-SEG group, consisting of one production worker outside the wood-cutting area and one administrative worker. These workers were not directly involved in wood-cutting activities and did not have direct interaction with the main sources of physical hazards. Therefore, the exposure experienced by the Non-SEG workers was indirect and primarily influenced by general workplace environmental conditions with lower exposure levels.The classification into SEG and Non-SEG groups was used as the basis for determining measurement locations, conducting the Health Risk Assessment (HRA), and performing spatial analysis using ArcGIS. This approach ensured that the resulting risk assessment accurately reflected actual exposure conditions according to the characteristics of each worker group.

Quantitative methods were used when the research data were numerical and analyzed using statistical techniques to objectively assess exposure levels to physical hazards (Sugiyono, 2018). Quantitative data were collected through direct measurements of physical factors using calibrated industrial hygiene instruments. All measurements were conducted in accordance with relevant Indonesian National Standards (SNI) to ensure that the results were valid and consistent. In addition, measurements were taken at selected locations within the work area to represent actual workplace conditions, with measurement points determined based on the layout of the work environment.

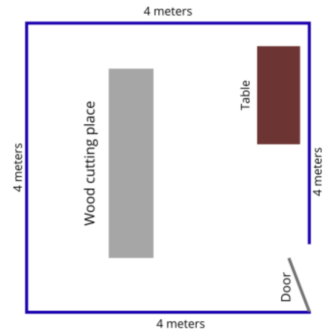

Fig 2. Workplace Layout Plan

Environmental noise measurements were conducted using a sound level meter in accordance with SNI 8427:2017 concerning the Measurement of Environmental Noise Levels using a Sound Level Meter for area noise and a noise dosimeter for personal noise exposure. Hand arm vibration measurements were performed on workers operating circular saw machines using a hand arm vibration meter, referring to SNI 7054:2019 on the Measurement of Hand Arm Vibration Exposure among Workers.

Thermal work climate (heat) measurements were carried out using a heat stress monitor to obtain the Wet Bulb Globe Temperature (WBGT) index, following SNI 16-7061-2004 regarding the Measurement of Thermal Work Climate Using the Wet Bulb Globe Temperature (WBGT) parameter. Lighting measurements were conducted using a lux meter in accordance with SNI 7062:2019 on the Measurement of Lighting Intensity in the Workplace.

All physical hazard measurement results were subsequently compared with the Occupational Exposure Limits (OELs) specified in the Regulation of the Minister of Manpower of the Republic of Indonesia No. 5 of 2018 on Occupational Safety and Health in the Work Environment, with additional reference to the 2025 edition of the ACGIH Threshold Limit Values (TLVs).

The physical hazard measurement data were then analyzed using the Health Risk Assessment (HRA) method to determine occupational health risk levels based on a combination of likelihood and severity values. The HRA results were classified into risk categories. Furthermore, the risk assessment outcomes were visualized using a Geographic Information System (GIS) through ArcGIS Pro software version 3.4 by mapping measurement points and generating risk zones based on HRA results. This spatial visualization enabled the identification of work areas with elevated occupational health risk levels.

3. RESULTS AND DISCUSSION

3.1 Identification of Physical Hazards and Exposure Characteristics

The identification of physical hazards at UD Jangkung Furniture was carried out through direct observation of work processes, workplace area layout, and machine usage during work activities. This identification stage focused on the relationship between hazard sources, the types of physical factors generated, and the groups of workers involved, both directly and indirectly, in each work activity.

Wood cutting operations using circular saw machines were identified as the primary source of physical hazards, as these machines operate continuously for approximately eight working hours per day. This activity generates physical factor exposures that have the potential to adversely affect worker health. Differences in worker involvement in wood-cutting activities resulted in variations in exposure characteristics, particularly in terms of exposure intensity, distance from the hazard source, and duration of exposure.

Workers assigned to the wood-cutting section experienced direct and continuous exposure, while workers in other sections were subject to indirect exposure with lower intensity levels. These differences in exposure characteristics formed the basis for classifying workers into Similar Exposure Groups (SEG) and Non-SEG groups to support exposure analysis and occupational health risk assessment.

3.2 Similar Exposure Group (SEG) and Non-Similar Exposure Group (Non-SEG)

To strengthen the analysis of physical hazard exposure risks, the results of the spatial mapping were further examined using the Similar Exposure Group (SEG) concept to distinguish workers with similar exposure characteristics from those classified as Non-SEG (Haryandi, 2020). This approach was applied to ensure that risk analysis was conducted based on similarities in hazard sources, work activity patterns, and exposure duration experienced by workers.

Based on systematic observations conducted at UD Jangkung Furniture, the assessment followed standard industrial hygiene procedures, including the identification of potential physical hazards and the grouping of workers according to exposure homogeneity. The initial stage involved analyzing work areas with similar processes and environmental conditions, allowing the identification of SEG that represent groups of workers with relatively similar exposure to physical hazards.

The physical hazards identified in the workplace included noise, heat stress, lighting, and vibration generated from work activities involving circular saw machines. These physical factors occurred simultaneously among workers directly involved in machine operation. This condition indicates that workers who were present and actively engaged in the same work process were exposed to comparable baseline levels of environmental risk and could therefore be classified within a single homogeneous exposure group.

At the measurement locations, work activities were primarily centered on wood-cutting operations as the main stage of the production process. These activities generated physical hazard exposure directly from machinery and work equipment, including noise, hand arm vibration, lighting conditions, and thermal work climate related to temperature and humidity. Based on the similarity of hazard sources, work patterns, and exposure duration, workers directly involved in wood cutting activities were classified as the Similar Exposure Group (SEG), as they experienced comparable exposure characteristics continuously during working hours.

Compared to Non-SEG workers, individuals within the SEG were exposed to higher levels of physical hazard risk, particularly noise and vibration. Prolonged exposure to hand arm vibration may lead to health disorders such as Hand Arm Vibration Syndrome (HAVS), which includes symptoms such as numbness, tingling sensations, and vibration-induced white finger. HAVS is a serious condition that may result in permanent damage, negatively affecting worker performance and comfort (Nabila et al., 2020). Continuous exposure to high noise levels may cause noise-induced hearing loss and is also associated with increased work-related stress and reduced sleep quality (Safiu et al., 2023). Other physical factors, such as lighting levels below or above recommended limits, may cause eye fatigue and reduce work concentration, while high thermal conditions may increase the risk of heat stress.

In addition to the SEG, several workers were classified as Non-SEG, including cleaning staff and administrative personnel. Although these workers operated within the same general workplace area, they were not directly involved in wood cutting activities and did not interact directly with production machinery. Their exposure was mainly limited to general environmental conditions without direct contact with primary hazard sources. Therefore, distinguishing between SEG and Non-SEG groups is methodologically important to maintain the validity of the analysis and to ensure that the assessment reflects actual exposure conditions based on the specific work activities of each group.

3.3 Health Risk Assessment (HRA)

Health Risk Assessment (HRA) was conducted to evaluate the level of occupational health risk faced by workers due to exposure to physical factors in the furniture industry. The risk level was determined by multiplying the probability of occurrence (*likelihood*) and the severity of potential health impacts (*severity*). This assessment integrates the results of physical factor measurements, exposure duration, and the characteristics of work activities to determine the level of occupational health risk (Nugrahaeni, 2020).

Likelihood describes how likely health problems may occur as a result of exposure to physical hazards. This likelihood is influenced by the frequency and duration of exposure, the use of personal protective equipment, and the condition of the work environment and equipment. Workers who are exposed more frequently and for longer periods, especially when exposure levels approach or exceed the Occupational Exposure Limit (OEL), are considered to have a higher likelihood of health impacts.

Rating	Frequency	Description
E	Almost Definitely/Very Often	Incidents occur almost every month in work activities, mainly due to continuous working conditions without adequate control.
D	Might Happen	The incident occurs about once a year during work activities.
C	Can Occur	The incident occurred in the work process, although it did not occur routinely.
B	Rarely Happening	Incidents have been reported in industry, but are rare.
A	Very Rare/Almost Never	Never reported to occur during work activities.

Table 1. Likelihood Criteria

Severity refers to the level of health impact caused by exposure to physical hazards, ranging from minor health complaints to serious illnesses and possible economic losses. The severity level increases as health effects become more serious and as their impact on work performance and productivity becomes greater.

No	Severity of Health Impacts	Information
1.	Negligible	Minimal to unknown hazard. Biological hazard severity (Hazard Group 1)
2.	Minor	Dangerous, irritant
3.	Moderate	Corrosive, flammable. Biological hazard level (Hazard Group 2)
4.	Major	Toxic, causes sensitivity
5.	Severe	Highly toxic, mutagenic, reprotoxic, respiratory irritant

Table 2. Severity Criteria

A risk matrix was applied to classify occupational health risk levels into low, medium, and high categories based on the combination of likelihood and severity scores. This classification serves as the basis for determining priorities in occupational safety and health (OSH) control measures and risk monitoring in the workplace.

Exposure Rating		Severity				
		Negligible	Minor	Moderate	Major	Severe
Qualitative	**Rating**	**1**	**2**	**3**	**4**	**5**
Almost Definitely/Very Often	E	low	Currently	High	High	High
Might Happen	D	low	Currently	Currently	High	High
Can Occur	C	low	low	Currently	Currently	High
Rarely Happening	B	Very low	low	low	Currently	Currently
Very Rare/Almost Never	A	Very low	Very low	low	low	low

Table 3. Occupational Health Risk Matrix Criteria

Quantitative risk assessment was conducted by comparing measured exposure levels in the workplace with the applicable Occupational Exposure Limits (OELs). The measurement results were expressed as a percentage of the OEL to indicate the level of exposure experienced by workers. Higher exposure values, particularly those approaching or exceeding the OEL, indicate a greater potential for adverse health effects.

			Severity				
			Negligible	Minor	Moderate	Major	Sevre
Qualitative	Quantitative to OEL	Rating	1	2	3	4	5
Almost Certain	>100%	E					
Likely	>50 to 100%	D					
Possible	10 to 50%	C					
Unlikely	1 to 10%	B					
Rare	<1%	A					

High	**Medium**	**Low**	**Very Low**

Table 4. Quantitative OEL

Qualitative occupational health risk assessment was conducted by translating quantitative OEL based results into descriptive categories of exposure probability. These qualitative categories range from “rarely occurs” to “always occurs,” representing the likelihood of workers being exposed to hazards during daily work activities. This qualitative approach was intended to facilitate risk interpretation, particularly for decision makers and workplace stakeholders. By combining quantitative and qualitative OEL based assessments, the risk evaluation becomes more comprehensive and can be used as a basis for determining control priorities and strategies for preventing occupational health risks.

Based on the assessment results, noise exposure was identified as the only physical hazard that exceeded the OEL and was classified as a high risk factor. In contrast, lighting, vibration, and thermal conditions were classified as medium-risk factors. These findings indicate that wood cutting worker, classified as a Similar

Exposure Group (SEG), face higher occupational health risks compared to Non-SEG workers. Therefore, control measures should prioritize noise exposure, followed by improvements in other workplace environmental conditions.

Rating	Qualitative	Quantitative to OEL	Control Management of Health Risk
E	Almost Certaini	95% UCL > 100%	Apply Hierarchy of Control ASAP and implement All medium risk requirement
D	Likely	95% UCL > 50 to 100%	Required exposure monitoring, workplace inspection medical surveillance biological monitoring
C	Possible	95% UCL to >10 to <50%	Specific chemical hazard training, periodic exposure monitoring
B	Unlikey	95% UCL to >1 to 10%	Procedure and training and general hazard communication
A	Rare	95% UCL < 1%	No Action

Table 5. Qualitative OEL

1. Identication Hazard									2. Risk Assessment				3. Risk Control
No	Activity Process	Potential Hazards	Risk	Measurement Result	TLV	OEL	Workers effect	Current control	Quantitavie to OEL	Frequency (F)	Control (C)	Risk level	Control
UD JANGKUNG KUSEN DAN PINTU													
1	Cutting Wood With a Circle Saw Machine	Physical Hazards: Getaran	Vibration syndrome of the hand arm or White finger disease	1.3095 m/s²	5 m/s²	26,19%	Wood Cutter Operator	No	95% UCL>10 to <50%	C	3	Medium	Administration: Work procedures, Worker rotation, PPE use training PPE : Anti-vibration gloves
2		Physical Hazards: Pencahayaan	Eye strain due to eyes being too tired	174,39 lux	200 lux	87%		No	95% UCL > 50 to 100%	D	3	Medium	Engineering Control : Adding additional lighting Administration : Work shift, Work Procedures
4		Physical Hazards: Kebisingan	Hearing loss, Work stress	86,32 dB	85 dB (8 Working hours)	101,55%		No	95% UCL > 100%	E	4	High	Administration: Work duration reset, Education regarding the dangers of noise, PPE use training APD : Ear Muff
5		Physical Hazards: Iklim Kerja	Heat Stress	28,75°C	31°C (Light workload)	92,9%		No	95% UCL > 50 to 100%	D	3	Medium	Administration: Work duration reset

Table 6. Health Risk Assessment (HRA) Results

3.4 Analysis of Noise Measurement Results

WORKING AREA	MEASURE		REMARK	DURASI	FREQUENCY	INTRINSIC GRAFITY
	STANDARD	ACTUAL				
Mebel	85	89,56	Normal	8 Hours	3 (three) times	High
	85	78,053				Low
	85	82,96				Low

Table 7. Environmental Noise Measurement Results

Based on the results of environmental noise measurements conducted in the furniture industry work area, the recorded noise levels were 89.56 dBA, 78.05 dBA, and 82.96 dBA. These values were compared with the reference standard or Occupational Exposure Limit (OEL) of 85 dBA for an 8-hour workday, as stipulated in the Regulation of the Minister of Manpower of the Republic of Indonesia No. 5 of 2018. The results indicate that most of the measured noise levels were below the OEL, suggesting that overall environmental noise conditions can be considered acceptable. However, one measurement result reached 89.56 dBA, which exceeded the OEL and may pose a potential health risk if workers are exposed continuously over a prolonged period.

WORKING AREA	MEASURE		REMARK	DURASI	FREQUENCY	INTRINSIC GRAFITY
	STANDARD	ACTUAL				
Mebel	85	95,42	Normal	8 Hours	3 (three) times	High
	85	81,46				Low
	85	82,63				Low

Table 8. Personal Noise Measurement Results

Personal noise measurements conducted on workers in the same area showed noise exposure levels of 95.42 dBA, 81.46 dBA, and 82.63 dBA. These findings indicate that one worker experienced noise exposure of 95.42 dBA, which exceeded the OEL and therefore presents a higher potential risk to health.

Noise exposure above the occupational exposure limit can lead to adverse health effects, particularly Noise-Induced Hearing Loss (NIHL), which results from permanent damage to the hair cells in the inner ear (Tana, 2002). In addition to auditory effects, excessive noise exposure may also cause non-auditory impacts such as work-related stress. These effects can manifest as increased blood pressure, pupil dilation, and elevated gastric acid production, potentially reducing concentration and increasing the risk of workplace accidents (Fahmi, 1997). Therefore, noise control measures should be implemented using a hierarchical approach, beginning with controls at the source and along the transmission path, and complemented by the use of personal protective equipment (PPE), such as earplugs and earmuffs, as a final protective measure to reduce noise exposure levels received by workers (Soeripto, 2008).

A measured noise exposure level of 86.32 dB exceeded the OEL of 85 dB, corresponding to an exposure percentage of 101.55%. This condition increases the likelihood of hearing impairment and work-related stress. Based on the Health Risk Assessment (HRA) matrix, this exposure level is classified as a high-risk category and represents the most critical factor requiring priority control measures.

3.5 Analysis of Vibration Measurement Results

WORKING AREA	MEASURE		REMARK	DURASI	FREQUENCY	INTRINSIC GRAFITY
	STANDARD	ACTUAL				
Mebel	5	1,24	Normal	8 Hour	3 (three) times	Low
	5	1,63				Low
	5	1,213				Low

Table 9. Vibration Measurement Results

Based on the vibration measurements conducted in the furniture industry area of UD Jangkung Material Kayu Kusen Pintu, the recorded hand arm vibration values were 1.24 m/s², 1.63 m/s², and 1.213 m/s². These measurements were compared with the reference standard or Occupational Exposure Limit (OEL) of 5 m/s² for hand arm vibration exposure. Measurements were carried out during wood-cutting activities using a circular saw, with a working duration of 8 hours per day.

The results indicate that all measured vibration levels were below the OEL, suggesting that overall vibration exposure in this work environment can be classified as acceptable. The relatively low vibration values indicate that the intensity of vibration transmitted to workers' hands and arms remains within the established tolerance limits, and therefore the risk of vibration-related health effects is considered low (Soeripto, 2008). However, vibration exposure still requires attention due to its cumulative nature. Repeated hand arm vibration exposure over long periods may lead to health disorders such as Hand Arm Vibration Syndrome (HAVS), which is characterized by symptoms including tingling, numbness, reduced grip strength, and impaired blood circulation in the fingers and hands (Nabila et al., 2020).

The average hand–arm vibration exposure of 1.3095 m/s² remains below the OEL of 5 m/s², corresponding to 26.19% of the allowable limit. Although this exposure level is within the safe range, repeated exposure may still result in cumulative effects. Therefore, the vibration risk level was classified as medium risk.

The relatively safe vibration exposure conditions are likely influenced by non-continuous tool usage, stable machine characteristics, and work methods that do not impose excessive mechanical pressure on equipment. In addition, proper machine maintenance plays an important role in reducing the level of vibration transmitted to workers. Although the measured values were below the OEL, preventive measures are still necessary to minimize long-term risks. Control efforts may include work-hour management and task rotation, routine machine maintenance, and the use of personal protective equipment such as anti-vibration gloves as an additional control measure, in accordance with industrial hygiene principles (Soeripto, 2008)

3.6 Analysis of Thermal Work Climate Measurement Results

WORKING AREA	MEASURE		REMARK	DURASI	FREKUENSI	INTRINSIC GRAFITY
	STANDARD	ACTUAL				
Mebel	31	28,75	Secure	8 Hours	3 (three) times	Low

Table 10. Thermal Work Climate Measurement Results

Based on the results of thermal work climate measurements conducted in the furniture industry area, the recorded Wet Bulb Globe Temperature (WBGT) values were 29.72°C, 28.73°C, and 27.97°C. These values were compared with the reference standard of 31°C for an 8-hour workday. Overall, the thermal work climate conditions can be categorized as normal. The WBGT values indicate that most measurements were below or close to the Occupational Exposure Limit (OEL) established for light workloads, suggesting that the risk of heat stress is relatively low compared to high-temperature work environments.

These findings are consistent with the study by Sunaryo and Rhomadhoni (2020), which reported that work climate conditions with WBGT values exceeding the OEL may impose additional physiological workload and lead to health problems such as dehydration and heat rash. In contrast, WBGT values within acceptable limits tend to have no significant impact on worker physiological conditions.

In addition, the average WBGT measurement of 28.75°C remained below the OEL of 31°C for light workloads, corresponding to 92.9% of the allowable limit. Although this value is close to the threshold, it may increase the potential for heat stress if environmental conditions change. Therefore, the thermal work climate was classified as a medium-risk category. With an 8 hour work duration and non-continuous exposure intensity, the thermal conditions in this furniture industry are still considered tolerable for workers, particularly given the relatively light workload, and are unlikely to cause excessive heat stress.

3.7 Analysis of Lighting Measurement Results

WORKING AREA	MEASURE		REMARK	DURASI	FREKUENSI	INTRINSIC GRAFITY
	STANDARD	ACTUAL				
Mebel	200	174,39	Not safe	8 Hours	1 (one) times	Medium

Table 11. Lighting Measurement Results

According to the Regulation of the Indonesian Ministry of Manpower No. 5 of 2018, the minimum required lighting level for rough work is 200 lux. Measurements conducted in the furniture industry work area indicated an illumination level of 174.39 lux, which does not comply with the established standard and is therefore considered unsafe. Exposure to inadequate lighting over an 8-hour working period may cause visual fatigue, decreased work precision, and an increased likelihood of operational errors, particularly in tasks requiring high accuracy, such as wood-cutting activities.

Previous studies have reported that insufficient lighting can lead to eye strain, blurred vision, and general fatigue, potentially affecting workers' health and overall well-being (Králiková, 2021). The measured lighting intensity of 174.39 lux was below the Occupational Exposure Limit (OEL) of 200 lux, representing approximately 87% of the recommended standard. Although the effects of inadequate lighting are not immediate, prolonged exposure may result in cumulative visual discomfort and reduced work performance. Consequently, this condition was classified as a medium-risk category.

Overall, lighting levels that do not meet the minimum standard indicate the presence of potential physical hazards in the workplace and underscore the importance of implementing appropriate control measures to enhance visual comfort and occupational safety.

3.8 Spatial Mapping of Physical Hazard Exposure

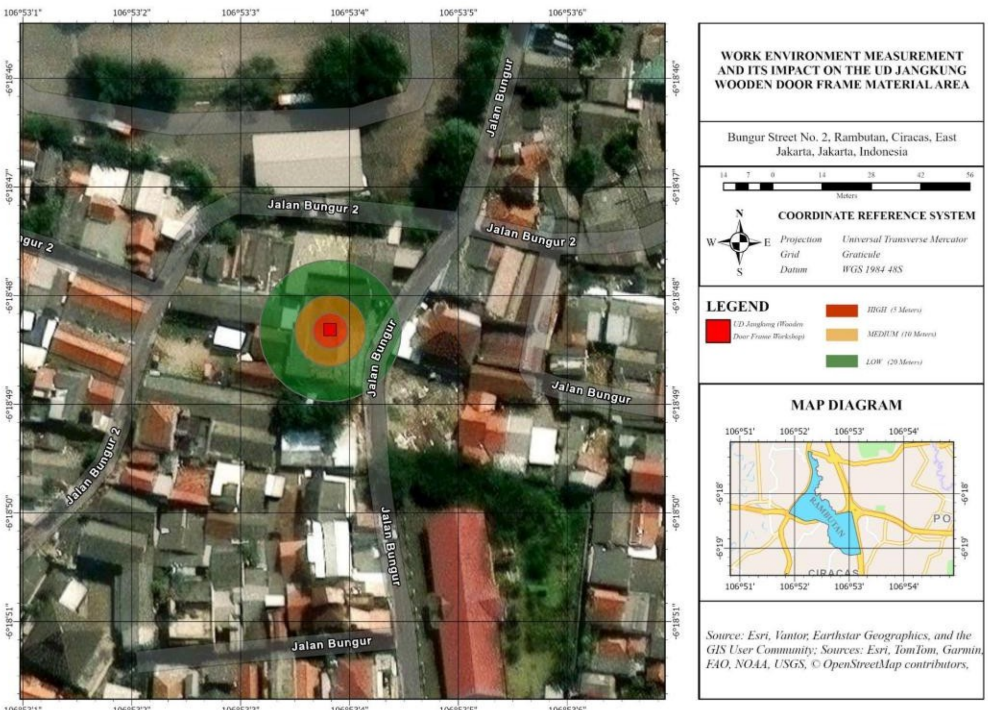

Fig 3. Spatial Mapping Results Using ArcGIS Pro Version 3.4

ArcGIS Pro version 3.4 is a professional GIS software used for two-dimensional (2D) and three-dimensional (3D) map production, spatial data analysis, and the management and presentation of geographic information. This software is web-based and therefore requires an internet connection for its operation (Nusantara, 2020). ArcGIS was developed based on the concept of thematic GIS to manage data derived from primary and secondary surveys in order to support the processing and analysis of spatial information according to the designated study area (Wibisono, 2021).

In this study, ArcGIS Pro version 3.4 was employed as a spatial analysis tool to map the level and distribution of exposure risk to physical hazard factors in the work environment. The spatial approach enables visualization of the relationship between hazard sources and work areas, allowing the impacts of noise, vibration, lighting, and thermal conditions on workers to be analyzed based on risk level and proximity to the exposure source.

The mapping process was conducted by defining the boundaries of the work area, determining the coordinate points of measurement locations, and integrating the results of environmental measurements into the ArcGIS system. Each exposure value was linked to its corresponding coordinate point, enabling spatial visualization of risk distribution and classification into high, medium, and low exposure zones, as illustrated in Figure 3.

The spatial mapping results of physical hazard exposure at UD Jangkung Material Kayu Kusen Pintu indicate a concentric pattern centered on the main production area. Zones with high exposure levels are located around machinery and intensive production activities, placing workers in these areas at the greatest risk of physical hazard exposure. These findings confirm that occupational health and safety (OHS) risks are not evenly distributed within the workspace, particularly in small and medium scale furniture industries characterized by limited space and closely arranged machinery layouts (Sihaloho & Siregar, 2020).

Zones within a radius of approximately 5 meters from the activity source are categorized as unsafe zones due to the highest exposure levels resulting from direct proximity to production machines. Zones within an approximate radius of 10 meters are classified as medium-exposure zones, where exposure intensity begins to decrease but may still pose health risks if exposure occurs continuously. Given that the workplace is located in a densely populated residential area, this zone extends beyond the internal work environment and may also affect the surrounding community, particularly when all machines operate simultaneously (Baharuddin & Ali, 2025).

Zones within an approximate radius of 20 meters are classified as safe zones, characterized by relatively low exposure intensity. The reduction in exposure at this distance highlights the role of distance in mitigating exposure in accordance with industrial hygiene principles. Nevertheless, continuous monitoring remains necessary, considering that workers' average working duration of approximately 8 hours per day may result in continuous exposure (Hanif et al., 2022).

The integration of ArcGIS in industrial hygiene studies provides added value in location based decision-making through spatial risk visualization. This approach enables more targeted prioritization of OHS control measures, whether technical, administrative, or personal protective equipment based, according to the risk level in each work zone, while also strengthening the outcomes of the Health Risk Assessment (HRA) (Hanif et al., 2022; Baharuddin & Ali, 2025).

4. CONCLUSION

This study aims to evaluate exposure to physical factors in the work environment of UD Jangkung Furniture, particularly during the wood cutting process using a *circle saw* machine, as a basis for assessing workers' health risks. The evaluation was conducted through measurements of physical environmental factors and the grouping of workers based on the *Similar Exposure Group* (SEG) approach. The measurement results and initial analysis indicate the presence of potential physical hazards that need to be systematically managed to prevent both short-term and long-term health effects. Therefore, a comprehensive risk assessment approach through *Health Risk Assessment* (HRA), supported by spatial-based exposure mapping, is required

Based on the results of the study, the following conclusions can be drawn:

1. Exposure to physical factors during the wood cutting process shows varying levels of risk, with noise identified as the primary factor that exceeds the Threshold Limit Value (TLV) at several measurement

points, while vibration, thermal working conditions, and lighting remain at low levels but may pose cumulative health effects
2. Based on the *Similar Exposure Group* (SEG) approach, *circle saw* machine operators are classified as a group with similar exposure characteristics in terms of job type, hazard sources, and exposure duration.
3. Workers' health risk assessment should be further conducted through *Health Risk Assessment* (HRA) by considering the aspects of likelihood and severity to obtain a more accurate estimation of risk levels.
4. Exposure analysis can be strengthened through intake calculations and the implementation of biological monitoring to directly assess the health impacts of exposure on workers.
5. The use of ArcGIS has the potential to map the distribution of physical factor exposures in the work environment, thereby supporting spatial-based risk control strategies.
6. Recommended control measures include machine maintenance, work–rest scheduling, consistent use of personal protective equipment (PPE), and increased occupational safety and health education to support sustainable management of occupational health risks.

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REFERENSI

Aprilia, R., Kartika, E., & Nathanael, S. (2024). The influence of work environment, occupational health, and occupational safety on employee productivity (Case study at PT Optima Sinergi Convestama, Semarang City). *Jurnal Ilmiah Aset*, 26(1), 23–28. https://doi.org/10.37470/1.26.1.233

Badan Standardisasi Nasional. (2004). *SNI 16-7061-2004: Measurement of work climate (heat) using wet bulb and globe temperature index*. Jakarta: National Standardization Agency of Indonesia.

Badan Standardisasi Nasional. (2017). *SNI 8427:2017 Environmental noise level measurement*. Jakarta: National Standardization Agency of Indonesia.

Badan Standardisasi Nasional. (2019). *SNI 7054:2019 Measurement and evaluation of hand arm vibration exposure in the workplace*. Jakarta: National Standardization Agency of Indonesia.

Badan Standardisasi Nasional. (2019). *SNI 7062:2019 Measurement of workplace lighting intensity*. Jakarta: National Standardization Agency of Indonesia.

Baharuddin, S. R., & Ali, A. M. T. (2025). Utilization of spatial data for identifying occupational accident risks at PT PJM. *Jurnal Kesehatan Fatimah*, 1(2), 72–77.

Fahmi, U. (1997). *Health, safety and environment*. Jakarta: Bina Diknakes.

Haqi, D. N. (2010). *SEG (Similar Exposure Group) Talk as an alternative solution to improve knowledge and work attitudes (Study among workers in Production Unit I of PT Wiharta Karya Agung in preventing noise hazards)*

(Doctoral dissertation). Universitas Airlangga.

Hanif, M. G., Asmony, T., & Nururly, S. (2022). The influence of work motivation and work environment on employee performance at the Livestock Service Office of Dompu Regency. *Jurnal Pustaka Aktiva*, 2(1), 21–28. https://doi.org/10.55382/jurnalpustakaaktiva.v2i1.141

Haryandi, Setiawati, V. R., & Mayasisca. (2020). Implementation of a hearing conservation program in the mining industry as an effort to prevent occupational diseases due to noise exposure: A case study in the grinding process plant area of PT ABC, West Sumbawa, West Nusa Tenggara. *Hexagon: Journal of Engineering and Science*, 1(2), 1–8.

International Commission on Non-Ionizing Radiation Protection. (2020). Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz). *Health Physics*, 118(5), 483–524.

Králiková, R., Lumnitzer, E., Džuňová, L., & Yehorova, A. (2021). Analysis of the impact of working environment factors on employees' health and wellbeing: Workplace lighting design evaluation and improvement. *Sustainability*, 13(16), 8816. https://doi.org/10.3390/su13168816

Lajaria, R. T., & Utha, R. (2024). Identification of green job potential as an alternative business opportunity for micro, small, and medium enterprises in the culinary sector in Kendari City. *MANDAR: Management Development and Applied Research Journal*, 7(1), 102–112. https://doi.org/10.31605/mandar.v7i1.4555

Nabila, A., Fitri, A. M., Buntara, A., & Utari, D. (2020). Analysis of factors associated with hand-arm vibration syndrome complaints among construction workers. *Journal of Health Research "Forikes Voice"*, 11, 16. https://doi.org/10.33846/sf11nk103

Nugrahaeni, A. (2020). Health risk assessment in the utility area of PT Pertamina Lubricant Production Unit Gresik. *The Indonesian Journal of Public Health*, 15(2), 224–235. https://doi.org/10.20473/ijph.v15i2.2020.224-235

Nusantara, G. C., & Dewanto, B. G. (2020). Analysis of solar energy potential in three-dimensional building modeling based on OpenStreetMap data (Case study: Universitas Gadjah Mada, Yogyakarta). *Elipsoida: Journal of Geodesy and Geomatics*, 3(1), 38–45. https://doi.org/10.14710/elipsoida.2020.7757

Parjaman, T., & Akhmad, D. (2019). Mixed-method research approach as a "middle ground" for the quantitative–qualitative dichotomy. *Moderat: Jurnal Ilmiah Ilmu Pemerintahan*, 5(4), 530–548. http://dx.doi.org/10.25157/moderat.v5i4.3077

Pratama, M. R. A., & Tejamaya, M. (2024). Health risk assessment of benzene, toluene, and xylene chemical exposure among lubricant laboratory workers at PT X. *National Journal of Occupational Health and Safety*, 5(2), Article 1070. https://doi.org/10.7454/njohs.v5i2.1070

Rizal, R. (2015). *Occupational safety and health in industrial environments*. Jakarta: Institute for Research and Community Service, Universitas Pembangunan Nasional "Veteran" Jakarta.

Safiu, D., Suryadi, I., Nur, N. H., & Abdillah, M. N. (2023). The effect of noise exposure on stress levels and sleep quality among agro-industry workers in Gowa Regency. *Media Publikasi Promosi Kesehatan Indonesia*, 6(2), 353–357. https://doi.org/10.56338/mppki.v6i2.3033

Sihaloho, R. D., & Siregar, H. (2020). The influence of the work environment on employee performance at PT Super Setia Sagita Medan. *Jurnal Ilmiah Socio Secretum*, 9(2), 273–281.

Soeripto, M. (2008). *Industrial hygiene*. Jakarta: FKUI Publishing.

Sugiyono. (2020). *Quantitative, qualitative, and R&D research methods*. Bandung: Alfabeta.

Sunaryo, M., & Rhomadhoni, M. N. (2020). Description and control of work climate related to health complaints among workers. *Medical Technology and Public Health Journal*, 4(2), 171–180. https://doi.org/10.33086/mtphj.v4i2.1635

Tana, L. (2002). Noise-induced hearing loss among steel industry workers in Java Island. *Jurnal Kedokteran Trisakti*, 21(3).

Thabroni, G. (2022). *Qualitative descriptive research methods*. Serupa.id.

Wibisono, G., & Despa, D. (2021). Implementation of ArcGIS 10.6 software in wastewater piping projects in West Jambi City Area Package C as information monitoring and database management. *Jurnal Profesi Insinyur Universitas Lampung*, 2(2), 12–20. https://doi.org/10.23960/jpi.v2n2.60