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ORIGINAL

The Effect of Noise, Vibration, Temperature, and Mental Workload on Work Productivity Through Job Stress at PT. Makassar Tene

El efecto del ruido, la vibración, la temperatura y la carga mental en la productividad laboral a través del estrés laboral en PT. Makassar Tene

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ABSTRACT

Introduction: work stress is one of the common problems faced by workers in both formal and informal sectors. In addition to noise, vibration, temperature and mental workload are also factors that affect employee productivity levels.
Method: quantitative research with a cross-sectional design with path analysis. The sample of this study was 100 respondents selected using the Proportionate Stratified Random Sampling technique. Data were collected through questionnaires and measuring instruments.
Results: the results of this study indicate that noise significantly affects work stress (p=0,002) does not affect work productivity (p=0,105) work stress as a significant mediator (p=0,002), vibration (WBV) does not affect work stress (p=0,543) does not affect work productivity (p=0,157), work stress as a mediator is not significant (p=0,547), temperature affects work stress (p=0,002), does not affect work productivity (p=0,918), work stress as a significant mediator (p=0,001), mental workload affects work stress (p=0,012), affects work productivity (p=0,042), work stress as a significant mediator (p=0,012).
Conclusion: Noise, temperature and mental workload are important factors influencing work productivity and work stress both directly and through work stress as an intervening variable.

Keywords: Noise; Vibration (WBV); Temperature; Mental Workload; Fatigue; Work Stress; Work Productivity.

RESUMEN

Introducción: el estrés laboral es uno de los problemas comunes que enfrentan los trabajadores, tanto en el sector formal como en el informal. Además del ruido, la vibración, la temperatura y la carga mental, también son factores que afectan la productividad de los empleados.
Método: investigación cuantitativa con diseño transversal y análisis de trayectoria. La muestra de este estudio fue de 100 encuestados seleccionados mediante la técnica de Muestreo Aleatorio Estratificado Proporcional. Los datos se recopilaron mediante cuestionarios e instrumentos de medición.
Resultados: los resultados de este estudio indican que el ruido afecta significativamente el estrés laboral (p=0,002), no afecta la productividad laboral (p=0,105) y actúa como mediador significativo (p=0,002); la vibración (WBV) no afecta el estrés laboral (p=0,543) ni la productividad laboral (p=0,157); el estrés laboral como mediador no es significativo (p=0,547); la temperatura afecta el estrés laboral (p=0,002) y no afecta la productividad laboral (p=0,918); el estrés laboral como mediador significativo (p=0,001); la carga mental afecta el estrés laboral (p=0,012) y afecta la productividad laboral (p=0,042); el estrés laboral como mediador significativo (p=0,012).
Conclusión: el ruido, la temperatura y la carga mental son factores importantes que influyen en la

productividad laboral y el estrés laboral, tanto directamente como a través del estrés laboral como variable interviniente.

Palabras clave: Ruido; Vibración (Wbv); Temperatura; Carga Mental; Fatiga; Estrés Laboral; Productividad Laboral.

INTRODUCTION

The working environment encompasses all conditions surrounding the workplace that may influence employees in carrying out their tasks. A conducive working environment is essential in supporting employees to perform optimally, whereas an inadequate environment may hinder performance and increase the risk of work-related accidents. In general, the work environment includes all facilities, equipment, and physical conditions that surround workers and may affect the process and quality of work execution. According to the Decree of the Minister of Manpower No. 1450/MENKES/SK/XI/2002, the threshold limit value for noise exposure is 85 dBA for an exposure duration of 8 hours per day and 40 hours per week.[1] Exposures above this limit can lead to various adverse health outcomes, including hearing impairment, fatigue, and decreased work performance.

The work environment is widely recognized as a contributing factor to occupational accidents and diseases. Data released by the International Labour Organization (ILO, 2018) indicate that approximately 380 000 workers—equivalent to 13,7 % of the 2,78 million global occupational fatalities—die each year due to workplace accidents or occupational diseases. Additionally, more than 374 million workers suffer from injuries or illnesses annually as a result of hazardous working conditions. These alarming figures underscore the urgency of evaluating workplace hazards and implementing preventive measures. Productivity, as a key indicator of organizational progress, is also directly influenced by environmental and psychosocial factors; therefore, enhancing productivity across all components of a company's operational system is crucial for advancing economic growth.[2]

Work stress constitutes another significant factor associated with the working environment. At certain levels, stress can stimulate the body to perform more intensively, allowing workers to complete tasks faster. However, continuous or excessive stress leads to detrimental physiological and psychological consequences, including reduced concentration, emotional exhaustion, and impaired decision-making. Environmental factors such as machine-generated vibration and noise have been shown not only to disrupt physical well-being but also to interfere with cognitive functioning and social interaction among employees. Prolonged exposure may reduce concentration, slow reaction time, and create communication difficulties within the workplace.[3]

In addition to noise and vibration, workload—both physical and mental—plays a substantial role in shaping worker performance. The heavier the workload, the more likely productivity will decline, particularly when workers experience fatigue or cognitive overload. Physical workload can be assessed using medical or ergonomic instruments to determine the level of exertion required, while mental workload reflects cognitive demand and psychological pressure experienced during task performance. Thermal comfort also contributes significantly to workplace well-being. For Indonesian workers, a comfortable air temperature typically ranges between 24°C and 26°C, and the difference between indoor and outdoor temperatures should not exceed 5°C. The Wet Bulb Temperature Index (WBTI) serves as a key parameter for evaluating thermal work climate and is derived from dry bulb, wet bulb, and globe temperature measurements.[4]

Initial observations conducted by the researchers at PT. Makassar Tene revealed several potential hazards that may contribute to occupational safety and health problems. These include high noise levels within the refined sugar production area that may pose risks when exposure occurs over extended periods; mechanical vibrations originating from production machines such as centrifuges; elevated room temperatures in processing areas; and significant mental workload experienced by employees. Symptoms of job stress were also apparent, which may negatively influence worker productivity and overall well-being.

Although many studies have examined the impact of environmental factors such as noise, temperature, vibrations, or workload on worker health and productivity, there remains a clear gap in research that comprehensively assesses these factors simultaneously within the context of sugar processing industries in Indonesia. Existing research often focuses on individual aspects of the work environment, resulting in a limited understanding of how multiple occupational hazards may interact and contribute collectively to worker stress, fatigue, and decreased productivity. Specifically for PT. Makassar Tene, no integrated assessment has been conducted that evaluates physical hazards (noise, vibration, temperature) alongside mental workload and stress levels to provide a holistic depiction of workers' occupational conditions. Therefore, the objective of this study is to analyze the working environment—including noise exposure, machine vibration, thermal conditions, physical workload, and mental workload—and to evaluate their combined impact on worker health, stress levels, and productivity at PT. Makassar Tene.

METHOD

Study Design

This study employs a quantitative research design with a cross-sectional approach to assess the working environment and its relationship with work productivity among employees at PT. Makassar Tene. The research was conducted during the period of September to October. The independent variables in this study include noise, whole-body vibration, temperature, and mental workload, while the dependent variable is work productivity with work fatigue serving as an intervening variable.

Population and Sample

The study population consists of all workers involved in the operational activities at PT. Makassar Tene. The sample was selected using a purposive sampling technique based on predetermined inclusion criteria: active workers assigned to production areas, employed for at least six months, and willing to participate in the study. Workers who were absent during the data collection period or declined to complete the required assessments were excluded from the analysis.

Focus Analysis

The focus of this study is to evaluate the influence of physical and psychosocial work environment factors on employee productivity. Specifically, the analysis examines the direct and indirect effects of noise exposure, whole-body vibration, temperature, and mental workload on work productivity, with work fatigue acting as an intervening variable. This analytical focus aligns with the study's purpose of understanding how multiple workplace stressors interact to affect worker outcomes.

Instruments, Techniques, and Procedures

Multiple instruments were used to measure the variables of interest:

- Noise levels were measured using a sound level meter.
- Whole-body vibration (WBV) was measured using a vibration meter.
- Temperature and heat stress conditions were assessed using a heat stress area monitor.
- Mental workload was measured using the NASA Task Load Index (NASA-TLX) questionnaire.
- Work productivity was assessed using a structured questionnaire.
- Work fatigue was measured using the DASS-42 questionnaire.

All instruments and questionnaires were used according to standard measurement procedures. Field measurements were conducted in production areas during regular working hours to ensure accurate representation of workers' exposure conditions.

Data Collection

Data collection consisted of two main components:

- Environmental Measurements, including noise, vibration, and temperature, conducted directly at the worksite using calibrated measurement tools.
- Worker Assessments, including questionnaires on mental workload, work productivity, and work fatigue, administered to eligible workers during scheduled data collection sessions.

Researchers coordinated with company management to ensure minimal disruption to production processes while maintaining data accuracy.

Data Analysis

Collected data were processed and analyzed using SPSS for univariate and bivariate analysis. To examine the direct and indirect relationships among variables, path analysis was conducted using Structural Equation Modeling (SEM) with a SMART PLS framework. This analytical approach allows assessment of the mediating role of work fatigue between workplace environmental factors and worker productivity.

Ethical Considerations

This study received ethical approval from the Ethics Committee of the Faculty of Public Health, Universitas Hasanuddin, with approval number 1705/UN4.14.1/TP.01.02/2025. All participants provided informed consent prior to data collection, and confidentiality was maintained throughout the research process.

RESULT

Table 1 provides an overview of the demographic characteristics of the 100 respondents, including age, gender, years of service, and daily working hours. The largest age group consists of workers aged 35–45 years,

representing 38,0 % of respondents, followed by those aged 46–55 years (27,0 %) and 26–34 years (21,0 %). The smallest age group is 17–25 years, comprising 14,0 % of the sample. The gender distribution shows that the workforce is predominantly male, with 93,0 % of respondents identifying as men, while only 7,0 % are women. Regarding years of service, 78,0 % of workers have been employed for more than five years, while 22,0 % have worked for less than five years. Most respondents work eight hours per day (87,0 %), whereas 13,0 % report working less than eight hours.

Table 1. Distribution of Respondents Based on Age, Gender, Length of Service, and Length of Employment

Respondent Characteristics	Frequency (n)	Percentage (%)
Age (Years)		
17-25 Years	14	14,0
26-34 Years	21	21,0
35-45 Years	38	38,0
46-55 Years	27	27,0
Total	100	100,0
Gender		
Woman	7	7,0
Man	93	93,0
Total	100	100,0
Years of service		
<5 Years	22	22,0
>5 Years	78	78,0
Total	100	100,0
Length of working		
<8 Hours	13	13,0
8 Hours	87	87,0
Total	100	100,0

Table 2 presents the results of the bivariate analysis examining the distribution of work productivity across categories of noise, vibration (WBV), work climate (temperature), and mental workload. For noise exposure, 38,6 % of respondents in the "qualify" category exhibit good productivity, while 62,5 % of those in the "not eligible" category do so. For vibration, 57,6 % of workers in the "qualify" category demonstrate good productivity compared to 43,9 % in the "not eligible" category. In terms of work climate, 19,6 % of respondents in the "qualify" category show good productivity, whereas 79,6 % in the "not eligible" group report good productivity. Regarding mental workload, 23,9 % of respondents in the "qualify" category demonstrate good productivity, compared to 83,3 % in the "not eligible" category. The p-values associated with each variable are presented in the table.

Table 2. Bivariate Analysis of the Relationship between Noise, Vibration (WBV), Work Climate (Temperature) and Mental Workload on Work Productivity

Variables		Work Productivity				Total		P-value
		Not enough		Good				
		N	%	N	%	N	%	
Noise	Qualify	27	61,4 %	17	38,6 %	44	100,0 %	,026
	Not eligible	21	37,5 %	35	62,5 %	56	100,0 %	
	Total	48	48,0 %	52	52,0 %	100	100,0 %	
Vibration (WBV)	Qualify	25	42,4 %	34	57,6 %	59	100,0 %	0,223
	Not eligible	23	56,1 %	18	43,9 %	41	100,0 %	
	Total	48	48,0 %	52	52,0 %	100	100,0 %	
Working Climate (Temperature)	Qualify	37	80,4 %	9	19,6 %	46	100,0 %	0,000
	Not eligible	11	20,4 %	43	79,6 %	54	100,0 %	
	Total	48	48,0 %	52	52,0 %	100	100,0 %	
Mental Workload	Qualify	35	76,1 %	11	23,9 %	46	100,0 %	0,000
	Not eligible	9	16,7 %	45	83,3 %	54	100,0 %	
	Total	44	44,0 %	56	56,0 %	100	100,0 %	

Figure 1 illustrates the path analysis model constructed to evaluate direct and indirect effects among variables. The model includes pathways connecting noise, vibration, work climate, and mental workload to work stress and work productivity.

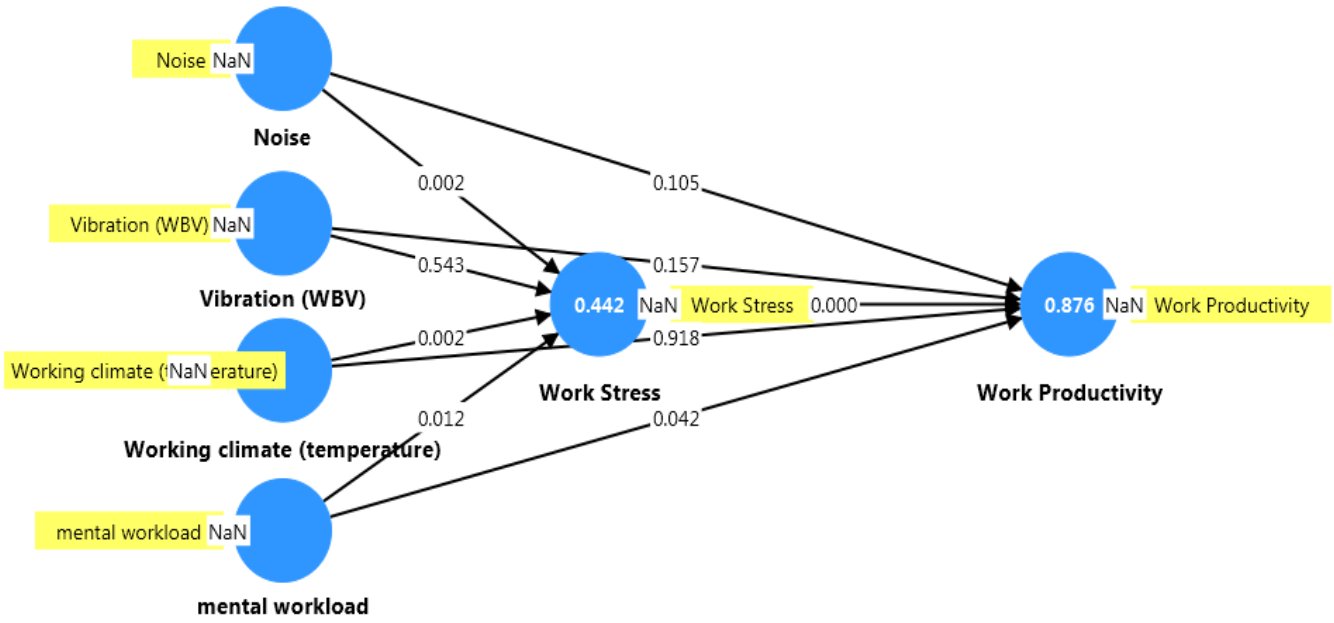

Figure 1. Path Analysis

Table 3 summarizes the results of the direct effect hypothesis testing. The table contains path coefficients, p-values, confidence intervals, and effect size (F-square) values. Several pathways display p-values below 0,05, indicating statistically measurable direct effects, whereas others present p-values exceeding 0,05. Effect size values across pathways range from low to high, reflecting variation in the magnitude of influence among the variables measured.

Table 3. Testing the direct effect hypothesis

Hypothesis	Path Coefficients	P - Values	95 % Path Coefficient		F-square	Note
			Lower Limit	Upper Limit		
Noise -> Work Productivity	-0,044	0,105	0,029	0,286	0,013	Low
Noise -> Work Stress	0,246	0,002	0,051	0,352	0,104	Currently
Vibration (WBV) -> Work Productivity	-0,062	0,157	-0,268	0,035	0,030	Low
Vibration (WBV) -> Work Stress	-0,048	0,543	-0,192	0,075	0,004	Low
Work Climate (Temperature) -> Work Productivity	-0,007	0,918	0,065	0,499	0,000	Low
Work Climate (Temperature) -> Work Stress	0,357	0,002	0,158	0,550	0,136	Currently
Mental Workload -> Work Productivity	0,160	0,042	0,201	0,610	0,115	Currently
Mental Workload -> Job Stress	0,278	0,012	0,068	0,475	0,085	Low
Work Stress -> Work Productivity	0,859	0,000	0,687	0,964	3,283	Currently

Table 4 presents the results of the indirect effect hypothesis testing using the Sobel test. The table includes indirect path coefficients, p-values, 95 % confidence intervals, and Z-Sobel values. Some variables demonstrate statistically measurable indirect effects through work stress, indicated by p-values below 0,05 and Z-Sobel values exceeding 1,96. Others show p-values above 0,05, indicating the absence of a statistically measurable indirect effect on work productivity.

Table 4. Testing the indirect effect hypothesis is carried out using the Sobel test

Hypothesis	Path Coefficient	P - Values	95 % Path Coefficient		Z-Sobel	Note
			Lower Limit	Upper Limit		
Noise -> Work Stress -> Work Productivity	0,212	0,002	0,047	0,313	3,106	Influential
Vibration (WBV) -> Work Stress -> Work Productivity	-0,041	0,547	-0,171	0,064	0,604	No effect
Work Climate (Temperature) -> Work Stress -> Work Productivity	0,307	0,001	0,133	0,469	3,340	Influential
Mental Workload -> Work Stress -> Work Productivity	0,238	0,012	0,052	0,426	2,556	Influential

DISCUSSION

This study examined how various workplace factors—namely noise, whole-body vibration (WBV), work climate (temperature), and mental workload—contribute to worker productivity, with work stress considered as a mediating factor. The analysis explored the interrelationships between physical exposures and psychological demands to understand how they collectively shape productivity outcomes among workers in an industrial setting. Overall, the findings highlight that work stress plays a meaningful role in linking environmental and psychosocial conditions to worker performance.

Noise exposure is a significant occupational hazard whose effects depend on sound intensity, duration, and frequency.[5] In this study, noise was found to influence productivity indirectly through its contribution to work stress. Noise levels recorded in multiple production areas of PT. Makassar Tene exceeded standard occupational thresholds.[6] which is consistent with literature indicating that excessive noise can disrupt concentration, elevate stress responses, and interfere with communication. These findings align with research by Cahyawati et al., which reported that noise exposure is associated with decreased productivity in industrial workplaces.[7] International research further supports the connection between chronic noise exposure and heightened physiological activation via the HPA axis, leading to increased cortisol secretion and elevated stress. Such mechanisms help explain how persistent noise exposure contributes to reduced performance through its impact on mental strain.

Whole-body vibration (WBV) occurs when mechanical vibration is transmitted through the body from equipment or machinery and may affect health and comfort depending on intensity and exposure duration. Although WBV is recognized in ISO 2631-1 (1997) as capable of influencing human comfort and performance, the present study did not find evidence that WBV meaningfully contributes to productivity reduction through stress. This observation is consistent with findings from Gatter et al., which reported that moderate WBV exposure did not elicit significant stress responses.[8] Literature on vibration measurement also emphasizes that exposure estimation varies based on measurement duration and work-cycle conditions.[9] These studies suggest that the vibration levels present in the evaluated work environment may fall within tolerable limits, thereby reducing the likelihood of contributing to stress or productivity decline.

Work climate, especially temperature, is known to affect comfort, physiological workload, and cognitive performance. Thermal discomfort increases physical fatigue and psychological strain, potentially lowering productivity.[2] This study indicates that temperature contributes to productivity outcomes by influencing the level of stress workers experience in the production environment. This aligns with research by Anggun Puspita, who found that work climate factors significantly affect occupational stress.[10] International studies similarly describe how heat exposure can increase perceived exertion, strain thermoregulatory systems, and impair attention. These physiological and psychological mechanisms help explain why workers in hotter industrial environments may experience elevated stress that impacts performance.

Mental workload reflects the cognitive demands imposed on workers, including decision-making responsibilities, multitasking, and time pressure. Numerous studies have identified high mental workload as a precursor to occupational stress.[11] The findings of this study also support the link between mental overload and stress-driven reductions in productivity. Mechanistically, excessive cognitive demands can overload working memory, reduce attentional resources, and impair decision-making efficiency. These effects correspond with global models such as the Karasek Job Demand–Control Model, which predicts increased strain when job demands surpass workers' perceived control. Within PT. Makassar Tene, demanding production tasks and rapid decision-making requirements likely contribute to elevated psychological stress that influences performance.

The findings underscore the need for a comprehensive approach to occupational health management that integrates environmental and psychosocial risk factors. Industries with similar operational characteristics may

improve productivity and worker well-being through:

- Implementation of engineering and administrative controls to manage noise exposure.
- Enhancement of ventilation and cooling systems to mitigate thermal discomfort.
- Continuous monitoring of WBV to ensure compliance with exposure standards.
- Optimizing job design to balance mental workload and reduce cognitive strain.

At a broader level, these results support the global call for integrated occupational health policies that consider both physical hazards and psychological demands as determinants of workplace performance.

Limitations

Several limitations should be acknowledged. First, the cross-sectional design restricts the ability to infer causality between variables, as exposures and outcomes were measured at the same time. Second, environmental measurements (noise, WBV, temperature) may not fully capture daily fluctuations, which could affect exposure assessment accuracy. Third, the use of self-report instruments for mental workload, stress, and productivity may introduce response bias. Fourth, the study was conducted within a single industrial site, limiting generalizability to other industries or regions. Finally, unmeasured confounding variables, such as personal coping mechanisms, organizational culture, or individual health status, could influence the observed relationships.

CONCLUSIONS

Noise, whole body vibration, work climate (temperature) and mental workload are important factors in influencing work productivity and work stress both directly and indirectly. The results of the study showed that noise significantly affected productivity through work stress, whole body vibration did not affect work productivity through work stress, temperature significantly affected work productivity through work stress, and mental workload significantly affected work productivity through work stress.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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