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Evaluating healthy workplace in geothermal industry

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Abstract
The geothermal industry is located in mountainous areas and far from urban centers that are at risk of danger. Hazard management is one aspect of occupational safety health management, including occupational environmental health. Therefore, this study aims to evaluate the healthy workplace in geothermal industry. Observation and measurement technique are used to determine the light intensity, noise, humidity and temperature in all room in the industry. The results state that there are three rooms that did not meet the standard, the noisy still eligible both for offices (65dBA) and PLTP (85 dBA), the humidity is quite high (60%) and the average temperature is 15-20^{o}C. Most of the indicators are still below the limit value based on the company and local regulations. The measurement of physical aspects in monitoring occupational environmental health has yielded positive results. However, there are still several workplace locations that require further improvement in terms of lighting, through the replacement of LED lamps, as well as the regulation of temperature and humidity within the space. The assessment of healthy workplace is needed to improve the well-being of the workers in geothermal industry.

Keywords: environmental health; geothermal industry; healthy wokrplace; occupational health and safety

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1. Introduction

Companies are established generally for profit. One of the success factors of companies in obtaining profits is productive human resources (Cintia &; Gilan, 2016). Productivity does not only depend on the ability of the workforce, but is also influenced by the work environment, one of which is the physical condition of the work environment that can affect the health of workers (Hamdi, 2013). According to Cintia & Gilan (2016), the physical work environment is any condition around the workplace that will affect employees either directly or indirectly. Some factors that can affect the physical work environment include lighting, temperature, humidity, air circulation, noise, and vibration in accordance with the Minister of Health Regulation Number 70 of 2016 concerning Industrial Work Environment Health Standards and Requirements. The health of the work environment is very influential on worker performance such as work stress. According to research by Putra & Saraswati (2022), the results of linear regression analysis state that every 1% increase in the value of the physical work environment variable will increase the value of the employee work stress variable by 0.513. The results of the regression coefficient test produce positive values so that it can be said that there is a positive influence of physical work environment variables on work stress. Good physical health environment affects worker job satisfaction will increase *(P-value*: 0.001) (Putra et al., 2022).

Previous research has discussed the health conditions of physical work environments in various industries such as the property industry (Rianda & Winarno, 2022), offices (Marlius & Sholihat, 2022; Putra & Saraswati, 2022), paint industry (Halim &

Meliza, 2022), and banking (Kusumadewi, 2022). Research conducted by Rianda & Winarno (2022) examines the effect of compensation and physical work environment on employee performance. However, it does not discuss the physical work environment in accordance with the applicable Minister of Health Regulation. Research conducted by Marlius & Sholihat (2022) analyzed physical and non-physical work environments on employee performance in the office. This study discusses aspects of the physical work environment in more detail such as spatial layout, lighting, room color, bentilation, and noise level. However, the temperature parameter is not calculated. A similar study was conducted by Halim & Meliza (2022). However, this study does not describe how the physical working environment conditions in the workplace. Based on previous research, there have been no studies that describe the physical working environment conditions in geothermal companies. The geothermal industry is located in the highlands and is different from industry in general. So this research makes the geothermal industry a research location.

In utilizing geothermal energy, the geothermal industry carries out various activities to support the company's operations. Among them are office building facilities, PLTP, workshops, WWTP, and others. The existence of these facilities must be supported by environmental requirements that must be met to support the health and safety of the environment of workers at PT. X. These requirements include the health of the work environment that must be met in order for the implementation of geothermal utilization operations at PT. X can run well without damaging the environment and causing health problems for workers.

In addition, handling health hazards in industrial work environments and meeting environmental health requirements is one of the important aspects in the implementation of an occupational health and safety management system as mandated in Law Number 36 of 2009 concerning Health, Government Regulation Number 50 of 2012 concerning the Implementation of Occupational Safety and Health Management System, and Government Regulation Number 66 of 2014 concerning Environmental Health Life and the latest is (Regulation of the Minister of Health Number 70 of 2016 concerning Industrial Work Environment Health Standards and Requirements.

A healthy industrial work environment is one of the factors that support the improvement of performance and production which at the same time can reduce the risk of health problems and occupational diseases. The industrial work environment must meet the standards and health requirements of the work environment as the minimum requirements that must be met. Industrial occupational environment health standards and requirements consist of threshold values, biological exposure indicators, and industrial occupational environment health requirements.

Industrial Work Environment Health is an effort to prevent diseases or health problems from industrial work environment risk factors consisting of physical, chemical, biological, ergonomic, and sanitary hazard factors to realize the quality of a healthy industrial work environment. In the Regulation of the Minister of Health Number 70 of 2016 concerning Industrial Occupational Environmental Health, it has provided a reference to industrial occupational environment health requirements standards that can be applied in the workplace. Industry must make efforts to health the work environment by conducting regular monitoring of aspects that have been regulated in accordance with the Regulation of the Minister of Health Number 70 of 2016 concerning Industrial Work Environment Health. All industries are required to meet standards and implement the health requirements of the industrial work environment, be it industries with large, medium, small or micro enterprises. Occupational health standards include: threshold values of physical and chemical factors, biological exposure indicators and environmental health quality standards.

Industrial work environment health requirements that must be met include physical factor requirements, biological factor requirements, manual load handling requirements, and health requirements on environmental media. The industrial work

environment must meet the standards and health requirements of the industrial work environment as the minimum requirements that must be met. Occupational Health Requirements that must be met are values or guidelines that must be met and implemented in the workplace including NAV or Threshold Value. The Threshold Value (NAV) of physical/chemical factors is the average intensity/concentration of exposure to physical/chemical hazards that can be accepted by almost all workers without causing health problems or disease in daily work as long as the time does not exceed 8 hours per day and 40 hours per week, consisting of TWA (Time Weighted Average), STEL (Short Term Exposure Limit), and Ceiling.

Therefore, the purpose of the study was to observe and compare the physical aspects of occupational health in the geothermal industry based on the regulation of the Minister of Health of the Republic of Indonesia No. 70 of 2016 concerning the health of the industrial work environment and the regulation of the Minister of Health No. 48 of 2016 concerning occupational health and safety of offices.

2. Methods

The method used in this study was carried out in 2 stages, namely observation using measuring instruments for each variable. After that, the measurement results are compared with quality standards through applicable regulations.

2.1. Variable Measurement

The variables measured are physical factors consisting of lighting, noise, temperature, and humidity in accordance with the Minister of Health Regulation Number 70 of 2016 concerning Industrial Work Environment Health Standards and Requirements. These four variables were chosen because they are the easiest and very influential on employee performance. Measurements were carried out in each room as many as 64 rooms divided into 4 zones, namely office zone (40 rooms), laboratory zone (10 rooms), workshop zone (9 rooms), PLTP zone (5 rooms).

Exposure measurements were performed using the Luxmeter LX-100 (Figure 1a). Light intensity measurements are taken every 8 am with the lights on. Noise is performed using a sound level meter (SLM) with decibel unit A (dBA) (Figure 1b). Temperature and humidity variables are measured using the Irtek humidity and temperature tool (Figure 1c).

2.2. Data Analysis

The data obtained is entered into Ms. Excel, then viewed the average and then compared with quality standards, namely the regulation of the minister of health No. 70 of 2016 concerning Occupational Environmental Health. According to the company's management, absolute figures from the measurement results should not be displayed. So that the data displayed is only in nominal form (meets and does not meet quality standards). Then, this study also evaluates the monitoring form that has been provided. Input for the development of the monitoring form will be given after measuring the factors of the physical environment in the 4 zones mentioned in subchapter 2.1.

Unlike the research conducted by Putra et al. (2022) which uses linear regression analysis or Kusumadewi, (2022) which uses statistical analysis with ANOVA, this study better describes the physical environment conditions from temperature, humidity, noise, and lighting variables because these variables are easy to measure for 40 rooms and do not involve the people studied. The limitation of this study is that it does not describe the correlation or influence of physical environmental health conditions with employee satisfaction levels, stress levels, or employee performance. The limitations of this study were also unable to display the values of temperature, humidity, lighting, and noise levels due to restrictions from the company. So that in the analysis of research data displayed with a nominal scale qualified and unqualified.

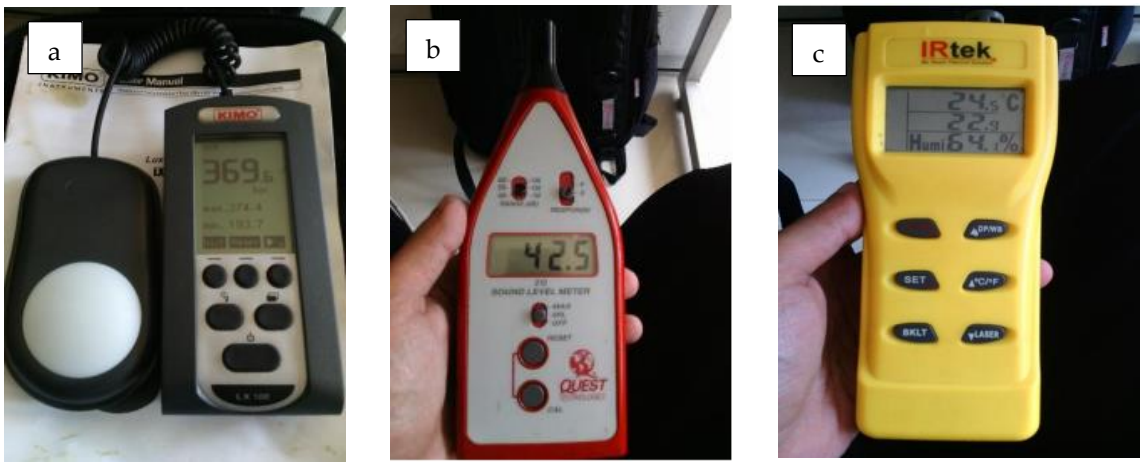

Figure 2.1 (a) Luxmeter LX-100; (b) Sound Level Meter; (c) Thermometer
Source: Indonesian Geospatial Information Agency, 2021

3. Results and Discussion

Based on 4 parameters measured, namely light intensity, noise, humidity and temperature, it was found that several workspaces showed measurement results that did not match the standards of the 64 rooms studied. Overall, the measurement results of 4 variables of physical environmental health factors meet the threshold values set by applicable regulations. However, some measurement results that are not up to standard can be caused by several factors. This will be discussed in the following sub-chapters.

3.1. Lighting

Lighting measurements were carried out in the morning at 8.00 WIB. This time was chosen as the time for workers to start their work in various zones available at PT. X. Lighting measurements are carried out at 40 office zone points available at PT.X. The Office Zone is located in the main building which is a place to conduct desk tasks and meetings. The average office zone has white paint. Walls with white color are considered to increase light levels in space by reflecting most of the incoming light (Sigura et al., 2022). Other studies state that rooms with white paint can increase alertness and performance in the workplace (Xie et al., 2023). This research is supported by research conducted by Kwallek et al., (1996) who examined the effects of monochromatic colors on workers' moods and clerical tasks. This study states that respondents with whitewashed workplaces have a lower level of distraction and are preferred by workers compared to rooms with paint with a combination of blue and red. Similar research states that bright color levels affect the mood of workers (Zeng et al., 2022).

The results of this study stated that there were 34 out of 40 rooms observed to have met the established quality standards (above 300 lux). This is possible because the majority of buildings have access to sunlight and large windows. According to Sigura et al. (2022), large office windows help the entry of sunlight. Uniquely, offices with windows closed with glass and those not covered with glass have different levels of light. Light that directly enters the room without any glass barrier produces 4300 lux in a white office room, while sunlight that enters through the window with glass produces a light level of only 2000 lux.

There are 6 rooms that do not meet quality standards. This is because the type of lamp used is different from 34 other rooms that have met the standard (Table 1). At the time of lighting measurement, some rooms were also found light bulbs that did not work, namely in the operating area there were 2 pieces and in the clinic area 1 piece. In rooms that do not meet the standards of lighting aspects in the work environment, it is necessary to improve the quality of the lights used. Based on the Regulation of the Minister of Health number 48

of 2016 concerning Office Occupational Safety and Health Standards, in order for lighting to meet health requirements, it is necessary to take action, namely natural and artificial lighting, efforts are made so as not to cause glare and have intensity according to its designation, the placement of light bulbs can produce optimal lighting and light bulbs are often cleaned, Light bulbs that start not working properly immediately Replaced. In the 6 rooms studied still use conventional lights because the lights have not completely turned off. In fact, by replacing conventional lamps with light-emitting diode (LED) lamps, it can increase light and be more energy efficient (Megahed &; Kotb, 2022). The reason why the department responsible for lighting is because this room is rarely used for work. So, it is not an urgency to directly replace conventional lamps into LED lamps which are considered more expensive economically.

Overall, of the 64 points studied, 85% of offcie zones, 50% in laboratory zones, 66% workshop zones, 60% of PLTP zones have met the threshold values determined by applicable regulations. At 5 points the laboratory zone is left to have a lower light intensity because it is a storage place for chemical, physical, and biological substances that do not require high light.

Table 1. Light Intensity Measurement

Quality Standards	Qualify (in units of space)	Not qualified (in units of space)
Office Zone	34	6
Laboratorium Zone	5	5
Workshop Zone	6	3
PLTP Zone	3	2

3.2. Noise

The monitoring and measurement results of noise levels in the office, laboratory, workshop, and geothermal power plant (PLTP) zones of PT. X can be concluded that the measured noise levels are still within acceptable limits, below 65 dBA for the office, laboratory, and workshop zones, and 85 dBA for the PLTP zone, in accordance with the quality standards for noise levels stipulated in the Minister of Health Regulation No. 70 of 2016 regarding Standards and Requirements for Occupational Environmental Health in the Industry.

Table 2. Noise Measurement

Quality Standards	Qualify (in units of space)	Not qualified (in units of space)
Office Zone	40	-
Laboratorium Zone	10	-
Workshop Zone	9	-
PLTP Zone	4	-

According to a report from Geoelec (2013), when there is a drilling rig, noise reaches 80-120 dB(A) within a radius of 100 m. Although at this level, noise does not directly pose a health hazard, workers in the PLTP Zone are required to use hearing protection. Each phase that occurs during drilling is differentiated based on the operation being performed, noise quality standards for air drilling, air drilling with suitable muffing, mud drilling, mud drilling with maximum muffling of 120, 80, 80, and 55 dB(A) respectively (Bošnjaković et al., 2019). This is supported by Bahadori et al. (2013), that in the geothermal industry, noise occurs in the drilling and construction phases. This explains why in table 2 that the noise power plant zone is still below the specified threshold value. This is because at the time of measurement there is no drilling, only normal operation of the plant. The sounds produced in normal operation include sound from turbines (73 dB-A), generators, fans, cooling towers, pumps, transportations, and fluid movement inside the tubes (Soltani et al., 2021).

According to research conducted by Ledingham & Cotton (2021), noise during the drilling phase has been monitored so as not to disturb the community. Although the geothermal industry is usually located in highland areas and there are not many houses around, monitoring is carried out with no drilling process at night and weekends.

3.3. Moisture

Humidity is often associated with temperature. In the geothermal industry located in the highlands has a cooler temperature than the temperature in urban areas. The temperature in the morning can reach 15oC while during the day, the temperature reaches 20-25oC. Based on the data obtained, it can be seen that most of the workspaces at PT. X has a high humidity exceeding 60%.

Table 3. Pengukuran Kelembapan

Quality Standards	Qualify (in units of space)	Not qualified (in units of space)
Office Zone	1	39
Laboratorium Zone	5	5
Workshop Zone	8	1
PLTP Zone	1	4

For humidity and temperature parameters are strongly influenced by the weather in industrial areas. PT. X is located at an altitude of ±1500 meters above sea level so it has a low mountain air temperature. Due to the low temperature, humidity in the working environment of PT. X tends to be high and when measuring the health of the work environment, some measurement results do not conform to established quality standards.

3.4. Temperature

Table 4. Temperature measurement

Quality Standards	Qualify (in units of space)	Not qualified (in units of space)
Office Zone	6	34
Laboratorium Zone	-	10
Workshop Zone	1	8
PLTP Zone	2	3

Based on the results of temperature measurements that have been carried out, it can be seen that several workplaces at PT. X Kamojang area is below the recommended number. This is due to the location of the company. located at an altitude of ±1400 meters above sea level whose daily temperature ranges from 15-20 ^{0} C. Recommendations that we can recommend according to the National Institute of Occupational Safety and Health (NIOSH) on the website of the Central of Disease Control and Prevention (CDC). Some policies that can be done to protect workers from cold conditions are: a. Schedule maintenance and repair work on conditions that are possible warmer day conditions. b. Reduce the burden of physical labor for workers. c. Provide warm water for workers. d. Provide heating room during break hours. e. Monitoring workers who may be at risk of cold stress Workers should avoid cold conditions whenever possible. But if cold weather is unavoidable, workers are expected to follow the following recommendations: a. Use appropriate clothing. 1) Use several layers of clothing that will provide better protection from the cold. 2) Do not use clothes that are too tight because it will cause blood flow to be interrupted. Blood requires circulation during cold weather. 3) Be careful when choosing clothes, do not use clothes that can cause difficulty in moving in dangerous circumstances. b. Be sure to use protection to protect your ears, face and hands when the weather

conditions are cold. 1) Shoes are expected to be waterproof and warm 2) Use a hat or head protection during cold weather, this will keep the body warm during cold weather because the amount of body heat will be lost in large quantities when the head is cold. c. Provide tools for cold weather such as extra socks, gloves, hats, and jackets. d. Provide a thermometer in the first aid kit. e. Avoid touching metal directly during cold weather with open arms. f. Monitoring one's own physical condition.

3.5. The Monitoring Form

In the form applicable to monitoring aspects of occupational physics in the workplace has not been divided into different zones for measurement of physical aspects of health of the work environment. Zone division needs to be done because the threshold values for each place are different. For example, the threshold value for the office zone is different from the threshold value for the PLTP zone so that zone division needs to be done. The PLTP zone as a place to measure the health of the work environment has not been listed on the monitoring form. In fact, PLTP is a place that also has workers and has a high level of noise hazard so it is necessary to measure the physical aspects of the health of the work environment in the PLTP zone. The inclusion of threshold values for each zone also needs to be added to the monitoring form of working physics aspects because each zone has a different threshold value and makes it easier to analyze measurement data so that it becomes more effective and efficient.

4. Conclusions

The conclusion of this study is the measurement of the health of the work environment at PT. X is performed by the HSSE function for routine and non-routine internal measurements as well as external measurements by 3rd parties. The results of physical measurement of health monitoring of the work environment have obtained quite good results. However, there are still several work environment locations that need to be improved, namely the lighting aspect by replacing the type of lamp that is brighter and humidity and room temperature with engineering to provide humidity control devices. In the health aspect of the work environment, companies can update the monitoring form based on work zones, making it easier to analyze measurement data so that it becomes more effective and efficient.

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Author Contribution

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Conflicts of Interest

The authors declare no conflict of interest.

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