A Field Study of Thermal Comfort in Indoor and Semi-Outdoor in Oil and Gas Company Semarang Indonesia

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Abstract

The study aimed to evaluate heats source using Wet Bulb Globe Temperature (WBGT) in ABC Oil and Gas Company located in Semarang, Indonesia. This study relies on thermal comfort responses from 153 questionnaires collected from November to December 2020 and objective measurements using WBGT parameters such as natural wet-bulb temperature, globe thermometer temperature, dry-bulb temperature, and humidity. Then the clothing insulation and metabolic rate are also included in the WBGT value. Then four areas do not meet for Threshold Limit Value by the American Conference of Governmental Industrial Hygienists (ACGIH) due to the WBGT results on moderate work showing more than 28 ºC. It was found that several areas do not meet the humidity requirements due to the humidity value being above 60%. In addition, heat source mapping is carried out to determine heat source radiation in the workplace. It is concluded that the heat source is at several points are detected. According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), "neutral" 's seven-point sensation scale had the most votes. The purpose of the study is also to provide recommendations for workers to avoid heats stress at work.

Keywords
Thermal sensation, thermal comfort, mapping, heat sources, oil and gas company workers.

1. Introduction
During the last decade, there has been a surge in the interest in assessing thermal comfort due to climate change and increased heat stress in cities. However, there have been few investigations on outdoor thermal comfort (Swaid et al. 1993, Nikolopoulou et al. 2001, Givoni et al. 2003, Spagnolo & de Dear 2003). On the other hand, many studies on thermal comfort, particularly for indoor environments, have been conducted. ASHRAE 55 Defines thermal comfort as "the state of mind that expresses satisfaction with the thermal comfort environment and measured by subjective evaluation. Thermal comfort suitable for one group or type of occupant may not be acceptable for another (Nakano et al., 2002). There are individual differences in preferences for thermal comfort, so it may not be possible to achieve an acceptable comfort level for all occupants. Wong NH and Feriadi (2004) mentioned that lots of outdoor thermal comfort research in humid subtropical climates are carried out in temperate and cold climates such as Hong Kong and Taiwan. However, there were very few studies carried out in Indonesia, especially in oil and gas companies. As a result, they were conducting a field study in Indonesia to examine the outdoor thermal environment and human thermal comfort perception.

Theoretically, the indices developed for indoor conditions can also be applied to outdoor environments. Due to the air conditioning can easily change an indoor environment. There are few options for making an outdoor environment comfortable. Indoor comfort indices are sometimes used in the outdoor environment. Spagnolo and de Dear (2003) reviewed the research on outdoor thermal comfort and questioned whether the theory developed indoor environment could be applied to an outdoor setting. Human adaptability is influenced by both indoor and outdoor climates as well. As a result, using both approaches to assess thermal comfort provides more reliable results (Zomorodian et al., 2016). Meteorological variables such as air temperature, humidity, radiation, wind speed, and human factor had included in outdoor comfort indices based on the energy balance of the human body (clothing and metabolism).

Another significant aspect of thermal comfort research is the distinctions between indoor, semi-outdoor, and outdoor settings, which have received little attention. Hoppe, P (2002) stated that physiological and psychological variables had to be considered and required different techniques for measuring indoor and outdoor thermal comfort. The difficulty in assessing thermal conditions is that the climate variables are much more diverse than indoor settings. Fanger (1970) discovered people in modern society spend the majority of their time inside. Thus the interior environment significantly influences occupants' productivity, health, and emotions, among other things. Indoor thermal comfort has been demonstrated in studies to considerably impact occupant happiness, health, and productivity (Yadeta et al., 2019). As a result, creating a high-quality indoor environment has become a significant concern in Oil and Gas companies.

Brown and Gillespie (1986) discovered that workers in the oil and gas industry are potentially exposed to the following hazards: impact from machinery parts or falling objects, exposure to toxic or harmful gases or chemicals, exposure to conductive and radiant heat transfer from machinery or pipes in processing, and exposure to thermal stress from climatic environments. Protective gear was required in the oil and gas sector to reduce the injury's severity and the risk of death when workers were exposed to the risks listed above. This research examined the importance of looking into the thermal performance of workers and the urgency to enhance it.

1.1 Objectives

Thermal comfort is widely recognized as one of the most significant components of indoor air quality. However, there have been relatively few studies on thermal comfort for the outdoor environment. This study examines thermal comfort in indoor and outdoor areas helpful in maintaining and improving occupants' health, comfort, and productivity. Several things must be done in this study to achieve this goal, there are:

1. Measuring WBGT for both indoor and outdoor as an objective measurement
2. Provide a thermal comfort questionnaire as a subjective measurement
3. Investigate the heat source and work areas that have a risk of heat exposure by mapping heat sources
4. Provide recommendations for workers to avoid heats stress at work.

2. Literature Review

Building design, opening design, and interior variables such as air temperature, air humidity, and wind speed all have a role in thermal comfort, particularly natural air cooling (Hendrarto et al., 2014). As mentioned before, there are individual differences in preferences for thermal comfort. Individual differences, according to Humphreys and Nicol (2002), are caused by phenomenological differences, such as (1) inter-individual differences in the temperature people consider neutral, (2) inter-individual differences in interpreting semantic scale categories, and (3) intra-individual variations in semantic judgments over time. According to Rupp et al. (2015), individual variations can be characterized as (1) physiological causes, such as metabolic heat disparities across people and age groups, and (2) cultural and behavioral differences manifested via clothing insulation. Personal differences, such as mood, culture, other individuals, organizational, and societal variables, impact thermal comfort. As a result, thermal comfort is defined as a state of mind rather than a physical condition (Noel et al., 2010). The condition of mind is used to define thermal comfort, which correctly highlights that determining whether or not to be comfortable is a cognitive process incorporating numerous inputs impacted by physical, physiological, and other aspects (Lin and Matzarakis 2008).

Olesen (2002) mentioned several factors related to the working environment, including hot and cold temperatures, colors, ventilation, and artificial or natural lighting, which can harm or benefit human health depending on the intensity and duration of exposure. As a result, it should be an appropriate location for the proportionate sound quality of life. The thermal balance of the human body in a given thermal environment is determined by elements such as air temperature, relative humidity, airspeed, average radiant temperature, clothing, and levels of human activity. Wang et al. (2018) investigated a Rubber factory's current indoor thermal environment in China and its impact on workers' thermal adaptation during the summer peak season. Workers were more tolerant of high temperatures than subjects in offices or residential buildings in the study. Hossain et al. (2019) provided an investigation of interior thermal conditions in garment factories and workers' subjective assessments at their workstations during Bangladesh's cool-dry, hot-dry, and warm-humid seasons. According to the study's findings, workers accepted a broader and significantly greater comfort temperature during the cool-dry and hot-dry seasons. The cumulative response of occupants to the thermal condition caused by various physical characteristics is thermal comfort. Providing thermal comfort to all building occupiers becomes a tough challenge.

Thermal comfort, indoor air quality, lighting quality (visual comfort), acoustic comfort, and office layout are all part of the physical indoor environment. Thermal comfort has the most significant impact on occupant comfort and productivity of all the elements (Frontczak and Wargocki 2011). According to Chua et al. (2016), there is a link between room temperature, illumination, and relative humidity and health-related concerns, including boredom, weariness, and attention challenges that influence worker productivity and performance. As a result, the physical environment's convenience affects the health of the building's residents and their job productivity. Tarantini et al. (2017) reviewed and explored the literature on the link between thermal comfort and workplace productivity using co-citation analysis. They concluded that providing pleasant room circumstances may improve worker welfare and productivity; the higher the operational level, the less productivity loss, the fewer people quit work due to illness, and health-related expenditures are reduced.

Parsons (2014), Chan and Yi (2016), and Krishnamurthy et al. (2017) observed that excess heat is standard in industrial workshops due to the demands of the manufacturing process. Heat stress is a prevalent physical work danger in the summer. Heat stress may have a negative influence on workers' health and performance at work. As a result, Qian et al. (2017) and Zhang (2016), workers who work in hot conditions are more likely to develop hypertension and have periodic electrocardiograms. Ghani et al. (2021) examined numerous thermal indices and discovered that the wet bulb globe temperature (WBGT) best-assessed heat stress in hot and dry settings. The WBGT is a complete evaluation index of heat stress for individuals exposed to hot environments, according to Alfano et al. (2014) and Budd (2008). It has been utilized in international and national standards for evaluating occupational heat stress exposure. The weighted average of the natural wet bulb and black globe temperatures is used to calculate the indoor WBGT rather than internal thermal environmental factors. Alfano et al. (2014) found that meteorological data or the four fundamental thermal ambient factors, namely indoor air temperature, mean radiant temperature, air velocity, and relative humidity, would be beneficial in determining the WBGT.

Furthermore, the ASHRAE questionnaire is also necessary to establish a benchmark for performance criteria to guide the industry and for methods of measurement or testing. The goal of ASHRAE Standard 55—thermal environmental conditions for human occupancy—is to "specify the combinations of the indoor space environment and personal variables that will generate thermal environmental conditions that are acceptable to 80% or more of the occupants inside a space.". While the standard does not define "acceptability," it is commonly acknowledged in the thermal comfort research field that "acceptable" is synonymous with "satisfaction" and that "satisfaction" is associated with "slightly warm, 'neutral," and "slightly cool" thermal sensation. In both laboratory and field investigations of thermal comfort, the subject of "thermal comfort" is the most frequently questioned. ASHRAE defines the thermal sensation as an occupant's sensory perception of their immediate environment (ASHRAE 2010).

3. Methods

Measurement of the heat stress in the working area is carried out by measuring the indicator of heat consisting of dry-bulb temperature, wet-bulb temperature, and radiant temperature. In addition, it is also necessary to measure the relative air and wind speed. General environmental temperature measured by the Wet Bulb Globe Temperature (WBGT) using Lutron Heat Index WBGT-208 Meter (see Figure 1). Measure environmental temperature and personal heat exposure in the workplace by directly measuring the area where workers do the work by measuring Wet Bulb Globe Temperature. The WBGT measurement tool is placed on a work table that is 1 meter -1.25 meter above the floor in 42 areas at ABC Oil and Gas Company in Semarang, Indonesia. These consist of 35 indoor areas and seven outdoor areas. There are seven outdoor areas such as Smoking Area (SA), Security Area for Tank Car (SATC), Flood Control Pump House (FCPH), Pump Area (PA), Pump Area Moving (PAM), Fire Station Outdoor (FSO), and Field (F). The location of the measurement point is determined at the place where the worker does the job. Moreover, subjective thermal comfort data were collected using a questionnaire derived from previous thermal comfort research (Spagnolo & de Dear 2003).

Figure 1. Lutron Heat Index WBGT-208 Meter

The questionnaire is given to workers in indoor and semi-outdoor areas, such as perceptions of temperature, wind, sun, clothes used at work, and the types of activities of workers before filling out the questionnaire. The questionnaire was distributed to wear the limits index (see Table 1) used in the ACGIH 2011 Threshold Limit Values (TLVs®) for Chemical Substances and Physical Agents and Biological Exposures Indices (BEIs®). The ACGIH exposures limits are intended to protect most workers from heat-related illness. The exposure limit should be reduced if the workers are wearing thicker garments.

Table 1. Correction of TLV for Clothing

Clothing Type	WBGT Correction (°C)
Work Clothes (long sleeve shirt and pants)	0
Cloth (woven material) coveralls	0
Polypropylene coveralls	+ 0.5
Polyolefin coveralls	+ 1
Double-layer woven clothing	+ 3
Limited-use vapor-barrier coveralls	+ 11

The threshold value of the work climate is the limit of exposure to the work environment climate or heat stress (WBGT values in °C) that should not be exceeded for 8 hours of work per day, five days per week with conventional breaks (see Table 2). The work climate requirements are based on the Threshold Limit Value (TLV) by the American Conference of Governmental Industrial Hygienists (ACGIH), published in 2013. The threshold value is determined based on the allocation of working time and rest time in one work cycle (8 hours per day) and the average metabolic rate of workers.

Table 2. Threshold Limit Value of Heat Stress

Allocation of work in a Work/Rest Cycle	WBGT (°C)			
	Metabolic Rate Category			
	Light	Moderate	Heavy	Very Heavy
75 – 100%	31,0	28,0	*	*
50 – 75%	31,0	29,0	27,5	*
25 – 50%	32,0	30,0	29,0	28,0
0 – 25%	32,5	31,5	30,5	30,0

* For physiological reasons is not allowed

The heat map is a graphical representation of data that utilizes a color-coded system. The heat map depicts where the emergency help group should be prepared to assist in an emergency—present study using Surfer software to create heat source maps. Surfer is a contouring and 3D surface mapping software program.

4. Data Collection

The researchers have conducted a review of related literature, direct observations. Objective measurements of thermal comfort using WBGT to correctly and factually represent the existing thermal condition of workers. Then do a subjective survey to know regarding the perception.

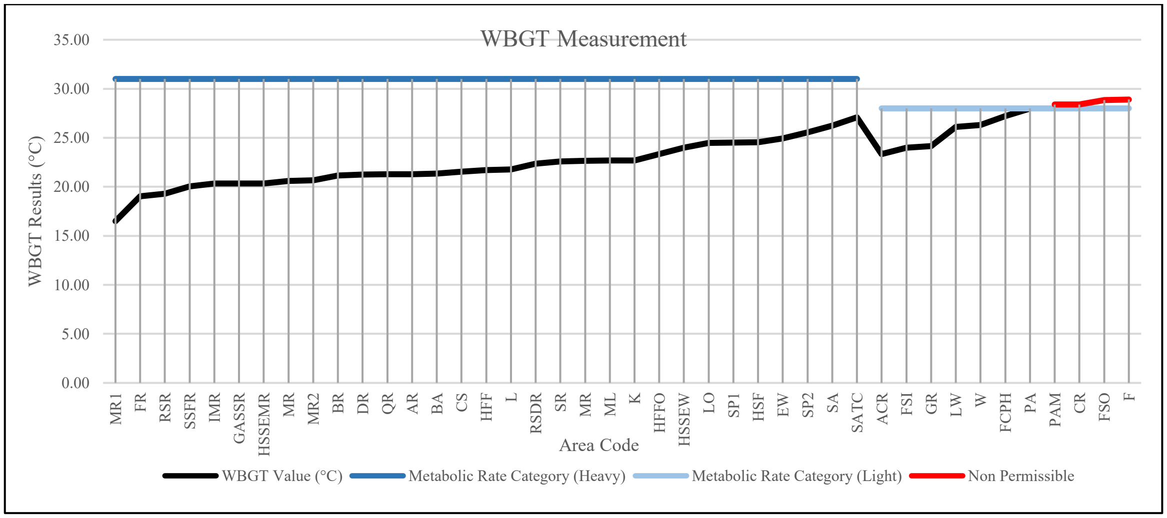

Figure 2. WBGT Data

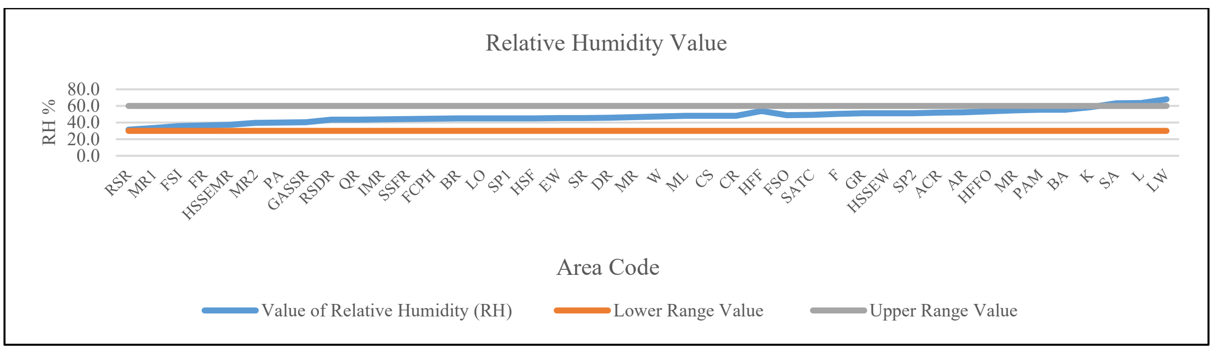

Figure 3. Relative Humidity Data

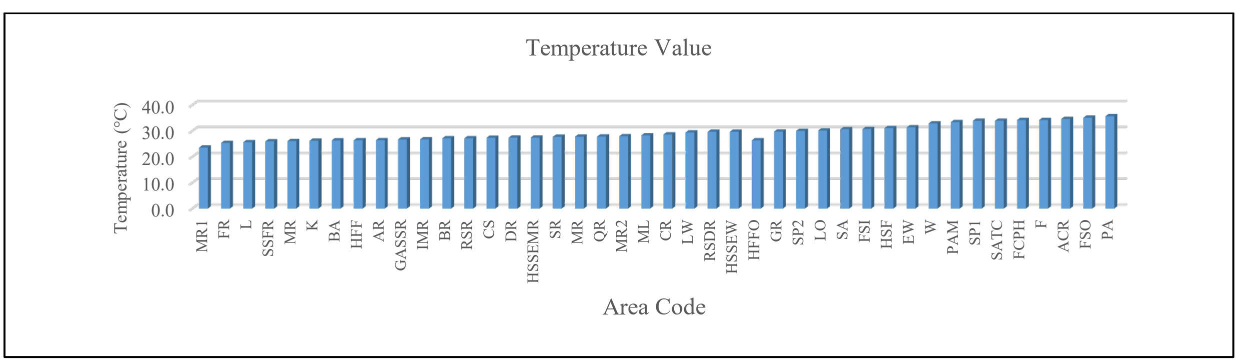

Figure 4. Temperature Data

Abbreviations: Meeting Room 1 (MR1), Finance Room (FR), Receive and Storage Room (RSR), Sales Service Finance Room (SSFR), IT Manager Room (IMR), General Affair and Sales Service Room (GASSR), HSSE and Maintenance Room (HSSEMR), Marine Room (MR), Meeting Room 2 (MR2), Ballroom (BR), Distribution Room (DR), Quality Room (QR), Archive Room (AR), Break Out Area (BA), Co-working Space (CS), Hallway First Floor (HFF), Laboratory (L), Receiving Storage and Distribution Room (RSDR), Stationary Room (SR), Medical Room (MR), Main Lobby (ML), Kitchen (K), Hallway First Floor Open Space (HFFO), HSSE Warehouse (HSSEW), Lubricant Office (LO), Security Post 1 (SP1), Hallway Second Floor (HSF), Engineering Warehouse (EW), Security Post 2 (SP2), Security Area for Tank Car (SATC), Additional Control Room (ACR), Fire Station Indoor (FSI), Genset Room (GR), Lubricant Warehouse (LW), Workshop (W), Flood Control Pump House (FCFH), Pump Area (PA), Pump Area Moving (PAM), Control Room (CR), Smoking Area (SA), Fire Station Outdoor (FSO), and Field (F).

5. Results and Discussion

The Wet Bulb Globe Temperature Index measurement conducted in 35 indoor and seven outdoor areas can be seen in Figure 2). The areas that do not meet the ACGIH Threshold Limit Values are PAM, CR, FSO, and F (see red line on the WBGT results). PAM workers monitor water availability (raw water) for refinery operations, fire protection, and office use. The worker is also in charge of inspecting product pumps and rally valves. Workers are required to work outdoors for approximately 1.5 hours. Workers in the PAM section usually stay indoors, but they sometimes check on the outdoor area twice a day with a temperature of 28.40 ºC and coverall clothing on and people who work at the fire station. At the same time, workers' task in the CR section is to receive and stockpile fuel. The highest temperature is in the pump area, 35.6 ºC, and in the fire station area, 35.1 ºC (see Figure 4). Eliminating the danger and the risk associated with it is the most effective control measure. In this case, the heat hazard cannot be eliminated, and substitution means the company cannot make the end product. As a result, one option is to change the clothing material that can cool down when the workers heat up (see Figure 7-PPE).

High humidity will inhibit evaporative heat escape from the skin and induce pain in hot and humid conditions, lowering the thermal comfort threshold (Szokolay 1985). However, increasing the airflow speed around occupants can help to increase evaporative heat loss from the skin by replacing humid, saturated air with fresh, unsaturated air (Szokolay 1987). As a result, raising the airflow rate can assist occupants in achieving thermal comfort. The ratio of the quantity of moisture that air can carry at the exact moment is known as relative humidity. RH is measured in percentages. High relative humidity and hot air temperatures are both unpleasant; the lower the relative humidity in a location, the lower the air temperature should be (Binggeli 2010). As the results (see Figure 3), Relative humidity not by ASHRAE's recommendation is a smoking area, laboratory, and lubricant warehouse. To evaluate and maintain the best room humidity, install a hygrometer (See Figure 7-engineering controls). The ASHRAE guidelines recommend relative humidity of 30 to 60 percent (ASHRAE, 2004). Mold and mildew can thrive in environments with high relative humidity (more than 60%). Dust mites, germs, and fungi are all attracted to moist, humid climates. Workers may feel eye irritation or a stuffy nose when the relative humidity is low (less than 30%).

According to ASHRAE standard 55, "Thermal Environmental Conditions for Human Occupancy," when the temperature is between 21 ºC – 26 ºC, individuals feel at ease. However, achieving general thermal comfort in a structure is a complex undertaking because it depends on various factors such as age, gender, metabolism rate, and the time of year (ASHRAE 2003). The indoor temperature in the oil and gas company with the highest maximum value is 35.6 ºC, and the minimum temperature is 23.5 ºC. Higher temperature conditions occur in a pump area, and minimum temperature occurs in meeting room 1. Every aspect of oil and gas production necessitates the use of industrial pumps. Pumps assist in the movement of process fluids from one location to another. The increase in fluid pressure is needed to overcome obstacles during flow. The pump area is a hot location, maybe because the water pump can work every day for a long time. Internal forces can also cause thermal stress on pipeline components. The vapors of certain volatile hydrocarbon fuels will cause supercooling of the remaining liquids if allowed to escape from the pipeline system at substantial rates. Thermal cracking of pipes and pump housings can occur due to supercooling (Pharris & Kolpa, 2017). Things that can be done to reduce exposure to heat stress include routine medical control, medical precautions, physical fitness programs, and ensuring water consumption by workers. In addition to conducting heat stress training for workers (See Figure 7-administrative controls).

The results of the survey related to the perception showed that 97 workers felt that temperature at the time of measurement was "neutral," 24 workers felt "cool," 14 workers felt "hot," 9 workers felt "slightly warm," 5 workers felt "warm." Four workers felt "slightly cold." The workers who feel the temperature is "hot" are in the work section, such as the loading master, field foreman, gardener, security, and grass tripe. On the other hand, the perception of heat is influenced by the clothing worn at work. From data obtained by workers who feel the temperature is "hot: wearing clothes such as jumpers, long sleeves, trousers, vests, socks, safety shoes, and helmets. The distribution of subjective thermal comfort votes is depicted in Figure 4.

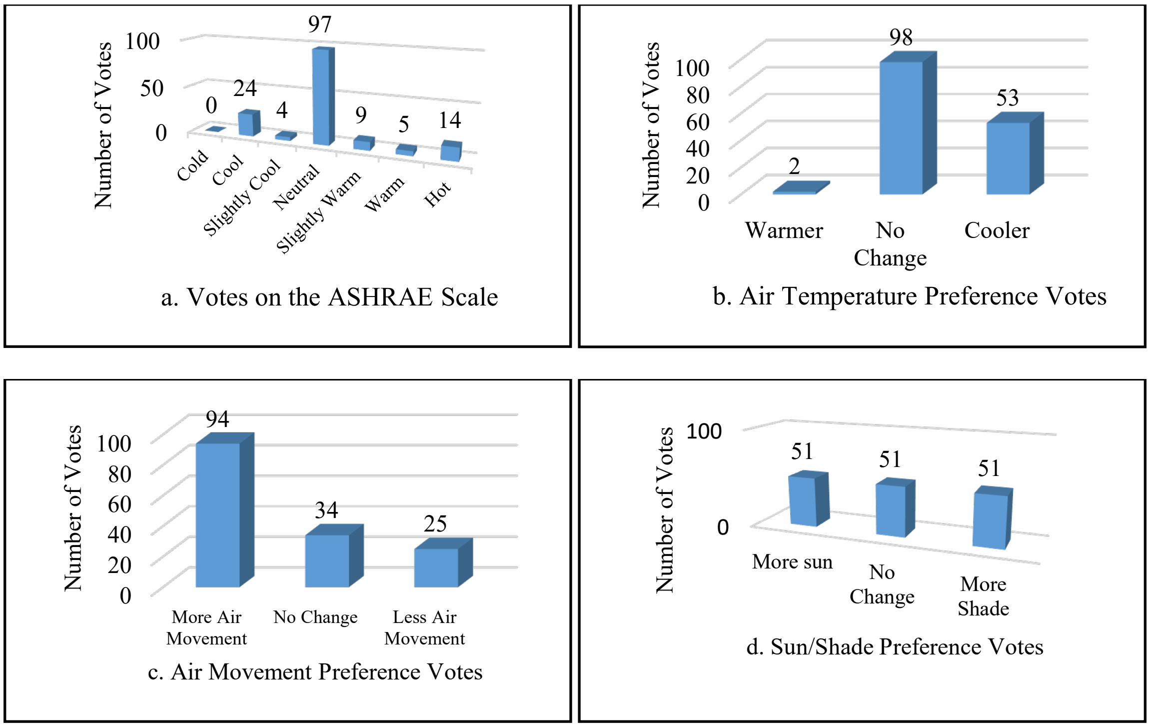

Figure 5. Frequency Distribution of Questionnaire Responses

Most of the clothing worn by workers is neutral in temperature (see Figure 5a). Because the air temperature in the workplace is typically hot, and the entire space is equipped with air conditioning and cotton clothing that is neutral in temperature. Workers who choose to be 'cooler' work in fields like engineering and marine (see Figure 5b). Workers are frequently hot when inspecting technical equipment because the ventilation engineer room is inadequate, with only one door and no operable windows. Workers who choose the desired wind conditions with no changes (see Figure 5c) have to work activities such as CR, which can endanger workers above the stockpile tank. Workers who choose the desired wind conditions have work activities such as the CR, which can be dangerous if located above the stockpile tank. Workers who prefer more wind movement have jobs like maintenance service, where the wind movement in the workshop room is not optimal because there is only one door and no windows to open. When working, a shadier environment is preferred (see Figure 5d). The scorching sun can make workers uncomfortable while performing work tasks and cause them to become tired quickly. Differences in perception of the sun depending on the worker's location are completing his work like loading masters want less sun because they work in a field with no cover.

One hundred five workers prefer to wear light colors, and 37 workers prefer to wear dark colors—workers like light clothing colors since they can affect their mood and make them calmer while working. Furthermore, compared to dark-colored clothing, light-colored clothing absorbs less heat, making light-colored clothing more comfortable for workers. The heat source map (see Figure 6) shows that the most significant heat source is the refinery area. This area is a place for controlling workers where the work carried out quality measurements manually at the refinery.

5.1 Graphical Results

Employees were given questionnaires to learn their subjective responses to thermal comfort, as shown in Figure 5. Occupational Safety and Health Administration (OSHA) explained that the human body relies on its ability to get rid of excessive heat (i.e., heat dissipation) to maintain a healthy internal body temperature in a hot environment, especially when physically engaged. Sweating and increased blood flow to the skin help to dissipate heat naturally. Workers cool down more rapidly if the external (environmental) heat and physical activity (metabolic rate) is reduced. In thermally stressful conditions, the effects of hypohydration are additive to the effects of environmental heat stress. A program to track and increase workers' hydration levels is an essential component of a comprehensive working-in heat policy found to lower the incidence of heat illness (Brake, R. and Bates, G 2000). As shown in Figure 6, the heat source is at several points are a refinery, control room, pump area, fire station, and lubricant warehouse.

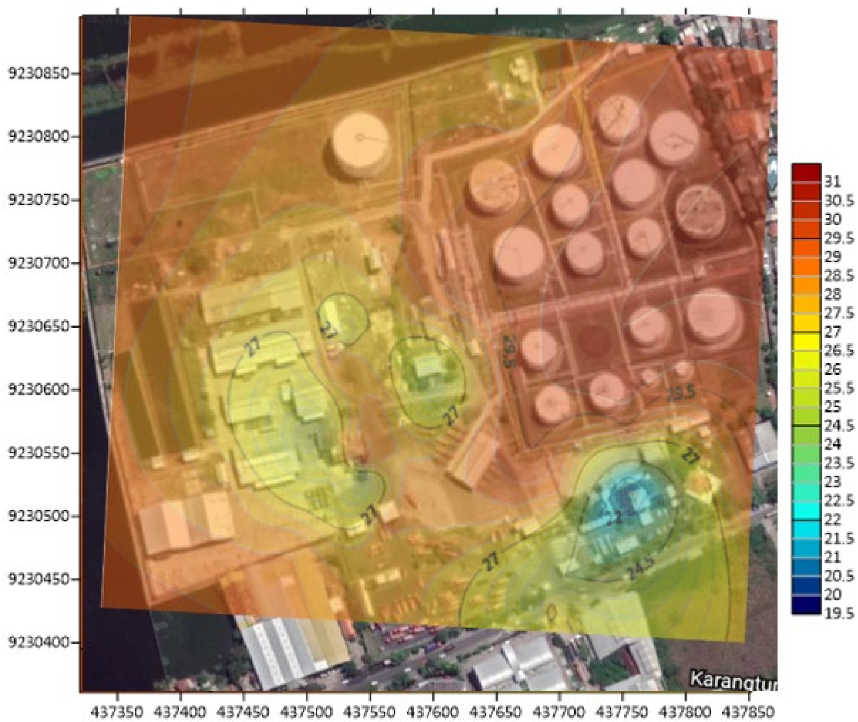

Figure 6. Heat Source Map

The following recommendations are suggested from Miller V. and Bates, G. (2007) for work that is undertaken in hot conditions (outdoors):

- Workers should be informed of the need and for proper hydration and fluid replacement beverages.
- Workers should check their hydration levels, either using urine test strips for specific gravity (SG), which should be made available or by looking at pee color and volume.
- The HSSE department should keep track of workers' hydration levels regularly (urine SG measurement)
- The following fluid is recommended:
    - Manual workers: 1 liter of plain water (supplemented by regular meal breaks) or industrial rehydration fluid per hour (containing electrolytes and some carbohydrates)
    - Operator machinery, etc.: 600 mL/hr of water (in addition to food and any other beverages consumed)
    - Workers that are sedentary: 400 mL/hr of water (in addition to food and any other drinks consumed).
- Food must be ingested throughout meal breaks to restore electrolytes and keep energy levels up.
    - Caffeinated beverages should be avoided before and during work shifts (possible by limiting availability)
    - If possible, the surroundings should be altered, such as by adding shade or increasing ventilation.

5.2 Proposed Improvements

The proposed improvements created an approach based on the hierarchy of hazard control. The hierarchy of controls has been used to determine how practical and effective control measures can be implemented (see Figure 7). The outcomes are expected to improve thermal comfort in oil and gas companies both indoors and outdoors.

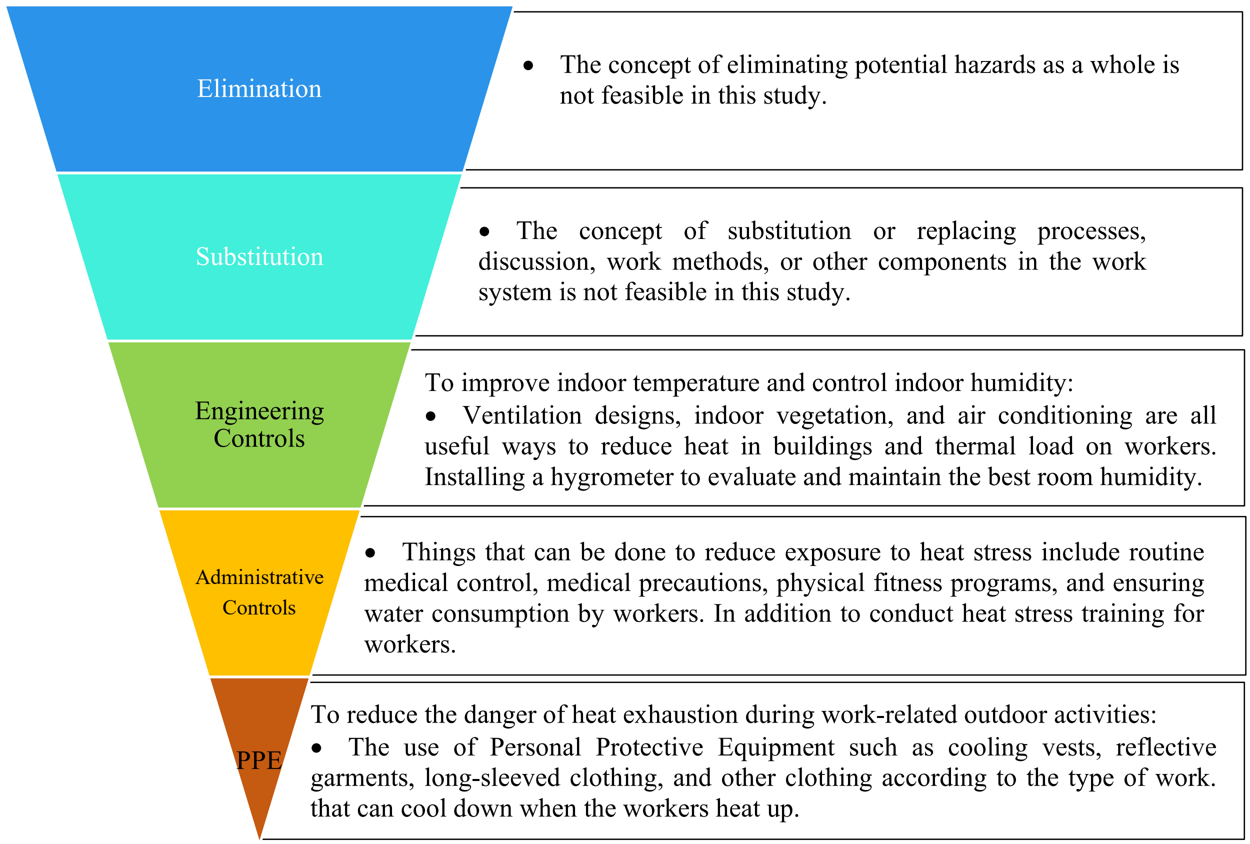

Figure 7. Recommendations to improve thermal comfort for workers

There are two distinct reasons for bringing fresh air into a building. Fresh air is brought in to provide oxygen and assist in the removal of CO2 and body odors. Whatever the climate, ventilation is always required (Binggeli, 2010). Without fans, natural ventilation circulates a source of fresh air at an acceptable temperature and humidity throughout a building. Air is moved from high-pressure areas to lower pressure areas by wind or convection. The volume, speed, and direction of the airflow are all controlled by mechanical controls. The heat loss induced by evaporation is increased by air movement, which is why a fan can make us feel more comfortable. This sensation is known as effective temperature, which creates the illusion of greater or lower temperatures by adjusting air moisture without changing the space's temperature.

In general, several ventilation systems are available to control ventilation in buildings. There are three types of ventilation systems: naturally ventilated, hybrid/mic mode, and mechanically ventilated. According to research carried out by Ezzeldin and Rees (2013), mixed-mode HVAC systems have higher air quality satisfaction and energy savings than traditional HVAC systems. However, an HVAC system should be chosen based on various parameters such as local temperature, building type, and tenant behavior patterns and expectations (Kim & de Dear, 2012). A comprehensive plan layout with a larger outdoor surface area for ventilation is required in a tropical environment. For maximum pressure and thus optimal ventilation, louver windows above panels are recommended—more cross ventilation with perpendicular windows (Sahabuddin, Firrdhaus, & Gonzalez-Longo, 2015). Furthermore, natural ventilation as a passive cooling method in buildings appears to have considerable benefits over other artificial cooling techniques, such as passive design techniques in tropical areas.

Furthermore, indoor vegetations have a variety of effects on people's thermal comfort. Plants can serve as figurative cues, reminding building occupants of outdoor environments and, as a result, expanding their thermal comfort range as if they were outside (Mangone et al. 2014). Supported by Purwaningsih et al. (2018), recommendations to improve thermal comfort by adding vegetation to the room must be considered to add landscape vegetation. The positive impact of plants may have a more significant impact on people's perceptions of thermal comfort than the negative impact of uncomfortable temperatures. Hellinga and de Bruin-Hordijk (2010) have discovered that having plants in the office reduces the adverse effects of glare and low light levels on office workers. As a result, if plants improve occupant thermal comfort, they may also help mitigate the negative impact of hot temperatures on worker productivity.

6. Conclusions

A total of 153 workers responded regarding the thermal comfort at their place of work. Four areas do not meet for Threshold Limit Value by the American Conference of Governmental Industrial Hygienists (ACGIH) in 42 areas due to the WBGT results on moderate work showing more than 28 ºC. It was found that several areas do not meet the humidity requirements because the humidity value is above 60%. According to the ASHRAE seven-point sensation scale responses, "neutral" had most of the votes. Including "cool" and "hot," those three categories represent 89% of the votes—heat perception is obtained by the type of clothing worn at work. It is essential to be aware of heat exposure in the pump room, outdoor fire station area, field (refinery), and control room. The comfort zones of the outdoors and the inside may differ. When we are outdoors rather than in an indoor environment, psychological factors may significantly impact us.

As mentioned before, there are individual differences in preferences for thermal comfort, so it may not be possible to achieve an acceptable comfort level for all occupants. It is required to ensure that each recommendation is effective in combating the effects of work environment factors. The implementation of technical engineering is prioritized, followed by administrative engineering, then the provision and monitoring of personal protective equipment (PPE). Some suggestions for reducing heat stress include installing insulation, ventilation, and shielding, scheduling work and rest hours to minimize worker exposure, providing drinking water and clothing vests, particularly in hotter areas. Of course, each recommendation may or may not be implemented immediately, but a more thorough investigation is required first. Systemic considerations, such as technical, operational, and financial feasibility reviews, must be carried out.

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