



Occupational Heat Exposure and Dehydration Prevention Practices in a Sugar Manufacturing Facility: A Qualitative Assessment in Lampung, Indonesia

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Abstract

Occupational heat exposure represents an important health and safety concern in the sugar manufacturing industry, where workers may experience prolonged exposure to heat generated by boilers, evaporation processes, and production machinery. Excessive heat exposure, particularly when combined with physical workload and inadequate fluid replacement, may increase the risk of dehydration and heat-related illness. This study aimed to assess occupational heat exposure conditions, existing workplace control measures, and dehydration prevention practices at a sugar manufacturing facility in Lampung, Indonesia. A descriptive qualitative approach was employed using workplace observations, field surveys, interviews with workers and company representatives, and a review of available occupational health and safety information. The assessment focused on production and boiler areas, perceived heat exposure, worker-reported symptoms, ventilation systems, personal protective equipment, drinking water availability, rest arrangements, and occupational health services. The findings were analyzed descriptively to identify existing preventive measures and potential gaps in workplace heat-stress management. The production and boiler areas were identified as workplaces with substantial potential for heat exposure due to continuous operation of processing equipment and heat-generating machinery. The facility employed approximately 485 workers and operated through three daily shifts. Workers reported experiencing hot working conditions, thirst, excessive sweating, fatigue, and dizziness during work activities. Existing occupational health measures included ventilation systems, cooling fans, personal protective equipment, access to drinking water, designated rest areas, workplace safety procedures, periodic medical examinations, and a company health clinic with 24-hour medical personnel. However, objective Wet Bulb Globe Temperature (WBGT) measurements and a specific worker hydration monitoring program were not documented. Consequently, the magnitude of occupational heat exposure and the prevalence of dehydration could not be established. The findings identify potential occupational heat hazards and highlight the importance of strengthening heat-specific preventive practices within an existing occupational health and safety system. Although general workplace safety and healthcare facilities were available, systematic heat exposure assessment, worker hydration monitoring, targeted education, and exposure-appropriate work-rest arrangements require further attention. Integrating these measures into occupational health management may support more comprehensive heat-stress prevention in sugar manufacturing facilities. Further quantitative investigations are necessary to evaluate environmental heat exposure, hydration status, and the effectiveness of preventive interventions.



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1. Introduction

Occupational heat exposure is a major concern in industrial health and safety because workers may experience prolonged thermal stress during physically demanding activities and continuous production operations. Heat exposure in occupational environments results from interactions between environmental temperature, humidity, radiant heat, airflow, metabolic workload, and protective clothing. These conditions may challenge physiological thermoregulation, increase cardiovascular demands, and contribute to fatigue, heat-related illness, and occupational injuries. Varghese et al. (2020) examined heat-related injuries in Australian workplaces from the perspectives of health and safety

representatives and identified workplace and organizational factors relevant to prevention. Similarly, [Ioannou et al. \(2021\)](#), through multi-country occupational observations and interventions, demonstrated the importance of environmental heat exposure and physiological strain in understanding workers' health and productivity. These findings suggest that occupational heat exposure should be considered a complex workplace hazard requiring coordinated preventive management rather than being evaluated solely through perceived ambient temperature.

The physiological response to environmental heat involves increased skin blood flow and sweat production to facilitate heat dissipation. However, sustained sweating during prolonged physical activity may produce substantial fluid losses, particularly when fluid replacement is inadequate. The balance between water intake and fluid loss is therefore important for maintaining hydration and physiological functioning. [Gandy \(2015\)](#) emphasized the importance of reliable water intake assessment in understanding hydration status and establishing appropriate recommendations. Field research by [Al-Bouwarthan et al. \(2020\)](#) further demonstrated the relevance of examining hydration status, physical workload, and environmental heat exposure together among construction workers in extreme summer conditions. These observations indicate that workplace hydration management should consider not only drinking water availability but also exposure duration, work intensity, and individual fluid replacement practices.

Dehydration and heat-related illnesses are influenced by multiple environmental, occupational, and individual factors. Workers performing physically demanding tasks in hot environments may experience elevated physiological strain, especially when heat exposure is combined with insufficient rest and inadequate hydration. [Kakamu et al. \(2021\)](#) investigated personal and environmental factors associated with heat-related illness among construction workers, highlighting the importance of evaluating both individual and workplace conditions. In addition, [Mizelle et al. \(2022\)](#) examined fluid intake and hydration status among agricultural workers and identified occupational and contextual barriers affecting appropriate hydration practices. These studies demonstrate that environmental heat exposure does not necessarily produce identical physiological effects among all workers and that subjective symptoms alone are insufficient for determining the presence or severity of dehydration. Consequently, systematic assessment of hydration status and associated occupational conditions is necessary for accurately evaluating heat-related health risks.

Occupational heat exposure may also affect workers' safety, concentration, and capacity to perform assigned tasks. Heat-related fatigue and physiological discomfort can create additional challenges in workplaces that depend on continuous machinery operation, repetitive movements, and sustained physical activity. [Han et al. \(2021\)](#) investigated workers' perceptions of workplace heat exposure and adaptation behaviors, demonstrating the relevance of worker awareness and behavioral responses to environmental heat. [Goodman et al. \(2023\)](#) further examined differences in heat management approaches among outdoor employees and contractors, emphasizing the influence of organizational arrangements on workers' capacity to manage exposure. These findings support the importance of incorporating workers' experiences and workplace organizational characteristics into occupational heat assessments. However, perceived thermal discomfort should not be interpreted as an objective measure of heat exposure or as evidence that occupational heat exposure limits have been exceeded.

Objective occupational heat assessment is necessary for determining exposure intensity and guiding appropriate preventive measures. The Wet Bulb Globe Temperature (WBGT) index is widely used in occupational health assessments because it incorporates environmental factors associated with thermal stress. Nevertheless, its interpretation should also consider metabolic workload, clothing characteristics, and occupational exposure duration. [Abbasi et al. \(2023\)](#) evaluated the validity of multiple empirical heat stress indices in predicting workers' physiological responses under different occupational and climatic conditions. Their findings demonstrated the relevance of selecting appropriate environmental heat indices when assessing physiological strain. Therefore, workplace assessment should distinguish between qualitative observations of potentially hot working environments and quantitative measurements capable of characterizing actual thermal exposure. Without objective environmental data, the severity of heat stress and compliance with occupational exposure recommendations cannot be reliably determined.

Preventive management of occupational heat exposure requires an integrated combination of engineering controls, administrative measures, hydration management, and worker education. Engineering approaches may include controlling heat sources, improving ventilation, reducing radiant heat exposure, and implementing appropriate cooling technologies. Personal cooling systems have also been investigated as supplementary strategies for managing occupational heat strain. [Mori et al. \(2022\)](#) examined the potential of fan-attached jackets to mitigate physiological heat strain in hot or humid conditions, while [Del Ferraro et al. \(2022\)](#) evaluated the cooling performance and evaporative resistance of a ventilation jacket designed for occupational environments. Similarly, [Wang et al. \(2023\)](#) investigated a phase-change cooling garment intended to improve thermal comfort among factory workers. These findings demonstrate the potential of different cooling technologies, although their suitability depends on workplace conditions, metabolic workload, protective equipment requirements, and operational feasibility. The implementation of such technologies should therefore be evaluated alongside broader workplace heat management practices.

Administrative and behavioral interventions are also important components of occupational heat prevention. These may include regular opportunities for fluid replacement, appropriately scheduled rest periods, heat acclimatization, education concerning heat-related symptoms, and procedures for responding to suspected heat-related illness. [Chicas et al. \(2021\)](#) investigated cooling interventions among agricultural workers, providing field-based evidence concerning the use of personal cooling approaches. [Santos et al. \(2022\)](#) evaluated a participatory Heat Education and Awareness Tools intervention among agricultural workers, illustrating the relevance of structured worker education in occupational heat management. In addition, [Kakamu et al. \(2024\)](#) examined the timing of salt intake in relation to heat-related illness, indicating that hydration-related preventive practices may require attention to the circumstances and timing of fluid and electrolyte replacement. Collectively, these studies reinforce the need for preventive strategies that address both environmental conditions and worker behavior. Nevertheless, the effectiveness of individual interventions cannot be assumed without appropriate workplace monitoring and outcome evaluation.

Sugar manufacturing represents an occupational setting in which thermal exposure may arise from boilers, evaporation equipment, heating operations, and other production processes. At the sugar manufacturing facility examined in Lampung, Indonesia, the original field assessment described approximately 485 employees working under a three-shift production system. The production and boiler areas were identified through workplace observation and interviews as locations with potential heat exposure, while workers reported symptoms including thirst, fatigue, dizziness, and excessive sweating. Existing occupational safety measures included ventilation facilities, protective equipment, access to drinking water, rest areas, workplace safety procedures, and occupational health services. However, objective WBGT measurements

and systematic worker hydration assessments were not documented, limiting evaluation of actual thermal exposure and confirmed dehydration outcomes. The central research issue is therefore the distinction between the availability of general occupational health infrastructure and the implementation of specific, evidence-based heat management practices. Accordingly, this study aims to qualitatively assess occupational heat exposure conditions, existing workplace preventive measures, and implementation gaps in dehydration prevention practices at a sugar manufacturing facility in Lampung, Indonesia. The findings are intended to support the identification of priorities for future environmental monitoring, hydration assessment, worker education, and occupational heat risk management.

2. Materials and Methods

2.1. Study Design and Occupational Setting

This study employed a descriptive qualitative approach to assess occupational heat exposure conditions, existing workplace control measures, and dehydration prevention practices at a sugar manufacturing facility, referred to as PT X, in Lampung, Indonesia. The study focused on identifying potential occupational heat hazards, documenting workplace safety practices, and examining the implementation of preventive measures within the company's occupational health and safety (OHS) management system. A qualitative approach was considered appropriate for describing workplace conditions, employee experiences, organizational practices, and potential implementation gaps where quantitative environmental and physiological measurements were unavailable. The assessment was conducted through workplace field surveys, direct observations, interviews with workers and company representatives, and examination of available occupational health and safety information. Particular attention was given to production and boiler areas because these locations involved industrial processes capable of generating substantial environmental heat, including boiler operation, sugar processing, evaporation, and other machinery-related activities. The assessment considered the interaction between workplace heat sources, physical work activities, protective equipment, ventilation, and organizational arrangements that could influence worker exposure.

The facility employed approximately 485 workers and operated continuously through a three-shift system. According to the original company-level information, the morning shift operated from 08:00 to 15:00, the afternoon shift from 15:00 to 23:00, and the night shift from 23:00 to 07:00. A rotating schedule involving three working days followed by one day off was also reported. These characteristics were considered relevant to occupational exposure assessment because the organization of working hours, task assignments, and rest opportunities may influence the duration and frequency of worker contact with heat-generating equipment. However, the total workforce represented the company's reported employee population rather than the number of participants interviewed.

The qualitative assessment was informed by previous research examining heat exposure perceptions, workplace adaptation practices, and occupational heat management. [Varghese et al. \(2020\)](#) highlighted the relevance of workplace safety representatives' perspectives in understanding occupational heat-related injuries, while [Han et al. \(2021\)](#) demonstrated the importance of examining worker perceptions and heat adaptation behaviors. [Goodman et al. \(2023\)](#) further emphasized that organizational practices and employment arrangements may influence workers' opportunities to manage heat exposure. These studies provided a conceptual basis for examining both environmental conditions and organizational prevention practices in the present industrial setting. The available source manuscript did not specify the exact dates or total duration of fieldwork, number of interviewees, participant recruitment criteria, or length of observation sessions. These details therefore could not be established retrospectively. The present study was treated as a descriptive workplace assessment rather than a quantitative exposure study, intervention trial, or epidemiological investigation of confirmed dehydration cases.

2.2. Data Collection and Workplace Heat Exposure Assessment

Data collection was based on three principal sources: direct workplace observations, interviews with workers and company representatives, and available company occupational health and safety information. These sources were used to describe existing occupational conditions and preventive measures associated with heat exposure and potential dehydration risk. Workplace observations focused on production activities, boiler operations, heat-generating machinery, ventilation arrangements, protective equipment, and the general availability of facilities relevant to occupational heat management. The assessment considered the presence of mechanical ventilation, cooling fans, work areas near major heat sources, drinking water facilities, rest areas, and occupational healthcare services. Attention was also given to work organization, including shift scheduling and reported work–rest arrangements, because these factors may influence cumulative occupational heat exposure.

The environmental observations were qualitative and did not establish the magnitude of thermal exposure. The original assessment did not report objective Wet Bulb Globe Temperature (WBGT) measurements or complete measurements of air temperature, relative humidity, radiant temperature, and air velocity. Consequently, the study could not determine actual heat stress levels or compare workplace conditions quantitatively with occupational exposure limits. This distinction is important because the physiological effects of occupational heat exposure depend on environmental conditions, metabolic workload, clothing characteristics, and individual thermoregulatory responses. [Abbasi et al. \(2023\)](#) demonstrated the importance of selecting and validating appropriate heat stress indices when evaluating physiological strain under different occupational and climatic conditions. Worker interviews were used to obtain descriptive information concerning perceived workplace temperatures, heat-related discomfort, working conditions, and possible symptoms associated with occupational heat exposure. The original report identified complaints including thirst, fatigue, dizziness, and excessive sweating, particularly among workers assigned to production and boiler areas. These complaints were interpreted as self-reported experiences potentially associated with hot working conditions rather than objective evidence of dehydration or clinically diagnosed heat-related illness.

The distinction between perceived heat exposure and physiological heat strain was considered important in interpreting the interview findings. Previous field research has demonstrated that subjective perceptions, environmental measurements, and physiological indicators provide complementary but different information about occupational heat exposure. [Ioannou et al. \(2021\)](#) investigated occupational heat stress through multi-country field observations and intervention assessments, illustrating the value of combining environmental and physiological measurements. Similarly, [Al-Bouwarthan et al. \(2020\)](#) examined worker activity, hydration status, and heat strain under extreme environmental

conditions, providing evidence of the importance of integrated occupational exposure assessment. Information concerning worker hydration practices was evaluated through the reported availability of drinking water and descriptions of workplace prevention measures. The assessment considered whether the company provided water facilities and whether specific hydration monitoring procedures were documented. However, the original study did not include quantified water consumption, urine specific gravity, urine osmolality, changes in body mass, or other objective indicators of hydration status.

The interpretation of these limitations was informed by [Gandy \(2015\)](#), who discussed methodological considerations associated with water intake assessment, and [Mizelle et al. \(2022\)](#), who examined fluid intake and hydration status among agricultural workers using a mixed-methods approach. These studies demonstrate that water availability, reported drinking behavior, and physiologically assessed hydration status represent different dimensions of hydration management. Accordingly, the availability of drinking water at PT X was treated as a workplace resource rather than evidence that workers maintained adequate hydration. Additional information was obtained from descriptions of the company's occupational health and safety system. The original manuscript reported written safety policies, safety briefings, occupational safety procedures, personal protective equipment, an Occupational Health and Safety Committee (P2K3), workplace safety facilities, periodic medical examinations, and occupational healthcare services. The company was also reported to maintain a health clinic with medical personnel available throughout the day and night.

The assessment incorporated information concerning periodic medical check-ups, workplace health complaints, availability of first aid and emergency arrangements, and occupational risk management procedures. These organizational practices were considered relevant because the management of heat-related occupational hazards requires both environmental prevention and the capacity to recognize and respond to worker health complaints. However, the availability of company-level services was not interpreted as proof that every worker received the same level of protection. The original report did not provide complete individual medical examination records, heat-related illness incidence data, or documented evaluation of preventive program effectiveness.

2.3. Qualitative Data Analysis and Evaluation of Preventive Practices

The collected information was analyzed descriptively to identify potential occupational heat hazards, worker-reported symptoms, existing preventive measures, and gaps in workplace heat management. Information obtained through observation, interviews, and company records was considered according to its source and the degree of supporting documentation available. The analytical presentation focused on four interrelated dimensions: workplace heat exposure conditions, worker experiences and potential dehydration-related symptoms, existing occupational health and safety controls, and opportunities for improving preventive management. These dimensions reflected the research objectives and provided a practical structure for organizing the findings without assuming that unreported quantitative measurements had been performed.

Workplace heat exposure conditions were evaluated through descriptions of production processes, heat-generating equipment, ventilation, shift operations, and physical activities performed in potentially hot work areas. Worker experiences were examined through reported perceptions of workplace heat and complaints such as thirst, fatigue, dizziness, and excessive sweating. Because these symptoms are nonspecific and were not supported by physiological hydration assessments, the analysis did not classify individual workers as dehydrated. Existing preventive measures were examined according to their occupational health functions, including engineering controls, administrative measures, personal protective equipment, hydration resources, health education, and occupational medical support. Engineering controls included measures such as ventilation and the management of heat-generating equipment. Administrative practices included shift organization, rest arrangements, worker education, and occupational safety procedures. Hydration-related measures involved drinking water availability and any documented worker hydration management practices. Occupational healthcare support included the availability of medical personnel, first aid facilities, and periodic health examinations.

The evaluation was informed by published research on occupational heat management and worker adaptation. [Goodman et al. \(2023\)](#) emphasized how organizational conditions influence practical heat mitigation strategies, while [Han et al. \(2021\)](#) identified the relevance of worker awareness and adaptive behaviors. These findings supported consideration of both workplace infrastructure and the practical implementation of preventive practices. The assessment also considered potential supplementary cooling strategies as contextual scientific evidence. Research on ventilation jackets, fan-assisted garments, and phase-change cooling clothing has demonstrated that personal cooling technologies may reduce selected measures of thermal strain under particular conditions ([Del Ferraro et al., 2022](#); [Mori et al., 2022](#); [Wang et al., 2023](#)). However, these studies were used only to contextualize potential preventive approaches. The original PT X assessment did not establish that these specialized cooling technologies were used or evaluated at the facility. A distinction was maintained between controls reported as available, controls whose implementation could not be independently established from the manuscript, and control measures explicitly identified as absent or insufficiently documented. This distinction was especially important because the original control-measures **Table 1** marked numerous practices as implemented, while the accompanying results stated that objective WBGT monitoring and a specific worker hydration monitoring program were not documented. Accordingly, the reported existence of a preventive measure was not considered equivalent to evidence of its effectiveness. For example, ventilation and cooling fans were regarded as available workplace controls, but the study did not quantify their effect on environmental temperature or physiological heat strain. Similarly, water provision and rest facilities were considered preventive resources, but their adequacy could not be determined without measurements of heat exposure, workload, fluid intake, and worker health outcomes.

The study did not employ inferential statistical analysis because individual-level quantitative exposure measurements, hydration measurements, and outcome datasets were unavailable. It also did not undertake a systematic literature review, scoping review, or meta-analysis. Published literature was used to support the interpretation of workplace prevention practices and identify relevant occupational health principles, rather than being treated as part of a formal evidence synthesis. The main limitations of the methodological approach were the absence of objective heat exposure measurements, lack of standardized hydration assessment, unspecified interview sample size and recruitment procedures, and incomplete documentation of observation duration and preventive control verification. Therefore, the results were interpreted as descriptive findings regarding occupational heat exposure conditions and prevention practices, not as evidence of a causal relationship between workplace temperature and dehydration or proof of preventive intervention effectiveness. The original manuscript did

not specify institutional ethical approval, written participant consent, or detailed confidentiality procedures for the interviews. These matters should be verified by the authors before publication. The workplace was identified using the anonymized designation PT X to limit organizational identification, while individual worker identities were not presented. Any final ethics and consent statements must reflect the procedures actually completed during the original assessment.

3. Results and Discussion

3.1. Workplace Characteristics and Potential Occupational Heat Exposure

The qualitative workplace assessment identified the production and boiler areas of the sugar manufacturing facility as locations with substantial potential for occupational heat exposure. Heat-generating processes included boiler operation, sugar processing, evaporation, heating, and continuous machinery operation. These activities represented identifiable sources of environmental heat within the production environment. However, the assessment did not include objective measurements of workplace thermal conditions, and the magnitude of heat exposure could not be quantified. Company-level information indicated that the facility employed approximately 485 workers and maintained continuous production through a three-shift operating system. The reported shifts were scheduled from 08:00 to 15:00, 15:00 to 23:00, and 23:00 to 07:00. The original report also described a work arrangement involving three working days followed by one day off. This organizational structure indicated that industrial operations continued throughout the day and night, although the actual duration of individual worker exposure to heat-generating equipment was not documented.

Field observations and interviews identified the boiler area, general production area, and workstations associated with liquid and crystalline sugar processing as locations where workers could encounter elevated environmental heat. Boiler operation represented an important potential heat source because of combustion and steam-generation processes. Additional thermal exposure could occur around machinery used for heating, evaporation, and other sugar-processing activities. Workers interviewed during the assessment described these environments as hot, particularly in areas close to boilers and production machinery. Some workers reportedly perceived the conditions as tolerable despite experiencing thermal discomfort. These observations provided information regarding workers' experiences but did not establish whether environmental heat exposure remained within recommended occupational limits. The potential occupational heat burden was influenced by several contextual factors, including physical activity, proximity to heat-generating machinery, protective clothing, and work organization. The original assessment also noted that employees could remain standing for extended periods and perform repetitive tasks during production operations. Nevertheless, task-specific metabolic workloads, individual exposure durations, and heat exposure variations between shifts were not measured.

The company recognized workplace heat as a physical occupational hazard within its broader occupational health and safety management system. Other identified workplace hazards included noise, vibration, chemical exposure, ergonomic hazards, and psychosocial factors. This recognition suggested that thermal exposure was included within general workplace hazard identification practices, although the documentation did not establish a complete quantitative heat-risk assessment. Overall, the findings identified potentially important sources of occupational heat exposure in the production and boiler areas. The absence of objective WBGT measurements, detailed environmental data, and task-specific exposure assessments prevented further determination of heat exposure severity or compliance with applicable occupational exposure recommendations.

Table 1. Workplace Characteristics and Potential Occupational Heat Exposure Factors

Assessment parameter	Findings	Evidence limitation
Industry	Sugar manufacturing	Facility described as PT X
Workforce	Approximately 485 employees	Total workforce, not sample size
Production schedule	Three shifts per day	Individual exposure times unavailable
Morning shift	08:00–15:00	Reported schedule
Afternoon shift	15:00–23:00	Reported schedule
Night shift	23:00–07:00	Reported schedule
Main heat sources	Boilers and production machinery	Heat generation identified qualitatively
Potential exposure areas	Boiler and production sections	No area-specific heat measurements
Worker activities	Standing and repetitive production tasks	Metabolic workloads not quantified
Heat perception	Hot but reportedly tolerable	Subjective assessment
WBGT	Not documented	Exposure thresholds cannot be evaluated
Humidity, airflow, radiant heat	Not reported quantitatively	Environmental characterization incomplete

Note: The original manuscript does not establish the number of interviewed workers, their individual heat exposure durations, or measured environmental temperatures.

3.2. Worker-Reported Symptoms and Potential Dehydration Risk

Interviews with workers indicated that hot working conditions were associated with several reported physical complaints, particularly thirst, excessive sweating, fatigue, and dizziness. These complaints were described in relation to activities performed in the production and boiler areas, where workers could be exposed to heat-generating equipment while performing routine duties. Thirst and sweating were particularly relevant to the study objective because they may occur during occupational heat exposure and can indicate increased demands for fluid replacement. However, the presence of these symptoms does not independently establish dehydration. Similarly, fatigue and dizziness may arise from multiple occupational or non-occupational factors, including physical workload, insufficient rest, medical conditions, or other

workplace exposures. The original workplace assessment did not document cases of severe dehydration or workers fainting as a result of heat exposure. Nevertheless, no systematic surveillance dataset, observation period, diagnostic definitions, or complete medical records were presented to verify the absence of such events. Therefore, the available information was insufficient to determine the incidence of heat-related illness or confirmed dehydration among employees. Additional information from the company's occupational healthcare services indicated that workers had presented with complaints including dizziness, muscle aches, fever, gastrointestinal disturbances, diarrhea, and allergic conditions. These complaints represented general healthcare presentations rather than a dataset specifically identifying heat-related illness. In particular, the available records did not establish that dizziness or gastrointestinal complaints were caused by workplace heat exposure.

The existing occupational healthcare system included a company clinic, medical personnel reportedly available 24 hours per day, first aid facilities, company physicians, and annual medical examinations. Periodic examinations were described as being adapted to occupational risk categories, with worker fitness assessed according to the company's medical evaluation procedures. Although this infrastructure may support occupational health surveillance, the original assessment did not document a dedicated hydration monitoring program. No systematic information was available regarding fluid consumption, urine-based hydration indicators, pre- and post-shift body mass, or repeated physiological measurements during heat exposure. The reported symptoms therefore indicate potential worker discomfort and justify further investigation of occupational heat-related risks. However, the prevalence, severity, and clinical significance of dehydration could not be determined from the qualitative information alone.

Table 2. Reported Occupational Heat-Control Measures and Documentation Status

Control measure	Evidence from original narrative	Revised status
Ventilation and fans	Described as available	Reported existing
Drinking water	Clean water facilities described	Reported existing
General PPE	Multiple types described	Reported existing
Company clinic	24-hour personnel reported	Reported existing
Annual medical examinations	Described in Results and Discussion	Reported existing
General OHS procedures	Policies and SOPs described	Reported existing
Rest facilities	Availability described	Reported existing
Work–rest cycle every 1–2 hours	Listed in original Table 1	Not independently verified
Boiler insulation	Listed in original Table 1	Not independently verified
Formal heat acclimatization	Listed in original Table 1	Not independently verified
Specialized cooling rooms	Listed in original Table 1	Not independently verified
Electrolyte drinks	Listed in original Table 1	Not independently verified
Objective WBGT assessment	Narrative states not performed	Reported absent
Specific hydration monitoring	Narrative states not implemented	Reported absent
Heat-stress education	Listed in table; narrative calls for strengthening	Extent unclear

Note: Status reflects the strength and consistency of the manuscript's evidence, not an independent verification of company operations. In particular, the contradictions concerning WBGT monitoring and hydration surveillance require confirmation from the authors.

3.3. Existing Occupational Health Controls and Implementation Gaps

The facility reported implementing various occupational health and safety measures intended to protect employees from workplace hazards. These included written safety policies, an Occupational Health and Safety Committee (P2K3), safety briefings, occupational safety induction, standard operating procedures, personal protective equipment, safety signs, emergency arrangements, and periodic medical examinations. For environmental heat exposure, the original observations described ventilation systems, cooling fans, and arrangements intended to improve airflow in production areas. These measures represented general engineering or environmental controls relevant to worker thermal comfort. However, no quantitative measurements were provided to demonstrate their effectiveness in reducing heat exposure. The company also reported access to clean drinking water, rest facilities, sanitation services, and occupational healthcare. These resources are relevant to the prevention of heat-related illness because workers require opportunities for fluid replacement and recovery from physically demanding activities. The original manuscript indicated that employees received approximately 30 minutes to one hour of rest during a work shift, although the distribution of these breaks and their adequacy for specific heat exposure conditions were not documented.

Personal protective equipment was reportedly provided according to workplace hazards. Examples included helmets, face and eye protection, hearing protection, masks, gloves, and safety shoes. The assessment did not determine the extent to which this equipment affected body heat dissipation or physiological strain during work. An important reporting inconsistency was identified between the original occupational control table and the narrative findings. The **Table 2** marked 15 preventive measures as implemented, including WBGT monitoring, hydration-related health assessments, heat acclimatization, cooling rooms, and electrolyte provision. However, the narrative explicitly reported that objective WBGT monitoring and a specific worker hydration monitoring program had not been implemented. Because implementation records and supporting measurements were not provided for all listed measures, the original checkmarks could not be accepted as equivalent evidence of verified implementation. The revised assessment therefore distinguishes general controls described in the narrative, measures requiring additional verification, and monitoring gaps explicitly reported in the original findings. The main identified improvement priorities included objective occupational heat measurements, systematic hydration-related surveillance, clearer heat-stress education, and work–rest arrangements appropriate to the actual environmental conditions and physical demands of assigned tasks. These priorities reflected gaps in the available documentation rather than demonstrated failures of every existing occupational health measure.

3.4. Occupational Heat Exposure and Physiological Health Risks

The findings of this qualitative assessment indicate that sugar manufacturing operations involve several potential sources of occupational heat exposure, particularly in production areas and around boiler equipment. Although the study did not quantify environmental heat levels, the combination of industrial heat sources, physical workload, protective clothing, and continuous production activities represents a relevant occupational health concern. The principal contribution of the assessment is the identification of potentially heat-exposed work areas and limitations in the documented evaluation of worker thermal risk. Previous research has demonstrated that occupational heat exposure is influenced by interactions among environmental conditions, individual physiological characteristics, work intensity, and organizational arrangements. Ioannou et al. (2021), through occupational observations and interventions conducted across multiple countries, demonstrated the relevance of combined environmental and physiological assessments in understanding heat strain. Similarly, Al-Bouwarthan et al. (2020) investigated construction workers exposed to extreme summer heat in Saudi Arabia and emphasized the importance of examining activity patterns, hydration status, and physiological responses together.

These findings provide an important context for interpreting the conditions at PT X Lampung. Workers performing physically demanding duties near boilers and processing equipment may experience increased thermoregulatory demands even when the environmental conditions are subjectively perceived as tolerable. However, the absence of WBGT values and workload measurements prevents direct comparison between the present workplace and the exposure levels investigated in previous studies. The distinction between perceived workplace heat and objectively measured thermal exposure is particularly important. Han et al. (2021) examined perceptions of workplace heat exposure and adaptation behaviors among Chinese construction workers, highlighting the relevance of workers' experiences in understanding occupational risk. Nevertheless, perceptions can vary according to acclimatization, workload, clothing, and individual characteristics. Therefore, the subjective description of hot but tolerable working conditions in the present study should not be interpreted as evidence that heat exposure was within safe occupational limits.

Objective workplace monitoring would allow a more detailed assessment of environmental thermal conditions and help identify differences between work areas, production activities, and shifts. Abbasi et al. (2023) evaluated the predictive validity of multiple occupational heat stress indices under different environmental and work conditions, illustrating the importance of appropriate heat assessment methods. In industrial facilities with continuous heat-generating processes, monitoring should consider not only ambient temperature but also humidity, radiant heat, airflow, workload, and protective clothing. Occupational heat exposure may also have implications for workplace safety. Varghese et al. (2020) examined heat-related injuries in Australian workplaces from the perspectives of health and safety representatives, demonstrating that occupational heat risk management involves organizational and behavioral considerations in addition to environmental controls. This perspective is relevant to sugar manufacturing, where workers may interact with industrial equipment and undertake repetitive tasks during extended production operations. However, the present study did not collect systematic data on occupational injuries, productivity losses, physiological heat strain, or medically confirmed heat-related illness. Therefore, no association between heat exposure and workplace accidents can be established for PT X Lampung. The observed industrial conditions instead support the need for more systematic occupational heat hazard assessment and proactive preventive management.

3.5. Hydration Management and Evaluation of Preventive Controls

The prevention of dehydration is an important component of occupational heat management because sweating during prolonged heat exposure can increase fluid replacement requirements. However, workplace hydration management involves more than providing drinking water. It also requires consideration of fluid accessibility, work intensity, exposure duration, recovery opportunities, and individual circumstances. Gandy (2015) discussed the methodological challenges associated with assessing water intake and determining appropriate hydration recommendations. Similarly, Mizelle et al. (2022), in a mixed-methods study of agricultural workers, investigated fluid intake and hydration status in an occupational setting. These studies emphasize that water availability, reported fluid consumption, and objectively measured hydration status are related but distinct components of hydration assessment. In the present study, drinking water facilities were reported to be available, but the accessibility and utilization of these resources during specific work activities were not evaluated quantitatively. Furthermore, no worker-level fluid intake measurements or physiological hydration assessments were documented. Thus, the availability of drinking water should be interpreted as an existing preventive resource rather than confirmation of adequate hydration among workers.

The reports of thirst, dizziness, fatigue, and excessive sweating suggest that monitoring worker symptoms may be relevant in potentially hot work areas. Nevertheless, these symptoms are not specific to dehydration, and their occurrence cannot establish the presence of clinically significant fluid deficits. Kakamu et al. (2021) examined personal and environmental factors associated with heat-related illness among construction workers, providing a broader perspective on the multiple determinants of heat-related health risks. Hydration-related prevention may also require education regarding appropriate fluid replacement practices. Kakamu et al. (2024) investigated the relationship between salt intake timing and heat-related illness, demonstrating that electrolyte-related behaviors may be relevant to occupational heat prevention. However, these findings do not support universal electrolyte supplementation for all workers or establish the appropriateness of a particular drinking regimen at PT X. Such practices should be determined according to workload, heat exposure, health conditions, and applicable occupational guidance. The facility's existing control measures included ventilation, cooling fans, personal protective equipment, rest areas, general safety procedures, and occupational medical services. These measures correspond to different functions within workplace hazard management, but their implementation does not automatically establish effective heat-stress protection.

Engineering controls should prioritize reducing the heat burden at its source or limiting workers' exposure. Depending on technical feasibility, these controls may include insulating heat-generating equipment, improving ventilation, installing radiant heat barriers, and reducing unnecessary proximity to thermal sources. Their effectiveness should be evaluated using environmental measurements rather than inferred from equipment availability alone. Personal cooling technologies may provide supplementary options for specific industrial activities. Del Ferraro et al. (2022) evaluated the cooling properties of a ventilation jacket, while Mori et al. (2022) investigated fan-attached clothing under hot or humid environmental conditions. Wang et al. (2023) also examined the use of phase-change cooling garments to improve thermal comfort among factory workers. These investigations demonstrate the potential of wearable cooling technologies, although effectiveness

depends on environmental conditions, clothing design, physiological characteristics, and workload. The present study did not report the use of these specialized garments at PT X. Therefore, they should be considered potential technologies for future feasibility assessment rather than existing company interventions. Administrative prevention strategies are equally relevant. The facility operated continuously through three shifts and reported routine rest arrangements, but the adequacy of rest duration could not be evaluated without objective exposure measurements and workload information. [Goodman et al. \(2023\)](#) emphasized differences in heat-management approaches across workplace organizational arrangements, suggesting that practical implementation may depend on management practices and workers' access to preventive resources.

Worker education represents another potentially important intervention. [Santos et al. \(2022\)](#) evaluated a participatory Heat Education and Awareness Tools intervention among agricultural workers, illustrating the relevance of structured educational approaches to occupational heat management. At PT X Lampung, general safety briefings and training were reported, but the content, frequency, and reach of heat-specific education were not clearly documented. Accordingly, occupational heat prevention at the facility could be strengthened by evaluating existing controls against the requirements of specific work areas, developing documented heat-exposure monitoring procedures, assessing hydration-related practices, and ensuring that preventive recommendations are appropriate to workers' actual occupational conditions.

3.6. Occupational Health Implications, Study Limitations, and Future Directions

The present qualitative assessment provides a descriptive overview of potential occupational heat exposure and dehydration prevention practices within a sugar manufacturing facility. The findings suggest that general occupational health and safety infrastructure was available, including workplace safety procedures, ventilation, personal protective equipment, medical services, and periodic health examinations. However, the documentation did not establish a complete system for objectively assessing occupational heat exposure or monitoring worker hydration status. This distinction has important implications for occupational health management. General safety infrastructure provides a foundation for workplace protection, but heat-specific prevention requires an understanding of environmental thermal conditions, physical workload, exposure duration, access to recovery facilities, and individual worker health considerations. The absence of objective exposure measurements makes it difficult to determine whether preventive controls are adequate for particular production activities. Several methodological limitations must be acknowledged. First, the research used a descriptive qualitative approach without quantitative measurements of WBGT, ambient heat, radiant temperature, humidity, or airflow. Second, the number of interviewed workers, participant selection procedures, and duration of field observations were not documented. Consequently, the representativeness and completeness of the interview findings could not be assessed. Third, the reported symptoms were based on qualitative information rather than systematically collected clinical or physiological data. No objective measurements of hydration status, body temperature, fluid intake, or pre- and post-shift body mass were available. Therefore, neither dehydration prevalence nor the incidence of heat-related illness could be determined.

Fourth, the original manuscript contained inconsistencies regarding the reported implementation of selected occupational controls, particularly WBGT monitoring and hydration surveillance. These inconsistencies limited the ability to establish which preventive activities were implemented, planned, or merely included as examples of recommended practices. Fifth, the study did not include repeated workplace assessments, comparative measurements between production areas, or quantitative evaluation of intervention effectiveness. As a result, changes in environmental exposure, worker health, and productivity could not be attributed to existing preventive measures. Despite these limitations, the assessment identifies practical priorities for strengthening occupational heat management. Future evaluations should consider environmental heat monitoring in production and boiler areas, documentation of exposure patterns and metabolic workload, assessment of drinking water accessibility and hydration practices, and systematic recording of heat-related symptoms and clinical events. Where feasible, repeated assessments across work shifts and operational conditions would provide a stronger basis for determining exposure variability and the suitability of existing controls. Further research could also evaluate the feasibility of targeted preventive interventions, including improvements in engineering controls, heat-specific education, exposure-appropriate rest arrangements, and selected personal cooling technologies. Such investigations should incorporate objective environmental and worker health measurements before drawing conclusions regarding reductions in dehydration risk or heat-related illness. Overall, the present findings demonstrate the importance of distinguishing between general workplace safety provisions and specific evidence-based occupational heat management practices. The study contributes a descriptive assessment of potential heat hazards and prevention-related documentation gaps in sugar manufacturing, while highlighting the need for systematic monitoring and stronger empirical evaluation of worker protection measures.

4. Conclusions

This qualitative assessment identified the production and boiler areas of a sugar manufacturing facility in Lampung, Indonesia, as workplaces with potential occupational heat exposure associated with continuous machinery operation, thermal processing activities, and physically demanding work. Workers reported experiencing hot working conditions and symptoms including thirst, excessive sweating, fatigue, and dizziness, suggesting the need for greater attention to heat-related occupational health risks. The facility had established several occupational health and safety measures, including ventilation systems, cooling fans, personal protective equipment, drinking water facilities, designated rest areas, workplace safety procedures, periodic medical examinations, and occupational healthcare services. However, important gaps remained in the documentation and implementation of heat-specific preventive practices, particularly objective Wet Bulb Globe Temperature (WBGT) monitoring, systematic assessment of worker hydration status, and evaluation of exposure-appropriate work–rest arrangements. The absence of quantitative environmental measurements, physiological hydration assessments, and systematic worker-level health data prevented determination of actual heat exposure severity, dehydration prevalence, or the effectiveness of existing preventive measures. Therefore, the findings should be interpreted as a descriptive evaluation of potential occupational heat hazards and workplace prevention practices rather than evidence of confirmed dehydration or demonstrated intervention effectiveness. Strengthening environmental heat monitoring, hydration-related health surveillance, worker education, and appropriate engineering and administrative controls may support more comprehensive occupational heat risk management. Future investigations incorporating objective exposure measurements, standardized hydration assessments, and longitudinal worker health monitoring are recommended to evaluate the adequacy and effectiveness of preventive interventions in sugar manufacturing environments.

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Informed Consent Statement: Written informed consent has been obtained from the patient's guardian to publish this case report, including clinical details and images.

Data Availability Statement: All data supporting the findings of this study are contained within the article. No additional datasets were generated or analyzed.

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