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PRELIMINARY STUDY ON INVESTIGATION OF THE HEAT STRESS AFFECTING THE LABOR PRODUCTIVITY, A CASE STUDY: GARMENT FACTORY IN PHNOM PENH

Kinnaleth Vongchanh[a,b]*, Sarin Chan[a,b]

[a]Thermal Lab, Department of Industrial and Mechanical Engineering, Institute Technology Cambodia, Phnom Penh, Cambodia.
[b]Research and Innovation Center, Energy Technology and Management Unit, Institute Technology Cambodia, Phnom Penh, Cambodia.

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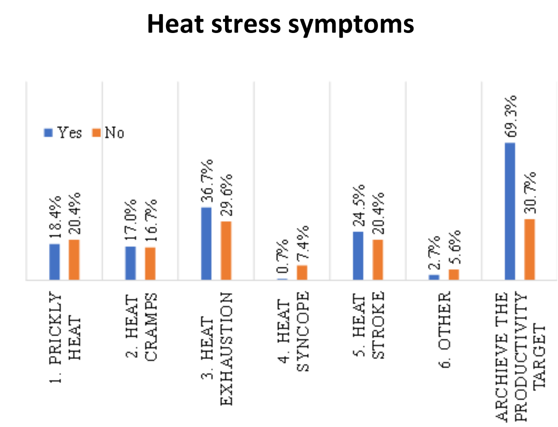
*Corresponding author
kinnalethv@itc.edu.kh



Relation of heat stress symptoms with required overtime working hours

Abstract

This paper aims to investigate low labor productivity affected by heat stress; focusing on various parameters including outdoor and indoor temperatures and humidity, indoor air quality, and the outfit used. Survey of 130 questionnaires together with measurements of indoor and outdoor air temperatures and humidity were carried out in a garment factory in Phnom Penh, Cambodia during May 2019, which is one of the hottest months of the year. The indoor wet bulb globe temperature, $WBGT_{id}$, with the evaporative cooling system in operation was ranging from 26 to 34°C; while the outdoor air dry-bulb temperature was around 25 to 41°C. The survey results show that the participants experienced all types of heat-stress symptoms, including heavy sweating, muscle cramps, tiredness/weakness, dizziness, headache, nausea or vomiting, and fainting. Even though the majority of respondents found the workplace temperature comfortable and around 65% could manage bad feelings due to heat stress, about 80% of respondents reported feeling hot and uncomfortable at working place within the period of 1 to 3 months in a year. During the hot months, some 39.6% had feeling thirsty, more than 22% felt exhaustion and had excessive sweating; and around 9% want to move and stay in a comfortable place. To cope with the heat stress, workers mostly drink water, but some also need to move away for a while or remove extra layer of outfit. Finally, noticeable number of workers, 41.3% and 33.7%, respectively, acknowledged heat stress negatively impact their productivity and cause irritation in working together.

Keywords: Heat stress, WBGT, labor productivity, outfit, garment.

1.0 INTRODUCTION

Climate change is likely to result in a global temperature rise of at least 1.5°C, as well as an increase in the frequency and intensity of heat waves [1]. The higher ambient temperature and the more frequent and intense heatwaves can significantly raise the risk of heat stress. Predictions based on climate change scenario anticipate negative impact of heat stress on human health, prosperity, ecosystem, infrastructure, and economy, especially on the world's poor and low-income countries [2] [3].

The increase of heat in future projection in most part of the world triggered more attention in workplace heat which is important occupational health hazard [4]. In a study, labor capacity was found to reduce to 90% in the peak months for the past few decades [5]. Heat stress can strongly affect productivity and health of people and reduce the tolerance to other environmental hazards [6]. Neglecting the increasing risk of heat stress due to climate change could reduce labor capacity of heat-exposed jobs and result in greater adversity in reaching economic and social development goal of the affecting countries [7].

In addition to outdoor temperature, the indoor temperature can have sound impact on the health of city people as they spent most of the time staying indoors. [2]. Solutions to indoor climate issues implemented in developed countries may not applicable in developing countries due to various restrictions and running costs [8] .

The calculation using exponential equation to estimate the found tolerance time of 55min at 34°C *WBGT*. At hotter environment, 38°C *WBGT*, the tolerance time drops 4 to 5 min per degree increase in *WBGT*, while beyond 38°C *WBGT*, the estimated the tolerance time decreased by 2 to 3 min per degree increase in *WBGT* [9]. Heat stroke can be potentially damaging for people while exercising in hot environments [10]. Reports of death and injury in military populations due to exertional heat illness (EHI) and its most severe form, exertional heat stroke, date from antiquity. The thermal burden associated with states of dress and personal protection of Service personnel in their worldwide duties should be a focus of research as new equipment is introduced [11].

Results revealed notable variations among the monitored heat stress parameters under the targeted work environments, indicating that the proposed prototype was sensitive w.r.t the thermal ambience and physical work activity performed. For WBGT, the highest correlation was detected with FITS followed by DI and HI indices; indicating these direct indices as adequate substitutes for assessing the workplace thermal ambience without requiring cumbersome evaluations and costlier equipment.

Heat stress at the workplace is an occupational health hazard that reduces labor productivity, assessment of productivity loss resulting from climate change has so far been based on physiological models of heat exposure [12]. The term "heat stress" refers to the externally-based heat load created from a summation of factors in the environment. These factors include climatic conditions, metabolic workload, and clothing adjustments [6]. Heat stress can also affect mental health since it alters the mood and causes physiological distress [13]. Heat stress causes sweat and dehydration with subsequent volume depletion, which, if progress, may cause acute kidney injury [14]. Previous research has indicated that heat stress at work affects workers' willingness to work, their general well-being, and their productivity, as well as increasing their risk of an accident [13]. Excessive heat while working, generally at temperatures above 35°C, creates occupational health risks and reduces work capacity and labor productivity [3, 15]. Heat stress may come from climatic heat, process heat, the workload (metabolic heat), or the use of additional/special clothing [16]. The rest area is assumed to have the same wet bulb globe temperature (WBGT) as the work area. If the rest area WBGT is below 24°C, reduce resting time by 25%. However, no benefit of a cool rest area unless the work environment temperature was over 35°C effective temperature [17]

The garment factory is large and consists of many people and Cambodia is a hot and humid country; the air-cooling equipment is important to circulate cooled air into the working area. According to an ILO sector bulletin, the Garment, Textile and Footwear sector in 2018 accounted for 74% of country's total merchandise exports, therefore the sector is seen as one of the keys to the growth of Cambodia's economy [18]. Any changes that can negatively affect productivity in this sector should be investigated, monitored, identified, and improved if required. Many different factors can affect productivity, including management, workers' skills, tools/equipment, management, environmental conditions (e.g., ambient air and indoor air quality, temperature and noise), etc. Preliminary research conducted in Cambodia in 2016 by a research team led by Prof. Tord Kjellstrom with collaboration from H&M in one garment factory in Phnom Penh indicates that current heat levels were already affecting work productivity (with significant losses in daylight work hours due to workplace heat).

Therefore, the objectives of this study were to investigate the indoor wet bulb globe temperature ($WBGT_{in}$) and to study low productivity due to heat stress in a garment factory in Phnom Penh, Cambodia.

2.0 METHODOLOGY

The selected garment factory was located in Phnom Penh. It was established in 2009. The total area of the factory is about 30,000m^2. Total workers were approximately 3500. The questionnaire survey interviewed 130 participants from different tasks, including sewing, ironing, cutting, QC, and packaging. The interviewee was called to interview during working hours. The interview took about 15 minutes per participant.

The measurement survey and questionnaire survey were conducted during 10-22 May 2019 due to the limitation of the project period. Measurement of the indoor air condition was used T&D Thermo hydro datalogger TR-72WF for measuring of indoor dry bulb temperature and relative humidity of air 24 hours continuously for 12 days, RTR-576 wireless CO_2 data logger, and elapsed time TR-76Ui for measuring the CO_2 content in the factory, Hotwire anemometer AVM430-A for measuring the air contribution in a different location. The locations of the measuring points on the factory floor layout are shown in Figure 1 and the component of data measured at each point are listed in Table 1.

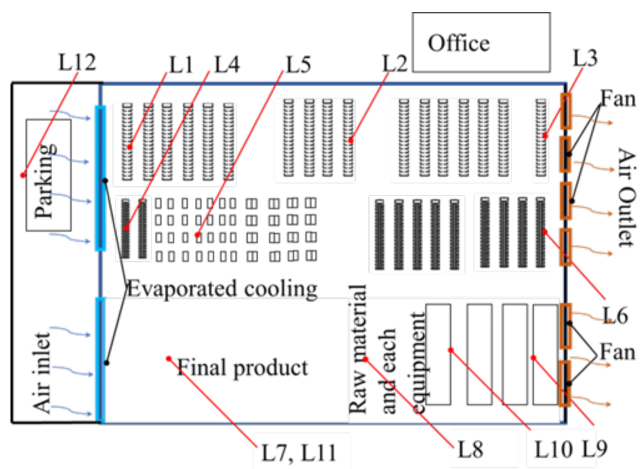


Figure 1 Location for the measurement of indoor and out air conditions

Table 1 List of the measurement location

No.	Component
L1	Inlet air T&RH at sewing dept
L2	Air T&RH at the middle of sewing dept
L3	Outlet air T&RH at sewing dept
L4	Inlet air T&RH at sewing dept
L5	Air T&RH at the middle of sewing dept
L6	Outlet air T&RH at sewing dept
L7 &L11	Air T&RH at the middle of ironing dept
L8	Air T&RH at the middle of packing dept.
L9	Inlet air T&RH at packing dept

In this study, we used Bernard et al (1999) method to calculate indoor WBGT in the case study of the garment factory [19].
For air velocity more than 3m·s^{-1}, the WBGT indoor can be calculated by

$$WBGT_{id} = 0.7\ T_{pwb} + 0.3\ T_a \quad (1)$$

For air velocity of 0.3-3 m·s-1, the WBGT indoor can be calculated by

$$WBGT_{id} = 0.67\ T_{pwb} + 0.33\ T_a - 0.048\ \log10v\ (T_a - T_{pwb}) \quad (2)$$

T_{pwb} Psychrometric wet bulb temperature, [°C]
T_a Dry bulb temperature, [°C]
v Wind speed, [m·s^{-1}]

3.0 RESULTS AND DISCUSSION

3.1 Questionnaire results

This study was conducted 130 survey questionnaires with random correspondents from different departments; major of the correspondents were from the sewing department, as shown in Figure. 2. The questionnaire results showed that 95% of females shared in participating the survey as the garment factory is a common job for female workers in Cambodia. About 51% of the total correspondents were in the age range 20-30 years old and most of them are working in the sewing department, as depicted in Figure 2.

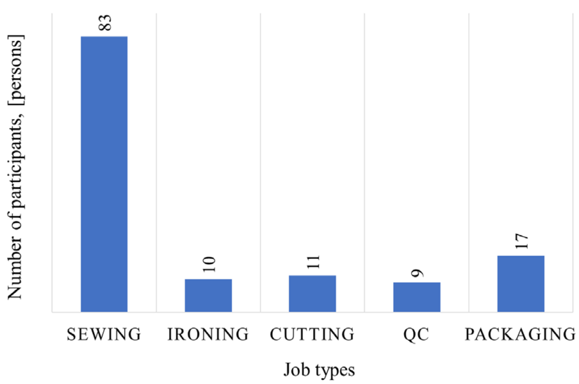


Figure 2 Percent share of different departments among the participants

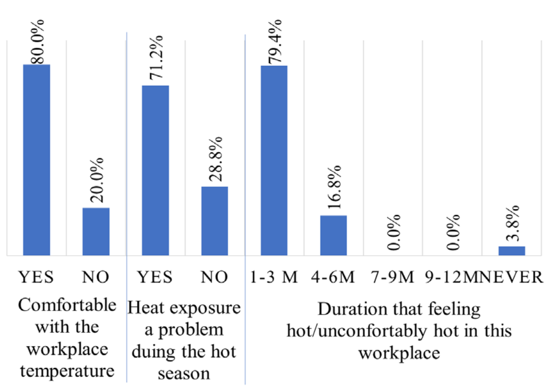


Figure 3 Feeling at workplace

Concerning comfortability in the working place, most of them (80%) answered that they felt comfortable but they felt trouble around 1-3 months during the hot season (summer); 79.4% of them felt inconvenient during the hot season, depicted in Figure. 3. During the hot season, 88% of them felt thirsty during the hot season, as illustrated in Figure 5. In addition, workers with 2-layers outfits felt slightly thirst than the 1-layer outfit; while the percent share of people wore 2-layer outfits lower than 1-layer outfits, described in Figure 4. They took an extra break time during summer from 5 to 120 minutes per day or someone took 1 day leave during the summertime.

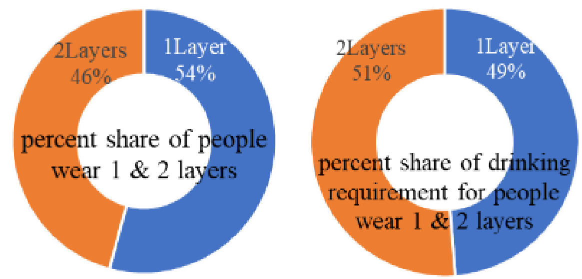


Figure 4 Comparison of feeling thirsty of a worker wearing 1layer or 2layers clothing

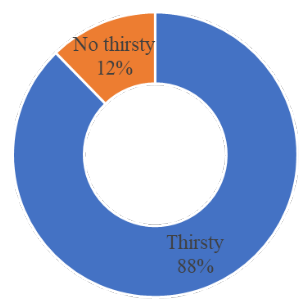


Figure 5 share of workers feeling thirsty during the hot season

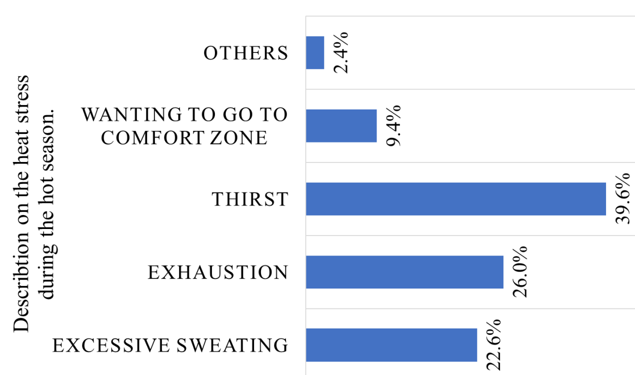


Figure 6 Description of the heat stress

To describe the heat stress of the correspondents, choices of heat stress effect were given, the results showed that the major effect was feeling thirsty (40%), exhaustion (26%), excessive sweating (22.6%), and wanting to go to a comfort zone, depicted in Figure 6. However, most of them mentioned that it was manageable (sharing 65%), and only a few of them felt extremely bad (sharing 5.2%). shown in Figure 7. From the answers of the heat stress symptoms (HSS), which is reflecting the cause of overtime working hours (OT) to the achieved product target (APT), 31% and 69% of them could be APT and Non-APT, respectively. The majority required OT working hours to APT. The APT and Non-APT groups had similar effects to heat stress. However, it indicated that the APT group got a higher percentage on heat exhaustion and heatstroke. While the Non-APT group had a higher percent share on prickly heat and heat syncope, as illustrated in Figure 8. From these responses, it can describe the worker with HSS with Non-APT, they got less serious HSS because they took more time to cope with the heat stress.

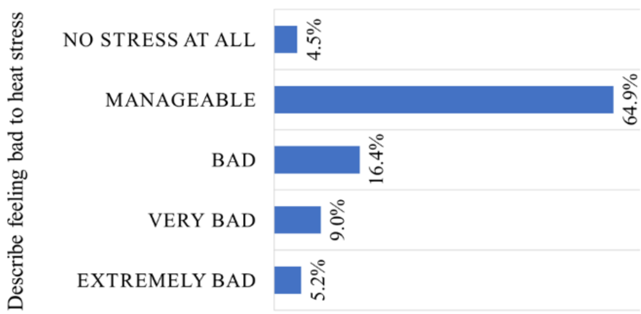


Figure 7 Level of acceptance to the effect of the heat impact

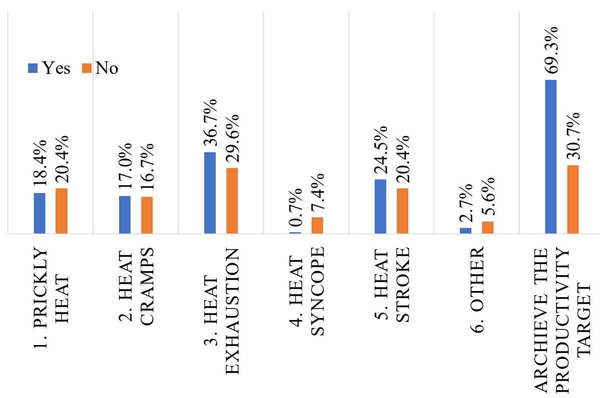


Figure 8 Relation of heat stress symptom with required OT working hours

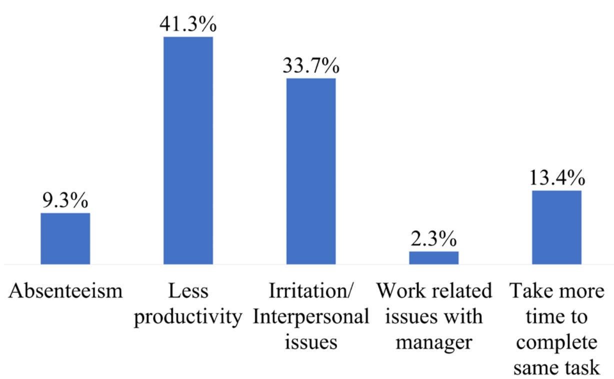


Figure 9 Heat stress effects to some specs during hot seasons

In this study, we focus on the heat stress affecting productivity during the hot season, questionnaire results described the feeling of the respondents that the less productivity (41%), irritation (33%), taking more time to complete the task (13%), and absenteeism happened during the hot season, shown Figure 9. Besides that, we try to investigate whether the heat strain has any effect due to the outfits or not, we found that many workers preferred long sleeves shirts and pants/skirts, and 2-layer outfits. It was found that about 46% wore 2layers outfits. We found a slight sign of heat strain due to the outfits; because many workers feel tired/weak and have headaches, described in Figure 10.

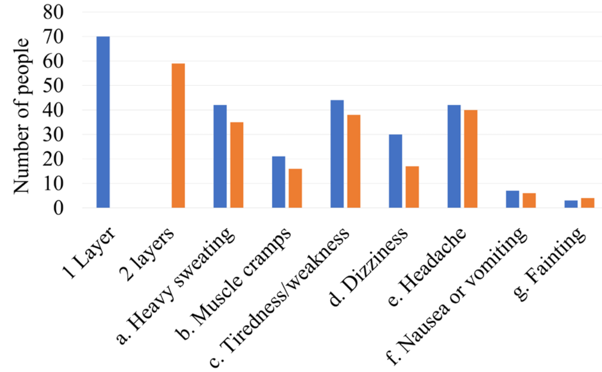


Figure 10 Relation of heat strain and outfit layers

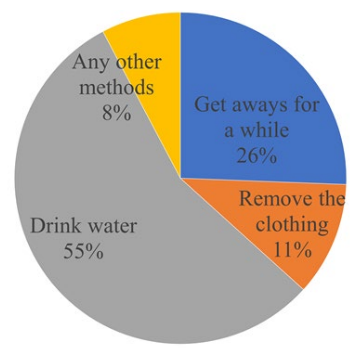


Figure 11 Heat coping method for garment workers

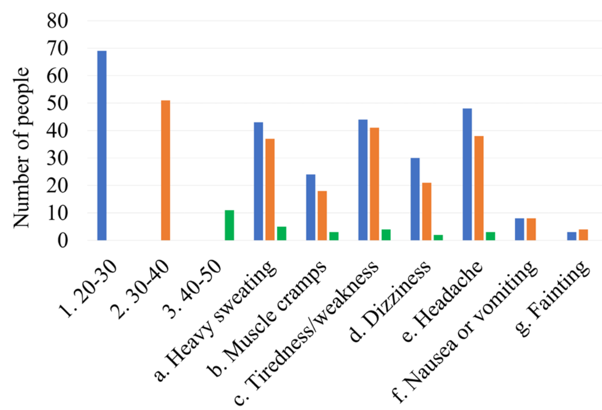


Figure 12 Relation of heat strain and ages

Moreover, the effect of heat strain on the ages was identified, we obtained 3 majors of ages (1) 20-29, (2) 30-39, (3) 40-50, the highest share was the group of age between 20-29 years old. The groups of ages, 20-29 and 30-39 years old, were having a very similar trend of heat strain, see Figure 12. When they felt the heat strain symptom, the common method to limit the heat were drinking water, getting away for a while, removing the cloth, etc., described in Figure 11.

3.2 Measurement Results

The air quality is excellent, good, fair, mediocre, and bad when the CO_2 level is less than 600 ppm, between 700 and 800 ppm, between 900-1000 ppm, between 1100-1500 ppm, and between 1600 and 2100 ppm, respectively, [20]. The CO_2 content in the factory was found between 361-422ppm, which means an excellent level of CO_2 content in the factory.

The measurement of velocity was conducted from 7 am-11 am and 1 pm-4 pm in 3 locations including an inlet, a middle, and an outlet of the workplace. The average velocity was about 0.98m·s-1 which was used for WBGTin in equation 2.

According to the obtained data the outdoor air temperature was around 27-39°C in the morning and it was very high (37-41°C) from 11 am to 3 pm, depending on the weather condition of the day. The ambient air temperature was described with T_{db} (dry-bulb temperature) because we did not be able to measure T_g, thus, $WBGT_{od}$ did not describe in this study.

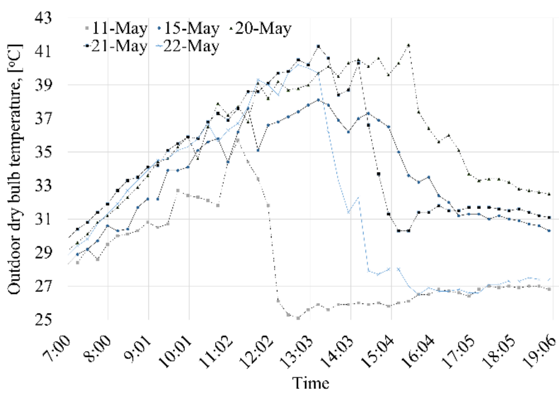


Figure 13 Ambient air temperature from 10-22 May 2019

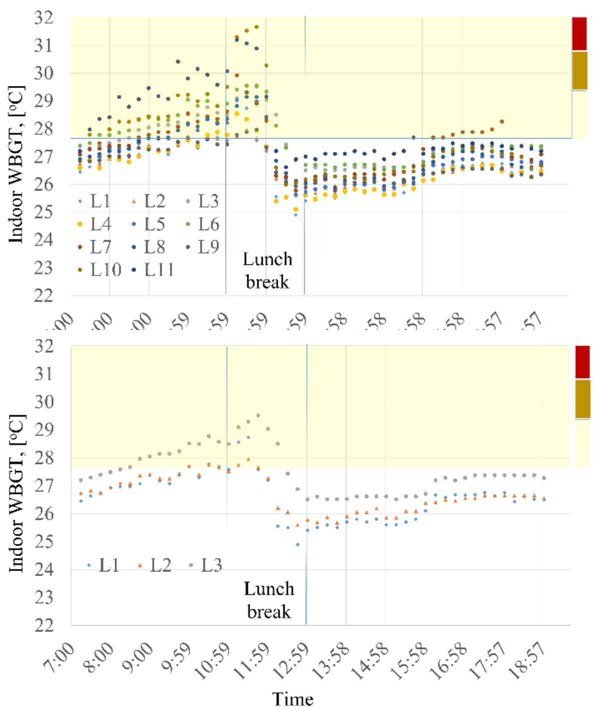


Figure 14 WBGT of the indoor at the measured locations on 11th May 2019

During the period of the measurement, we observed that there are 3 different conditions (1) shiny day and on operation, (2) shiny day and off operation, and (3) rainy day and on the operation. On 11th, 21st-22nd May 2019, there was a rainy day in the afternoon where the ambient air temperatures were very much lower than the shiny day, on 15th, and 20th May 2019, described in Figure 13. The different ambient conditions of 11th, 15th, 20th, 21st, 22nd May 2019 were selected to discuss the indoor WBGT, especially at the sewing department (L1, L2, and L3).

On 11th and 22nd May, ambient air temperature in the morning was about 28-36°C, the indoor WBGT was between 25-32°C. The indoor WBGT was 25-28°C in the afternoon which was lower than the indoor WBGT in the morning because there was rain in the afternoon. The WBGT of 3 locations, inlet (L1), middle (L2), outlet (L3), at sewing department, were not the same; the outlet air temperature was almost 1°C higher than the inlet air temperature, depicted in Figure 14. Similarly, the WBGTin on 22nd May 2019, when the ambient air temperature was cool; it could help the indoor air temperature cooler too, see Figure 14.

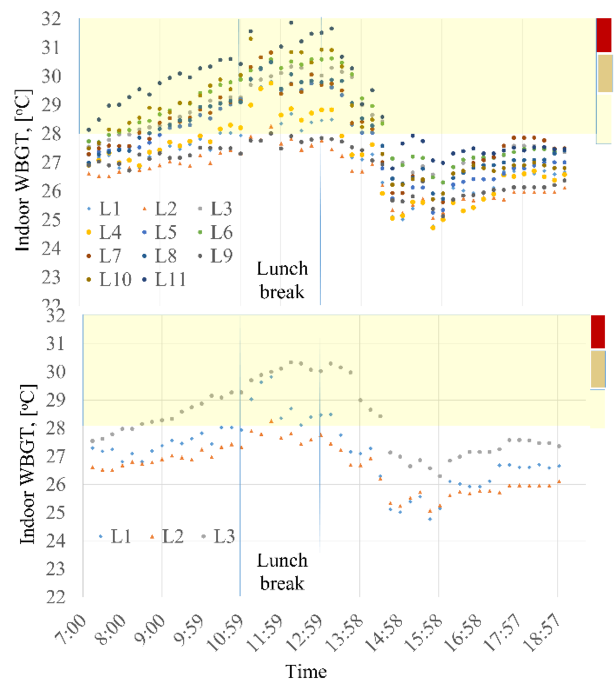


Figure 15 WBGT of the indoor at the measured locations on 22nd May 2019

On 15th May 2019, the ambient temperature was maximum at 38oC, it was raining in the afternoon; however, the factory was not in operation and the evaporative cooler was off, the indoor WBGT (32-35°C from 11 am to 3 pm) in the ironing department, see Figure 16. It was clear that the workplace without air circulation, as well as the effective evaporative cooler, caused very bad WBGT in the workplace.

On 20th May, the ambient air temperature was between 29-41°C, it was shiny day and on operation; thus, the evaporative cooling was on. However, the indoor WBGT was between 27-31°C which was in the caution zone, depicted in Figure 17. The WBGT at L1, L2, and L3 were different; the outlet air temperature was 2-3°C higher than the inlet air temperature. As a result, indoor WBGT was dependent on outdoor ambient conditions; the higher outdoor air temperature increased the indoor WBGT.

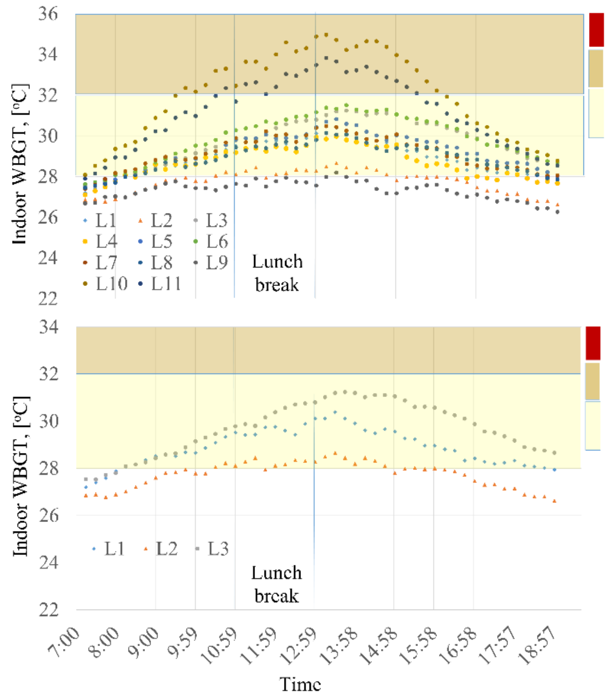


Figure 16 WBGT of the indoor at the measured locations on 15th May 2019

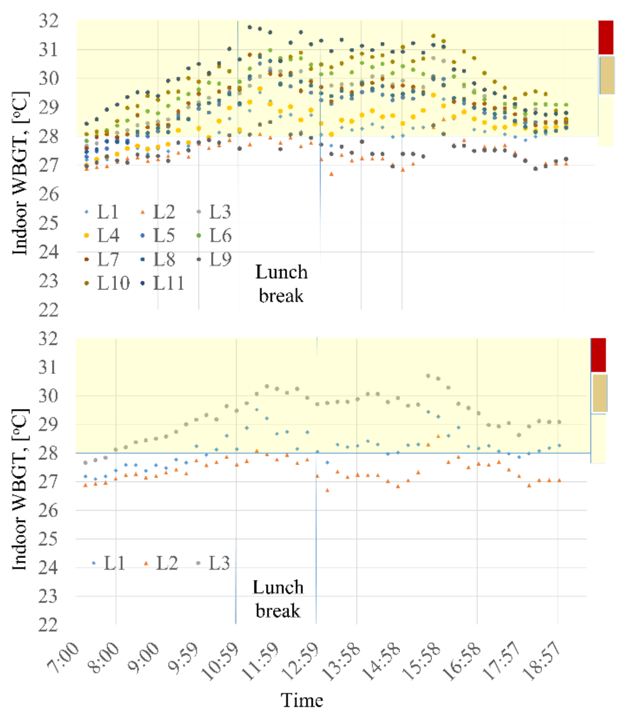


Figure 17 WBGT of the indoor at the measured locations on 20th May 2019

On 21st May 2019, the factory was in operation, thus, the evaporative cooling was on. The ambient air temperature was between 30-41°C, However, the indoor WBGT was between 27-31°C which was in the caution zone, depicted in Figure 18. It was a shiny day and it was raining from 2:15-3:45 PM. The WBGT of L1, L2, and L3 are different; the outlet air temperature was 2-3°C higher than the inlet air temperature. As a result, indoor WBGT was dependent on outdoor ambient conditions; the higher outdoor air temperature increased the indoor WBGT.

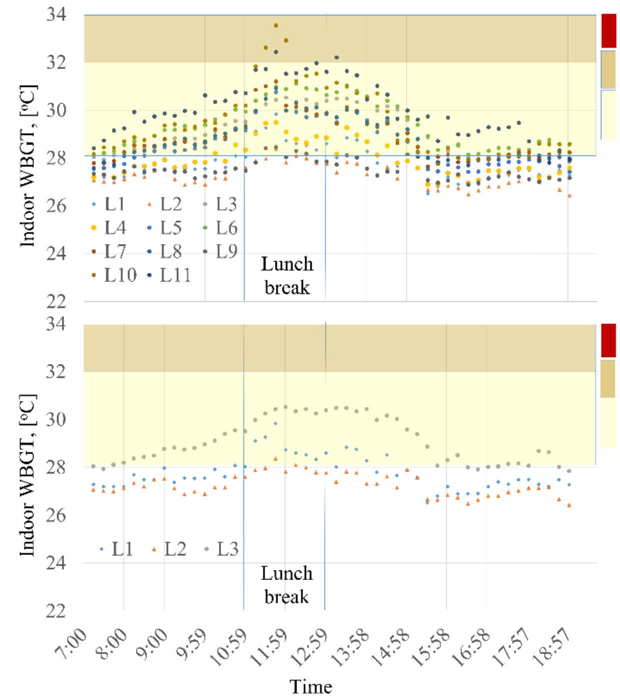


Figure 18 WBGT of the indoor at the measured locations on 21st May 2019

Based on the observation 3 locations (L1, L2, L3) at the sewing department, air temperature and velocity were clearly shown non-uniform; the inlet air temperature is always lower than the outlet air temperature (The worker sitting near the end of the line received hotter air than the worker sitting at the beginning of the line). The highest temperature in the garment factory was at L11 (ironing department) which means the workers at the ironing department received the highest air temperature; while the natural ironing task is harder than the sewing task, thus, lower air temperature at the ironing department is encouraged. Besides that, L10 (cutting department) was also high air temperature. Moreover, the different locations in the factory are clearly depicted that the air temperature of each location were having different air temperatures. The obtained results were to remind the garment/factory's manager to be aware of the distribution of air temperature which is required good arrangement of working space requiring to avoid obstacles blocking the airflow to improve the air distribution.

4.0 CONCLUSION

The obtained CO_2 values test were found in a good level of indoor air quality at the workplace, but the air distribution in different locations of workplaces was not homogenous. The recorded ambient condition (dry bulb temperature of the air at outdoor) was between 27-41ºC during 10-22 May 2019; thus, a major indoor air WBGT at the workplace place was between 26-34ºC causing tiredness or lack of energy, no motivation, and no energy. The highest WBGTid was found in the ironing department. Once the workers felt tired due to the heat, they tended to spend more time on non-productivity activities such as walking to drink some drink, to take a rest, to fan, etc. The more time is required to drink water is the higher the time spent walking, which was caused for productivity reduction; this factory does not allow the workers to keep the drinking bottle in the working area; the drinking water is allocated to a specific area. According to the obtained results showed that 88% of participants felt thirsty during the hot season; drinking water was a method to limit the heat exposure (55.6%), get away from the possible for a while (25%), and remove the clothing (11.1%). At the same time, the majority of participants wore a long sleeve for upper clothing (50.8%) and long pants for lower clothing (77.9%), and 2 layers outfit sharing 46%. Besides that, the requirement of drinking water during the hot season for 2 layers outfits was higher than 1layer outfits. At this moment, there is a sign of the effect of heat stress on lower productivity because workers spend time coping with the heat, therefore, airflow homogeneity in the large area is important to spread cool air to all workers in any position to avoid high WBGT in the workplace.

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