Heat stress investigation on laundry workers

Azlis Sani Jalil, Zulhilman Dor, Mohd Shahir Yahya, M. Faizal Mohideen Batcha, Khalid Hasnan

Faculty of Mechanical Engineering and Manufacturing,
Universiti Tun Hussein Onn Malaysia (UTHM)
86400 Parit Raja, Batu Pahat,
Johor, MALAYSIA
azlis@uthm.edu.my

Abstract

Heat stress is one of the occupational hazards in hot working environment. Hot conditions will put the body under a lot of stress. This paper will discuss the results on investigation of heat stress among employees at the selected Dr. Clean laundries around Johor Bahru, Johor. In this study, heat stress level was determined based on Wet Bulb Globe Temperature Index (WBGT) and Heat Stress Index (HSI). It was found that level of heat stress as defined by WBGT at one of the laundries (Dr. Clean Surplus Prisma Sdn Bhd, Bandar Baru Uda) had slightly exceeded Threshold Limit Value (TLV) limit as 28.78^{O}C; more than 28^{O}C and 28.5^{O}C as recommended by the ISO 7243 Standard and ACGIH Standard respectively. Whereas, Laundry 2 (Dr Clean Ambang Elit Sdn Bhd, Bandar Putra Kulai) and 3 (Dr Clean Prisma Ilusi Sdn Bhd, Taman Mutiara Rini) were recorded as 26.41 and 27.04 respectively. However, the Heat Stress Index of Belding and Hatch (HSI) value shows possibility of mild to moderate heat strain may occur at all outlets. HSI index for Laundry 1, 2 and 3 were exceeded range of 0-10 recommended by ISO 7243 as 28.45, 26.81 and 26.01 respectively. In conclusion, Dr Clean outlets in Johor could be considered as hot working environment since heat stress was determined among laundry workers; but in a very initial stage.

Keywords: Heat stress, hot working environment, ergonomics, laundry

1. Introduction

Generally, heat stress is a problem in hot working environments. Extreme hot environments can overwhelm the body's coping mechanisms leading to a variety of serious and possibly fatal conditions. Whenever, there is heat stress which is imposed on the human body from the surrounding thermal environment, there will be a resulting heat strain on the human body which may cause physiological reactions such as increased skin temperature, sweat production, increased heart rate and higher core temperature [1]. Under extreme conditions, the heat strain may cause health impairment. Some of the hazards identified are heat stroke, heat exhaustion, heat cramps, heat collapse, heat rashes, and heat fatigue.

This study was conducted at several Dr. Clean laundries which are located around city of Johor Bahru. Dr. Clean franchisees were chosen because its have similar concept on layout, machines, and location of each outlets in Malaysia. The laundry started its operation at 9.00a.m. and closed at 9.00p.m. everyday except on Sunday or public holiday. Normally, there were 4 employees working everyday in two shifts. Basically, the laundry outlets equipped with the same types of machine which is used for the dry cleaning process as well as normal washing process. This machine will generate heat during the process of dry cleaning and washing. Other than that, the ironing process also able to produce heat. This phenomenon has invited uncomfortable atmosphere at the working area.

The aims of this study are to determine heat stress at laundry workplace and identify appropriate solutions for solving problems of hot working environment. For this purpose, the heat stress of laundry workers were thoroughly investigated then the level of heat stress will be determined.

The experimental program of this study consists of two parts. The first part was directed to investigate heat stress effects on laundry workers based on the analysis on subjective assessment. There are a lot of parameters involved and some assumption on particular parameters has been made. The responses and

feedbacks from the laundry workers are important in order to get real view and condition on laundry environment. The experimental program was designed so as to gain better understanding on various aspects of laundry workers under heat stress environment. The second part of the experimental program was directed to investigate the heat stress on laundry workers regarding on the analysis on measured data. Several approaches have been applied in order to get the required data in this study. The equipments, reference data, and experimental procedures are described in detail in the following sections. Then, the test results are presented and conclusions are drawn.

2. Heat Stress

Heat stress is described in terms of external demands and limits placed on a person. In other word, heat stress can be described as the situation where the human body experiences problems in dissipating excess heat to the environment [2]. This occurs when the worker is exposed to a high-heat and low-humidity environment for an extended period of time. There are many places that have a high potential for inducing heat stress. Such places are iron and steel foundries, brick-firing and ceramic plants, rubber products factories, bakeries, steam tunnels, and last but not least laundry outlets. Four environmental factors affect the amount of heat stress felt by employees in hot working areas; temperature, humidity, radiant heat, and air velocity [3]. Other than that, physical work also plays a role in determining the heat load on the body. The individual reactions to heat is different depend on personal characteristic such as age, weight, fitness, medical condition, and the level of acclimatization [4].

3. Reference Data for Comparison

3.1 Wet Bulb Globe Temperature Index value according ISO 7243 Standard

The International Standard, ISO 7243 [5], which was published in 1982, is based on the WBGT-Index for evaluation of hot working environments. Before the publication of the ISO 7243 standard, the WBGT-Index had already been used in many countries and workplaces and Threshold Limit Values (TLV's) had already been established as a basis for environmental heat stress monitoring to control heat stress casualties at military training camps [6]. The WBGT Index is served as a basis of an international standard published by The International Organization for Standardization for expressing the combination of environmental factors and metabolic heat load. The ISO heat-stress standard in general resembles the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for heat stress. The TLV permissible heat-exposure values consider both the environmental heat factors and the metabolic heat production. Although WBGT is not a complete calculation for the many environmental and physical factors influencing heat stress, it goes a long way in providing useful guidelines for protecting people who work in hot environment. Since WBGT calculations are in wide use, and have proven utility, additional research is appropriate to investigate its value as a protecting estimate.

3.2 WBGT-Index Value According to The American Conference of Governmental Industries Hygienists (ACGIH)

The American Conference of Governmental Industrial Hygienist (ACGIH) TLV for heat stress refers "to heat stress conditions under which it is believed that nearly all workers maybe repeatedly exposed without adverse health effects". The TLV are based on the assumptions that the workers are acclimatized to the work associated heat stress present at workplace, workers are clothed in usual work clothing, workers have adequate water and salt intake, workers should be capable of functioning effectively, and the Time Weighted Average (TWA) deep body temperature will not exceed 38˚C (100.4˚F). The TLV permissible heat exposure values consider both the environmental heat actors and the metabolic heat production. The environmental factors are expressed as the WBGT while the metabolic heat production is expressed as work load category. The ACGIH publication "2000 TLVs and BEIs" provides recommended screening criteria for heat stress exposure for workers acclimatized to heat and for workers who are not acclimatized to heat is shown in **Table 2**.

3.3 Heat Stress Index for Belding and Hatch according to ISO 7243

The HSI as an index therefore is related to strain, essentially in terms of body sweating, for values between 0 and 100. At HSI = 100, evaporation required is the maximum that can be achieved, and thus represents the upper limit of the prescriptive zone. For HSI>100, there is body heat storage, and allowable exposure times are calculated based on a 1.8˚C rise in core temperature (heat storage of 264 kJ). For HSI<0 there is mild cold strain-for example, when workers recover from heat strain. The HSI index ratio of E_{req}/E_{max} is then compared to the **Table 3** in order to evaluate the heat stress levels of the environment in study.

Table 1 Reference Values of WBGT-Index from ISO 7243

Metabolic Rate Class	Metabolic Rates, M		Reference Value of WBGT			
	Related to a Unit Skin Surface Area (W/m^2)	Total (for a Mean Skin Area of $1.8m^2$) (W)	Person Acclimatized to Heat (°C)		Person not Acclimatized to Heat (°C)	
0 (resting)	M < 65	M < 117	33		32	
1	65<M<130	117<M<234	30		29	
2	130<M<200	234<M<360	28		26	
			No Sensible Air Movement	Sensible Air Movement	No Sensible Air Movement	Sensible Air Movement
3	200<M<260	360<M<468	25	26	22	23
4	M > 260	M > 468	23	25	18	20

Table 2 Screening Criteria for Heat Stress Exposure Using WBGT
(Source: 2000 TLVs and BEIs – Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. ACGIH, 2000)

	Acclimatized				Unacclimatized			
Work Demands	Light	Moderate	Heavy	Very Heavy	Light	Moderate	Heavy	Very Heavy
100% Work	29.5	27.5	26		27.5	25	22.5	
75% Work 25% Rest	30.5	28.5	27.5		29	26.5	24.5	
50% Work 50% Rest	31.5	29.5	28.5	27.5	30	28	26.5	25
25% Work 75% Rest	32.5	31	30	29.5	31	29	28	26.5

4. Experimental Procedure

4.1 Observation

There are four elements that lie under observation which are important in gaining some information regarding this study. There are site visit, observation on activities done by the workers, interviews and risk assessments.

4.2 Data Collection

The collection of data is the most crucial part of the study aside from analysis of findings. It is divided into two categories which are measurement the size of workplace area, and measurement of the heat stress and thermal comfort at the workplace area.

4.3 Data Analysis

The data obtained from the experimental program are heat stress indices (WBGT and HSI) has been analyzed in order to determine the correlation of the heat stress index with commonly used parameters such as air temperature. Besides, the gathered data also being compared with the standard in order to identify either the laundry workplace environment is within the limits or exceeds certain limits set by the standards.

5. Results and discussion

5.1 Analysis on Subjective Assessment

From the result shown in **Table 4**, the percentages of male and female employees are both equal which represented 50% from each

gender. Logically, male employees are more energy than female. Majority of the employees are aged between 18 to 29 years old which represented 80% from total employees. The other 20% employees aged between 30 to 39 years old. The percentages of employees with weight between 30 to 69 kg were 90% which show that most of the employees fit to perform their job. From the interview, 40% of the employees were in bad health. This may occurred by the unhealthy and hot working environment at the laundry outlet. The rest of the employees are in healthy condition. From the table, all of the employees are acclimatized since they have working at the laundry for many years. The level of acclimatization is important to ensure that the employees are immune with the hot working condition at the laundry outlet.

Table 3 Interpretation of Heat Stress Index (HSI-Index) Values

HSI Value	Effect of Eight Hour Exposure
-20	Mild cold strain (e.g. recovery from heat exposure)
0	No thermal strain
10 – 30	Mild to moderate heat strain Little effect on physical work but possible effect on skill
40 – 60	Severe heat strain, involving threat to health unless physically fit Acclimation required
70 – 90	Very severe heat strain Personal should be selected by medical examination, adequate water and salt intake must be ensured.
100	Maximum strain tolerated daily by fit acclimatized young men
Over 100	Exposure time limited by rise in deep body temperature

5.2 Analysis on Measured Data

Both heat stress indices; WBGT and HSI were calculated using the TLV of Time Weighted Average (TWA). TWA is defined by time-weighted average for a normal 8 hours workday or 40 hours work week, to which nearly all workers can be exposed, day after day, without adverse effects.

5.2.1 Estimation on Metabolic Rate

From the metabolic rate estimation, the suggested value for domestic work such as washing by hand and ironing is 170W/m2 or 2.9 Met. There could be difference between the real values and the estimation values because of the heat generated within the body cannot dissipate to the surroundings as the temperature of the surroundings is as warm as or warmer than the skin. Under this condition, the heart continues to pump blood to the body surface and this lead to the increased of the metabolic rate.

5.2.2 Evaluation on Clothing Insulation

The insulation value corresponds to the type of clothing worn by the workers at the laundry working area can be determined by adding all the insulation value together. From the result (refer **Table 5**), the total clothing insulation value for the laundry workers are 0.39 Clo or 0.076 $m^{2\circ}C/W$.

Table 4 Subjective data assessment on general questions

General Question	Percentages (%)
1) Gender	
Male	50
Female	50
2) Age	
Between 18 to 29 years old	80
Between 30 to 39 years old	20
Above 40 years old	
3) Weight	
Below 30 kg	
Between 30 - 69 kg	90
Above 70 kg	10
4) Medical Condition	
Very Healty	20
Healthy	40
Fever	40
5) Level of Acclimatization	
Acclimatized	100
Not Acclimatized	

Table 5 Overall clothing insulation value

Garment Description		Unit	
		Clo	$m^{2\circ}C/W$
Underwear / Shirts	Briefs	0.04	0.006
	Bra	0.01	0.002
Shirts	Short sleeve	0.09	0.029
Trousers	Normal trousers	0.25	0.039
TOTAL		**0.39**	**0.076**

Table 6 WBGT-Index from (3) Laundry Outlets Investigated

Hours	WBGT-Index		
	Laundry 1	Laundry 2	Laundry 3
1	28.98	26.64	27.5
2	29.12	26.61	27.6
3	28.20	26.46	27.4
4	27.85	26.25	27.1
5	28.60	26.43	26.9
6	29.11	26.46	26.8
7	29.37	26.21	26.6
8	29.02	26.22	26.5
WBGT-Index (TLV-TWA)	**28.78**	**26.41**	**27.04**

5.2.3 WBGT-Index Value According to ISO 7243 Standard

From the result shown in **Table 6**, Threshold Limit Value (TLV) sets by the ISO 7243 Standard is WBGT = 28°C for acclimatized person. The WBGT-Index at Laundry 1 is above the Threshold Limit Value at WBGT = 28.78˚C in average and could endanger the workers' health. The value of WBGT gained from this study is definitely higher than the reference value suggested by the ISO 7243 Standard. Therefore, the workers at the laundry working area are exposed to the heat stress. While the others laundry outlets, the WBGT-Index value for Laundry 2 and Laundry 3 are below the Threshold Limit Value (TLV-TWA) of ISO 7243 standard with WBGT average value 26.41˚C and 27.04˚C respectively. This result may cause by the low of production that are faced by the company since they starting their operation. The proper ventilation system at both laundry outlets also contributed to the lower of WBGT-Index. Definitely, both Laundry 2 and Laundry 3 were in safe condition and there will be no heat stress that may affect the employees.

5.2.4 WBGT-Index Value According to ACGIH Standard

From the standard, the reference value of WBGT for a person that is acclimatized to heat performs a "moderate" work and the work demand is 75% work; 25% rest is 28.5°C. The value of WBGT-Index at Laundry (1) is 28.78˚C. It showed that the calculated WBGT has exceeded the Threshold Limit Value (TLV) suggested by the ACGIH Standard. Therefore, the workers at the laundry working area might get exposed to the heat stress effects due to the high temperature. Hence, several of health issues are expected to arise resulting from the uncomfortable environment caused by the high temperature. The rest of two laundry outlets are reported below the Threshold Limit Value (TLV-TWA) and could be in safe condition to the employees

Table 7 HSI-Index from (3) Laundry Outlets Investigated

Hours	HSI-Index		
	Laundry 1	Laundry 2	Laundry 3
1	27.70	25.98	21.19
2	28.26	28.01	21.72
3	27.79	28.41	24.66
4	29.03	24.44	28.64
5	31.68	27.53	31.85
6	29.92	26.74	28.14
7	28.56	25.05	27.14
8	24.64	28.31	24.70
HSI-Index (TLV-TWA)	**28.45**	**26.81**	**26.01**

5.2.5 HSI-Index Value According to ISO 7243 Standard

According to standard, the permissible HSI value with no thermal strain affected is ranges between 0 to10. Table 7 shows that the calculated value of HSI from all the laundry outlets investigated falls in the range of 10 to 30. Laundry 1 presents the highest HSI value with 28.45 followed by Laundry 2 and Laundry 3 with the value of 26.81 and 26.01 respectively. Within this range, the effect of eight hour exposure is mild to moderate heat strain. There will be little effect on physical work but possible effect on skill.

5.2.6 Discussions

Variety of engineering controls can be introduced to minimize exposure to heat. In a laundry room, exhaust hoods installed over those sources releasing moisture will lower the humidity in the work area. In general the simplest and least expensive methods of reducing heat and humidity can be accomplished by opening windows in hot work areas, using fans, or using other methods of creating airflow such as exhaust ventilation or air blowers. Providing cool rest areas in hot work environments considerably reduces the stress of working in those environments. There is no

conclusive information available on the ideal temperature for a rest area. Preparing proper work procedures involving the management and the workers such as providing a mineral pot at the working area, wearing permeable clothing that permits the evaporation of sweat, taking lot drink water to replace the loss of body's fluid due to sweating; would minimize the effect of heat stress.

6. Conclusions

Heat stress has been determined at Laundry 1 (Dr. Clean Surplus Prisma Sdn Bhd, Bandar Baru Uda) with the WBGT value measured at 28.78˚C, which has exceeded the Threshold Limit Value (TLV) recommended by the ISO 7243 Standard and ACGIH Standard at WBGT 28°C and 28.5°C respectively. While the HSI value measured is 28.45 which falls in the range of 10 to 30. Within this range, the effect of eight hour exposure is mild to moderate heat strain. The others two laundry outlets, Laundry 2 (Dr Clean Ambang Elit Sdn Bhd, Bandar Putra Kulai) and Laundry 3 (Dr Clean Prisma Ilusi Sdn Bhd, Taman Mutiara Rini) recorded WBGT-Index with mean 26.41˚C and 27.04˚C respectively. The WBGT value recorded below the Threshold Limit Value (TLV) recommended. Its showed that there were no heat stress determined at both Laundry 2 and Laundry 3. But the HSI value determined both Laundry 2 and Laundry 3 are possibly affected with mild to moderate heat strain since the HSI value measured are 26.81 and 26.01 respectively.

For future study on this topic, there are a few recommendations that might help to get better result. The recommendations are as follows:

- Conduct a study to investigate the effect of weather changes on the heat stress index and thermal comfort index.
- Measurement of the parameters is conducted in a number of days in order to get a better average value.

Use new and variety of equipment for measuring the heat stress parameters to get more accurate data.

7. References

[1] International Ergonomics Association Executive (IEA) Council (August 2000). "The Discipline of Ergonomics" http://www.iea.cc/ergonomics

[2] World Health Organization (1985). "Health Factors Involved in Working under Conditions of Heat Stress." Technical Report Series No. 412. Geneva: World Health Organization.

[3] Ahasan, M.R. (2001). "Evaluation of Heat Stress and Physical Effort of Workers in A Re-rolling Steel Mill." Journal of Physiological Anthropology. Not Published.

[4] Belding H.S. and Hatch. T.F. (1955). "Index for Evaluating Heat Stress in Terms of Resulting Physiological Strain." Heating, Piping and Air Conditioning. Vol. 27. 129-136.

[5] International Standards Organization. (1982). "Hot Environments-Estimation of the Heat Stress on Working Man, Based on the WBGT-index." Geneva: (ISO 7243)

[6] National Institute for Occupational Safety and Health (1992). "Working in Hot Environments." XXIIIrd Pan AmericanSanitary Conference. Washington DC, USA: National Institute for Occupational Safety and Health.