

Investigation of heat stress in workplace for different work groups according to ISO 7243 standard in Mehr Petrochemical Complex, Assaluyeh, Iran

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ABSTRACT

Heat stress is a significant occupational health and safety for workers in petrochemical industries. Heat stress is a combination of heat load individual and environmental factors impose on workers' bodies, which in turn, have impacts on workers' performance, safety, and health. The present paper is carried out to determine the heat stress levels in workplace and to compare it with allowed Wet Bulb Globe Temperature (WBGT) according to ISO 7243 standard. the present study was carried out in three consecutive weeks in Mehr Petrochemical Complex in South Pars Special Economic Zone in Assaluyeh, 270Km southeast of Bushehr in spring of 2011. The study was carried out on workers in different parts including workers in packaging, mechanics, welding, and store keeping sections.

Environmental parameters of dry temperature, natural wet temperature, glowing temperature, and relative humidity were measured to calculate an index for Wet Bulb Globe Temperature according to ISO7243 standard, and metabolism rate was estimated according to ISO 8996 standard. Metabolism level for workers in two groups of mechanics and welding sections according to ISO 8996 standard was 95W/m^2 , and for workers of packaging and store keeping sections calculated as 75W/m^2 . Based on ISO 8996, work load for all four sections was light. The means of weather parameters such as dry temperature, natural wet temperature, glowing temperature, and relative humidity were statistically significant for all four sections. It was also indicated that the highest level of WBGT were obtained for workers in mechanics (33.26 ± 0.21), packaging (32.02 ± 0.2), welding (31.37 ± 0.2), and the lowest level was estimated for store keeping workers (27.4 ± 0.22), with changes being statistically significant.

DISCUSSION AND CONCLUSION: findings of the present study indicated significant changes between different groups in measured parameters and calculated indices, which confirm results of previous body of research. Workers in three groups of mechanics, packaging, and welding are exposed to heat stress, and among these three, mechanics workers' exposure to heat stress is higher, but WBGT index in store keeping work place is lower than allowed level. Thus, they have been experiencing favourable work atmosphere.

Keywords: Heat Stress; WBGT; Heat Strain; Metabolism; Work Load

INTRODUCTION

Heat stress is a significant occupational health and safety for workers in petrochemical industries. Heat stress is a combination of heat load individual and environmental factors impose on workers' bodies [1]. Investigating heat stress among workers in different workplaces indicated that rise in environmental temperature has significant and negative impact on workers' performance, attitude, satisfaction

level and output [2]. Dynamic and frequent interaction among workers and the workplace induces physiological and psychological tensions, which brings about sensitivity, irritation, and anxiety, and have direct impact on performance, output, and health and safety of workers [3]. So, awareness to impacts of workplace conditions on workers is important to improve their performance and output, and to prevent workplace accidents. Since decades

ago, much research has been carried out to investigate hot environments and obtain an optimal index for investigation of heat stress, much of which has been carried out on mine's hot environment and that of military workers. Among indices suggested in this bodies of research to investigate hot environmental conditions are Effective Temperature (ET) [4] and Wet Bulb Globe Temperature (WBGT) [5]. Also, many models based on body temperature variations when exposed to heat have been suggested [6, 7], and recently, ARIEM has been proposed by Cadarette et.al. which predicts body inner temperature in any time of exercise [8], Other indices such as P4SR (Predicted 4-hours Sweat Rate) [9], SWreq (Required Sweat Rate) [10], PSI (physiological strain index) [11], and CHSI (cumulative heat strain index) have been suggested to investigate hot environments. International Standard Organization (ISO) recommends WBGT and ISO 7243 for a quicker investigation of hot environments [13], and SWreq and ISO 7933 for more exact investigation of hot environments [14]. In the present paper, to investigate heat stress in workplace, WBGT index has been used. The main objective of the study was to compare heat stress in workplace with allowed rate according to ISO 7243 standard.

MATERIAL AND METHODS

The present study was carried out in three consecutive weeks in Mehr Petrochemical Complex in South Pars Special Economic Zone in Assaluyeh, 270Km southeast of Bushehr in spring of 2011. The region has located in southern Iran, in Persian Gulf coasts, and has a warm climate, with humid and warm weather in coastal areas, and arid and hot in inner parts. The annual average temperature is 24 degrees Celsius, with a maximum of 50 degrees Celsius, and the minimum of 6 degrees Celsius. Precipitation in the region is variable and low, between higher or lower than the annual average precipitation (217mm). The total area of Mehr Petrochemical Complex is 13 hectares. The complex produces heavy polyethylene products and located in 2nd phase of Pars Special Economic Zone in Assaluyeh.

The study was carried out on workers in different parts including workers in packaging, mechanics, welding, and store keeping sections. It should be noted that workers in packaging and store keeping sections was working in indoors, and workers in mechanics and welding was working in different parts of Petrochemical Complex outdoors.

The sample population were 20 male workers. The sample has the maximum number of workers possible, selected according to their workplace conditions, and previous research [1, 15]. All subjects were healthy, without any diseases. For environmental measurements, the researchers used a machine, made by British company, CASELLA, for measuring WBGT. It was calibrated to measure dry temperature, natural wet temperature, glowing temperature, and relative humidity. An index was calculated for Wet Bulb Globe Temperature according to ISO7243 standard, and metabolism rate was estimated according to ISO 8996 standard [16]. For outdoors, to calculate WBGT according to ISO 7243, the Eq. [1] was used:

$$WBGT_{out} = 0.7T_{nw} + 0.2T_g + 0.1T_{db} \quad \text{Eq. (1)}$$

Where T_{nw} denoted natural wet temperature, T_g , glowing temperature, and T_{db} , denoted dry temperature.

For indoors, to calculate WBGT according to ISO 7243, the Eq. (2) was used:

$$WBGT_{out} = 0.7T_{nw} + 0.3T_g \quad \text{Eq. (2)}$$

According to standard used, if the environment is heterogeneous, it is necessary that WBGT is calculated in three parts of body, heels, lower back, and head.

$$WBGT = \frac{WBGT_{head} + (2 \times WBGT_{waist}) + WBGT_{ankle}}{4}$$

WBGT index for different times of day during shift work is calculated according to standards as the following:

$$WBGT_{TWA} = \frac{(WBGT_1 \times T_1) + (WBGT_2 \times T_2) + \dots + (WBGT_n \times T_n)}{T_1 + T_2 + \dots + T_n}$$

The data has been analysed by SPSS 16 statistical application under Windows. Quantitative variables were presented in deviation and Mean±Std. and qualitative variables were given in percentage. The distribution of quantitative variables was analysed according to their distribution by Analysis of Variance (VAR), and repeated VAR. (P<0.05) was set as significance level.

RESULTS

Table 1 shows metabolism levels, work load, and clothing of the workers. Metabolism was extracted according to 8995 standard and workers' occupations. As indicated by Table 1, metabolism for workers in mechanics and welding groups is 95W/m², and for packaging and store keeping groups, is 75W/m². Work

load for all groups was light according to 8996 standard, with one-layer clothing for all workers. Table 2 gives the allowed level of indices according to adoptability and non-adoptability of workers to heat, metabolism and wind speed [13]. It should be noted that in the present study, all workers were assigned to groups according to their adoptability records.

Table 1. Metabolism, work load, and clothing

group	mechanics	welding	Packaging	Store keeping
Number of workers	5	5	5	5
metabolism (W/m ²)	95	95	95	95
work load(percentage)				
Very heavy				
Heavy				
Moderately heavy				
Light	100	100	100	100
Clothing (percentage)				
monolayer	100	100	100	100
Bilayer				

Table 2. The allowed level of indices according to 7243 standard for adopted and non-adopted workers

(WBGT) Wet Bulb Globe Temperature level		metabolism (W/m ²)
For non-adopted workers (Celsius)	Adopted workers (Celsius)	
32	33	M < 65
29	30	65 < M < 130
26	28	130 < M < 200
22(23)	25(26)	200 < M < 260
18(20)	23(25)	M > 260

Numbers in parenthesis is for times when wind speed is significant enough

Table 3. Means And Standard Deviation For Measured Parameters And Calculated WBGT Index

Group	Mechanics	Welding	Packaging	Store Keeping
Number Of Subjects	40	40	40	40
T _a (Celsius)	35/15±0/34	34/03±0/33	34/24±0/33	28/01±0/35
T _g (Celsius)	0/4 ±38/2	36/18±0/39	34/54±0/39	28/79±0/43
T _{nw} (Celsius)	30/7±0/28	28/73±0/27	30/76±0/27	26/99±0/29
RH (Percentage)	72/23±2/01	66/86±1/95	77/73±1/96	89/02±2/11
WBGT(Celsius)	33/26±0/21	31/37±0/2	32/02±0/2	27/4±0/22

Table 3 gives means and standard deviations for dry temperature T_a, glowing temperature T_g, natural wet temperature T_{nw}, relative humidity (RH), and WBGT index for all groups. From Table 1, it is obvious that the highest dry temperature T_a has been for workers in mechanics section (35.15±0.34), and the lowest dry temperature has been for store keepers (28.01±0.35). The statistical analysis indicated a significant difference between measured T_a levels for different groups (P<0.05). as the table

indicates, the highest glowing temperature T_g has been for mechanics workers (38.2±0.4), and the lowest, for store keepers (28.79±0.43), with significance for differences in T_g measured for different groups (P,0.05). with natural wet temperature T_{nw}, the highest level was obtained for packaging workers (30.76±0.27), and the lowest level, for store keepers (26.99±0.29), with significance of difference for T_{nw} in all groups (P<0.05).

As Table 3 indicates, relative humidity was highest for store keepers (89.02 ± 2.11), and was lowest for welding workers (66.86 ± 1.95). Statistical analysis indicated that there was a significant difference in RH between groups ($P < 0.05$). Calculated WBGT index was highest for mechanics workers (33.26 ± 0.21), packaging workers (32.02 ± 0.2), welding workers (31.37 ± 0.2), and was lowest for store keeping workers (27.4 ± 0.22), with significant differences between groups ($P < 0.05$).

Comparison of measured WBGT indices to allowed level given in Table 2 according to estimated metabolism rate (in 30 degrees Celsius) indicates that WBGT index for mechanics, packaging, and welding workplaces was respectively 3.26, 3.02, and 1.37 degrees Celsius higher than the allowed level. Thus, workers in all three groups are subject to heat stress, the mechanics workers being subject to more heat stress, but WBGT level for store keeping workers is lower than that allowed, thus experiencing favourable workplace.

DISCUSSION AND CONCLUSION

Heat stress is one of the physical harmful agents in many industries (especially in tropical area such as Assaluyeh-Iran). It can cause fatigue, lethargy, decreasing productivity, increasing errors, increasing the number of accidents and also heat-related diseases [17]. So there is a wide range of problems and they require special attention. As a result the measurement, evaluation and control of heat stresses are an important step forward in providing occupational health and safety. In the developing countries like Iran it needs to conduct more researches on this issue.

The present paper indicated that means of climatic differences such as dry temperature, natural wet temperature, glowing temperature, and relative humidity measured in workplaces for all four groups were statistically significant, with highest dry temperature and glowing temperature for mechanics workers, highest natural wet temperature for packaging workers, and highest relative humidity for store keeping workers. Comparison of measured WBGT indices to allowed level according to estimated metabolism rate (in 30 degrees Celsius) indicates that WBGT index for mechanics,

packaging, and welding workplaces was respectively 3.26, 3.02, and 1.37 degrees Celsius higher than the allowed level [13]. The present findings seem to be consistent with other studies [1-15]. Present paper also indicated that there was a significant difference in WBGT index calculated for groups, and when compared to 7243 standard, it was indicated that three groups of mechanics, packaging, and welding were subject to heat stress, with mechanics workers having the most exposure to heat stress. Which increases heart rate and systolic and diastolic blood pressure, body deep temperature, skin temperature and sweat secretion, which among them, the heart rate and body deep temperature are more reliable than others [18, 19]. The WBGT index calculated for store keeping workers was lower than allowed level, thus they experience favourable work conditions. In high heat stress, body cannot maintain its heat balance and so the heat is stored in the body and when the amount of heat stress increases, the amount of heat stored in the body will also grow. The limit value of body deep temperature, according to findings and recommendations of organizations such as WHO, ACGIH, NIOSH, and ISO 7933, is 38°C and is about 0.05 to 0.55 higher than the temperature mouth [16, 18]. Mei-Lien Chen (2003) in his investigation of heat stress on foundry showed that workers in casting experienced more heat stress than workers in steel welding. His measured levels for weather parameters was significantly lower than those measured by the present study, thus indicting that heat stress was high in Petrochemical Complex workplaces [1]. The present findings seem to be consistent with other studies. Worker heat stress and strain in aluminum smelters was studied by Perry W Logan and et al. They revealed heat stress higher than the allowed levels, which is in agreement with the present study [15]. As the present study found out, workers in three groups of mechanics, packaging, and welding experience heat stress in daily basis, which has significant effect on their performance, safety and health. The study recommends that workers, especially workers not adapted to heat, receive trainings necessary to work in such environments.

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