International Journal of Innovation Scientific Research and Review
Vol. 06, Issue, 03, pp.6081-6090, March 2024
Available online at http://www.journalijisr.com
SJIF Impact Factor 2023: 6.599

ISSN: 2582-6131

Research Article

ASSESSMENT OF INDUSTRIAL THERMAL STRESS IMPACTS IN OMDURMAN LOCALITY

[1,] * Dafallah Abdelgadir Mokhtar Esmail, [1]Mariam Saeed Ibrahim Essa, [2]Hind Abd- Almoula Mohammed Nour Fadlalla, [3]Hebaa Elfatih Naeem Mohamed Ahmed

[1]Assistant Prof. Faculty of Public and Environmental Health, El Imam El Mahdi University, Sudan.
[2]Assistant Prof., Faculty of Medical Laboratories, El Imam El Mahdi University, Sudan.
[3]Public Health Specialist Expanded Program of Immunization.

Received 23th January 2024; Accepted 24th February 2024; Published online 31st March 2024

ABSTRACT

This Cross-sectional description study in Omdurman locality (September 2017- March 2022) attempts to assess thermal stress in industries using a wet bulb globe temperature (WBGT) heat stress device to identify occupational health and safety measurements in sectors. Also, this study aims to: differentiate between d differentiate between different heat-related illnesses, heat exhaust, sunburn, and heat cramps, and a sum of 92 other factories that are considered as hot working areas in Omdurman industrial state Sectors included in the survey are food, oil and soaps, iron &metals, plastic, and Cement and derivatives. The study was conducted to assemble database of workers in that location. The study investigated a sample of 241 workers, considering health issues and collecting personal data. The study conducted a questionnaire to study the stress of heat among the 241 workers in 92 industrial factories to examine temperatures exceeding this study found a significant relation between a high score of heat stress measurements (WBGTC0) and heat stress illness; my study also clarified significant association between heat stress(WBGT) and heat stress in all symptoms of heat stress illness except the signs of heat stroke. This study documents the fact lack of following heat stress prevention measures between employers and employees, by way of the supply of suitable meals, training in hot situations, requiring acclimatization on work tasks that could exceed 8 hours, lack of medical check-ups, creating awareness of heat stress risks, sufficient supplies of cold drinking water and proper clothing, and suspending of work upon development of heat stress in the workplace. This study aims to propose the guidelines for Occupational Health and Safety (OHS) for the prevention of heat stress.

Keywords: Occupational Health and Safety(OHS), Thermal stress, wet bulb globe temperature (WBGT), Omdurman locality.

INTRODUCTION

1.1. General:

The thermal environment significantly affects the workers' health, productivity, and safety. However, under high-temperature conditions, exposed workers may fall sick, and consequently, their health would be affected; it has also been shown that their output efficiency may decrease considerably when environmental temperatures exceeding certain limits are lowered, peak efficiency is reached when temperatures are within a comfortable range, and the efficiency rates may vary for different activities. However, the incidence of accidents is reduced at comfortable work temperatures and is highly raised when temperatures are varied in different directions.

Industry is a significant hope and vehicle for development in Sudan. It represents one of the cornerstones of economic and social development, considering its potential role in enhancing and multiplying the capabilities of the national economy. Sudan's industrial sectors include food, leather, oils, and soap, as well as building, textile, engineering, printing, and packing. Omdurman locality is the national capital and a center of population density comprising various tribes, religious sects, customs, and cultures. It has the capital's most important industrial estate.

This includes factories as hose workers are exposed to high heat levels like food (29), oils and soaps (24), iron and metals (15), plastic (23), and cement and derivatives (1)—about 92 factories in total.

***Corresponding Author: Dafallah Abdelgadir Mokhtar Esmail,**
1Assistant Prof. Faculty of Public and Environmental Health, El Imam El Mahdi University, Sudan.

1.2. Problem statement:

The problem of managing work place hazards has become a significant concern in developing countries.

An ineffective system of identifying and controlling hazards is a significant element in the workplace. Thus, hazard and hazard exposure assessments are necessary because they involve the systematic collection and analysis of occupational hazards and exposure determinants, such as the magnitude of work tasks, frequency, variability, duration, and route of exposure profiles of individuals, and similarity exposed groups.(1)

Despite significant industrial developments in Sudan, there is no adequate research on thermal stress assessment, especially in the Omdurman area factories. This study aims to provide baseline data on workplace thermal stress assessment in Omdurman locality industrial sectors. Such data offer appropriate recommendations for future safety and health programs, which would hopefully help reduce possible workplace hazards.

1.3. Objective:

1.3. 1. General Objective

To assess the impact of thermal stress on preventive mitigation measures for removal or reductions.

1.3.2. Specific Objectives:

1. To assess thermal stress in industries using WBGT heat stress device for eventual identification of Occupational health and safety measurements in industries,

2. Differentiate between heat-related illnesses: heat exhaustion, sunburn, cramps, and stroke.
3. Establish baseline data according to results and guidelines concerning thermal stress.

LITERATURE REVIEW

Assessment of thermal stress impact in different industries is now considered severe because the thermal environment plays a vital role in workers' health, production, and safety. Working at high temperatures can cause exposed workers to fall ill, affecting their consequent health. Also, it may show that the output efficiency of workers decreases considerably when the temperature of the environment increases above certain limits.

Practical assessment must discover the employer's role in preventing hazards and improving the occupation and health of workers. For instance, workers have the right to know about workplace hazards, including how to identify and protect themselves and the rights afforded to workers under the Act. Also, they have the right to participate in workplace safety and health decisions that are free of reprisal for their participation. Participation, in part, is achieved through the committee or worker representative. The refusing worker believes the right to refuse work to be dangerous.(2)

2.1. Heat Stress:

Heat is a source of energy. So, high heat always causes high energy, and low heat causes low energy. Operations involving high air temperatures, radiant heat sources, high humidity, direct physical contact with hot objects, or strenuous physical activities have a high potential for inducing heat stress in employees engaged in such operations. Such places include iron and steel foundries, nonferrous foundries, brick-firing and ceramic plants, glass products facilities, rubber products factories, electrical utilities (particularly boiler rooms), bakeries, confectioneries, commercial kitchens, laundries, food canneries, chemical plants, mining sites, smelters, and steam tunnels. Outdoor operations conducted in hot weather, such as construction, refining, asbestos removal, and hazardous waste site activities, especially those that require workers to wear semi-permeable or impervious protective clothing, are also likely to cause heat stress among exposed workers.(3)

2.1.1. The body's heat exchange mechanism

Most heat problems in the workplace are caused by an imbalance of heat production and heat loss in the body. Humans can regulate their internal body temperature within narrow limits. This is accomplished by heat being carried by blood from muscles and deep tissues to the body's surface for dispersal.

The initial heating of the body is environmentally affected by the air temperature, humidity, airflow, and radiant temperature, all of which may vary widely during a daily work shift. The human body uses sweat as a means of evaporative cooling. The effective temperature an individual actually “feels” is a combination of the surrounding environment, work activity level, and clothing. The efficiency of the body’s cooling mechanisms can be affected by the work environment, including the tasks being performed, psychological stress levels, clothing, the surrounding environment, health, age, and physical condition of the worker.

Workplace heat exposures are different between hot-dry or warm-moist heat. In a hot-dry situation, the body releases heat readily through sweating and evaporation, but fluid-loss rates may be extreme enough to produce dehydration of body tissues. Warm-moist heat may retard the ability of sweat to evaporate and cool the body. In either situation, the body may absorb more heat than it can release through sweating. Depending on the individual, any heat may be a hazard, resulting in one or more symptoms.(4).

2.1.2. Factors Affecting Thermal Balance:

Three factors play an essential role in thermal balance. They are the Climatic conditions of the environment, work demands, and clothing. Climatic conditions are widely used to describe the degree of stress, as seen in casual descriptions of air temperature, relative humidity, and wind chill. However, they are not the only determinants of thermal stress. The role of metabolic rate in heat balance is vital because it substantially contributes to heat gain.

In heat stress, metabolic rate can add 10 to 100 times more heat to the body than radiation and convection combined.(5) Clothing ventilation is the third factor. Depending on the nature of the fabric, garment construction, and work demands, ambient air can move through the fabric or around the garment openings. Clothing ensembles that support air movement can enhance evaporative and convective cooling. Those designed and worn to limit such movement limit evaporative and convective cooling. An excellent example of using ventilation characteristics to regulate heat balance is arctic parkas with drawstrings around the waist, cuffs, and hood. As metabolism heats a person, cooling can be achieved by loosening some of the closures to increase the amount of airflow (ventilation) under the clothing.

- Personal factors include age, weight, degree of physical fitness, degree of acclimatization, metabolism, and use of alcohol or drugs.
- Medical conditions such as hypertension affect a person's sensitivity to health. However, even the type of clothing worn must be considered. Prior heat injury predisposes an individual to additional injury. It is difficult to predict who will be affected and when because individual susceptibility varies.
- Environmental factors include more than the ambient air temperature. Radiant heat, air movement, conduction, and relative humidity affect an individual's response to heat.(6,7)

2.1.3. Heat stress effect:

2.1.3.1. Heat rash:

Skin irritation may result from continuous exposure to heat or humid air. It is caused by rubbing, changing, or reacting to a person’s sweat with its salts and minerals. The sweat glands usually become blocked and infected (8).

2.1.3.2. Heat cramping:

Heat cramping is a phase that signals the start of physical danger and indicates that the worker should rest or slow down. Heat cramps are caused by heavy sweating with inadequate electrolyte replacement or redistribution. Signs and symptoms include:

- muscle spasms; and, or
- Pain in the hands, feet, and abdomen.

However, not all workers suffer heat cramps before more severe heat stress occurs.

2.1.3.3. Heat syncope: Heat syncope is a fainting (syncope) episode or dizziness that usually occurs with prolonged standing or sudden rising from a sitting or lying position. Factors that may contribute to heat syncope include dehydration and lack of acclimatization.

The symptoms of syncope include:
Light – headiness
Dizziness and
Fainting

2.1.3.4. Heat exhaustion:

Produces a define warning that the body is stressed by excessive heat from dehydration and increases heat stress on various body organs. Signs and symptoms may include:

- heavy sweating (This is a universal sign);
- pale, calm, moist skin
- Dizziness, fainting, light-headedness;
- nausea
- headache;
- irritability
- slightly elevated body temperature;
- weak, rapid, and, or irregular pulse
- decreasing blood pressure; and general fatigue and poor feeling.

2.1.3.5. Heat stroke:

Heat stroke is the most severe heat–related disorder. It occurs when the body cannot control its temperature: its temperature rises rapidly, the sweating mechanism fails, and the body cannot cool down. When heat stroke occurs, the body temperature can rise to 106 degrees Fahrenheit or higher within 10 to 15 minutes. Heat stroke can cause death or permanent disability if emergency treatment is not given.
Symptoms of heat stroke include:

- hot, dry skin or profuse sweating;
- Hallucination;
- Chills;
- Throbbing headache;
- high body temperature ;
- Confusion, dizziness, and

Slurred speech.(9)

2.1.4. Indexes of heat stress:

Several indexes can be used for assessing heat stress.

2.1.4. 1. Effective temperature:

The effective temperature is an index that combines dry-bulb, wet-bulb, and velocity to estimate a thermal sensation at a given temperature of still and saturated air. When taking measurements, ensure the dry bulb thermometer is shielded from radiation. Determination of effective temperature also requires an anemometer to measure air velocity in feet per minute.(10)

2.1.4. 2. Equivalent effective temperature

The use of black-globe temperature correction for the contribution by surrounding radiation sources. This is known as the equivalent effective temperature corrected for radiation.(11)

2.1.4. 3. Predicted 4-Hour Sweat Rate:

The predicted 4-hour sweat rate (P_4SR) is an index based on observations of sweat rates under various environmental conditions.
The P_4SR index requires globe temperature, wet bulb temperature, air velocity, and the workers' metabolic rate.

This index is probably of more value to physiologists than industrial hygienists.(12)

2.1.4. 4. Belding and Hatch Index (Heat Stress Index) (H.S.I)

It is based on comparing the amount of sweat required to evaporate to maintain thermal equilibrium to the maximum amount of sweat that can be evaporated in the specified climatic conditions.(13)

E_{req}=M=C=R

Where

E_{req}: is the evaporative heat loss required for thermal balance, BTU/hr.

E_{max}: is the maximum possible evaporative heat loss as dependent on environmental Conditions=2400 BTU/hr, so,

H.S.I=(E_{req}/ E_{max})×100

M= metabolic heat, C= convection, R= radiation,
BTU= British thermal unit

2.1.4. 5. WET Bulb-Globe Temperature

Measurement is often required of those environmental factors that most nearly correlate with deep body temperature and other physiological responses to heat. The Wet Bulb Globe Temperature Index (WBGT) is the most used technique to measure these environmental factors. The following equations calculate the WBGT values:

Equation Indoor or Outdoor Wet-Bulb Globe Temperature Indexes (WBGI)

- Indoor without solar load

WBGT = 0.7NWB + 0.3GT

- Outdoors with solar load

WBGT = 0.7NWB + 0.2GT + 0.1DB

Where:	WBGT	=	Wet Bulb Globe Temperature Index
	NWB	=	Natural Wet-Bulb Temperature
	DB	=	Dry-Bulb (air) Temperature
	GT	=	Globe Thermometer Temperature.(14,15)

2.1.5. Permissible heat exposure threshold limit value

These TLVS are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should function effectively under the given working conditions without exceeding a deep body temperature of 38°C (100.4 °F). They are also based on the assumption that the WBGT of the resting place is the same or very close to that of the workplace. Where the WBGT of the work area is different from that of the rest area, a time-weighted average should be used.(16,17)

Table (2-1): Permissible heat exposure threshold limit value

	------------- Work Load* ------------		
Work/rest regimen	Light	Moderate	Heavy
Continuous work	30.0°C (86°F)	26.7°C (80°F)	25.0°C (77°F)
75% Work, 25% rest, each hour	30.6°C (87°F)	28.0°C (82°F)	25.9°C (78°F)
50% Work, 50% rest, each hour	31.4°C (89°F)	29.4°C (85°F)	27.9°C (82°F)
25% Work, 75% rest, each hour	32.2°C (90°F)	31.1°C (88°F)	30.0°C (86°F)

*Values are in °C and °F, WBGT.

3. MATERIALS AND METHODS

3.1. Study Design:

A cross-sectional descriptive study design was conducted to study thermal stress and related stresses in workers of industries in the Omdurman locality (2017 – 2022).

3.2. Study area:

After obtaining permission from the companies, the study was conducted in different industrial sectors at Omdurman locality in Khartoum state, Sudan. Khartoum state is one of the 26 states in Sudan. It is the political and commercial center of the country, with an area of 0140 Km2.It lies between latitudes 15.10 to 16.35 degrees north and longitudes 31.35 to 34.20 degrees east. The state is divided into seven localities.

Omdurman locality is the national capital of Sudan and a center of population density comprising various tribes, religious sects, customs, and cultures. It has the capital's most important industrial estate. The study site includes factories, as house workers are exposed to high heat levels in foods (29), oils and soaps (24), iron and metals (15), plastic (23), and cement and derivatives (1). There are about 92 factories in total.

3.3. Study population

3.3.1. Industries:

Workplace assessment was conducted in 92 factories in the Omdurman locality. The distribution of the study factories by activities is illustrated in the following table:

Table (3-1) represents the distribution of the study factories by activities.

Activity	No. of factories
Food	29
Iron and Metal	15
Plastic	23
Cement α derivatives	1
Oil & soap	24
Total	92

3.3.2. Workers:

According to the record of the Occupational Health Department Omdurman locality, the total number of workers in targeted factories is 394 workers, table (3-2)

activity	No. of workers	%
Food	118	30
Iron and metal	60	15
Plastic	95	24
Cement α derivatives	2	1
Oil α soap	119	30
Total	394	100

3.4. Sample size and sampling techniques:

3.4.1. Sample size determination:

3.4.1.1. Industries' sample:

The present study assessed thermal stress in all 92 factories (total converge) from the Omdurman locality. Distribution of the factories by activities as illustrated in table (3-1):

3.4.1.2. Workers' sample:

The study sample of the workers was collected, including 241 workers. At a confidence level of 95% and a degree of precision over 0.05, use the following formula:

$$\textbf{Equation 3:} \quad n = \frac{N}{1 + N(e)^2}$$

n sample size, N= 394,e 0.04

934 \ 1+ 394(0.04)^2 = 241

The sample design was Stratified Random Sampling; stage one consists of selecting the primary sampling unit(cluster).The selection was done through the probability proportional to size (PPS procedure),then by simple random sampling from the factory were selected.

Table (3-3): Distribution of the study sample of workers by activity.

Activity	N of workers
Food	72
Iron and Metal	36
Plastic	58
Cement α derivatives	2
Oil α soap	73
Total	241

3.4.2. Sampling methods:

3.4.2.1. Workplace thermal stress assessment:

Each studied factory was assessed using total coverage in terms of heat stress measurement, which was measured as wet bulk globe temperature (WBGT) in °C using a heat stress monitor. However, the measurement stations were selected to cover all the heat source areas, including the passage and positions between the machines. The Wet Bulb Globe Temperature (WBGT) was calibrated daily before making measurements.

Heat stress assessment:

The heat stress assessment form was designed to collect WBGT heat stress data in all the hot areas selected for this study. This WBGT form is shown in **(Appendix 2)**.

Permissible heat exposure threshold limit value

	------------- Work Load------------		
Work/rest regimen	Light	Moderate	Heavy
Continuous work	30.0°C	26.7°	25.0°C

These levels coincided with international & national (TLVs) that are implicated by the Administration of Occupational Hygiene, Ministry of Khartoum state.

3.4.2.2. The Environmental Questionnaire. (Appendix 1).

Each worker in the industrial sector (Industrial sectors included in this study are food, oil and soap, iron and metals, plastic, and Cement α derivatives) was visited to collect data in the workplace using a predesigned questionnaire.

Each selected worker was subjected to a predesigned questionnaire to collect information about Personal worker and health impacts from heat stress exposure name, age, sex, occupation), Work duration, shift, working hours, habits, including questions related to smoking or others. Also, information about workers and health impacts from heat stress exposure, like; (heat exhaustion, heat cramps, and heat stroke)

4. RESULTS

Assessment of thermal stress among study factories

Table (4.1) Description of Heat stress measurements (WBGT (C^0)

	N	Minimum	Maximum	Mean	Std. Deviation
food	29	20.50	30.00	25.6828	2.59258
Oil and soap	24	14.70	35.70	23.7583	5.10549
Iron and Metal	15	21.90	27.50	25.5400	1.66639
Plastic	23	15.90	35.70	25.9130	4.23001
Cement and derivatives	1	17.40	17.40	17.4000	.

Table (4-1) shows the description of heat stress measurements in the study factories by activity, Regarding the WBGT heat stress measures, three sectors (plastic, food, and iron &m et al.) have mean WBGT heat stress between 25-25.9 Cº, while the rest of the industries, oil &soap industries at a mean WBGT measures 23.7 Cº.

Table (4-2) Distribution of sample of workers by heat stress and Activity (n=92)

Activity	Frequency	Percent %
FOOD		
With standard	19	65.5
Without standard	10	34.5
OIL		
With standard	18	75.0
Without standard	6	25.0
IRON		
With standard	10	66.7
Without standard	5	33.3
PLASTIC		
With standard	13	56.5
Without standard	10	43.5
Cement and derivatives		
With standard	1	100.0
Without standard	0	0

Table (4-2) shows the distribution of the sample of workers by heat stress. According to the WBGT standard, plastic factories have 43.5 without heat stress levels, followed by food and iron factories, which have 34.5,33.3 without heat stress levels. The remaining oil and cement factories have 25,100 without heat stress.

Heat-related illness among the study population :(Heat exhaust, sunburn, heat cramps, and stroke:

Table (4.3): Demographic Characteristics of the study population in Omdurman 2018-2022

Characteristics	category	Frequency	Percent %
Gender	Male	156	64.7
	female	85	35.3
Age group	less than 20 years	23	9.5
	20-30 years	113	46.9
	more than 30 years	105	43.6
income	less than 1000	39	16.2
	1000 - 3000	170	70.5
	more than 3000	32	13.3
family size	Three and less	40	16.6
	4 - 6	93	38.6
	more than 6	108	44.8
Education Level	illiterate	23	9.5
	primary education	76	31.5
	Secondary Education	98	40.7
	University Education	44	18.3
Marital status	Single	149	61.8
	Married	78	32.4
	Married and dependable	4	1.7
	Widowed or divorced	7	2.9
	Widowed or divorced and dependable	3	1.2

Table (4.3): show Demographic Characteristics of the study population; we found that male workers constitute the majority of workers (64.7%), About 56.4% of workers were less than 30 years old, while the rest (43.6%) were aged more than 30 years.

About 70.5% of workers interviewed had an income between 63 and 187 per month; in comparison, 16.2% had less than 63 per month. The remaining workers (13.3%) had more than 187 monthly. According to education level, about 41% of workers interviewed were illiterates and had primary education. In comparison, 40.7% of workers were classified as having secondary education, and the rest (18.3%) were classified as having university education.

About two-thirds of workers (61.8%) were single or unmarried, while the rest (32.4%) were married.

Heats-related illness: heat exhaust, sunburn, heat cramps, and stroke:

Table (4-4) distribution of the study population by heat-related illness (heat exhaust)

	Frequency	Percent
Headache	82	34.0
dizziness	2	.8
drowsiness	12	5.0
loss of appetite	9	3.7
non	136	56.4
Total	241	100.0

Table (4-4)) shows the distribution of the study population by heat-related illness (heat exhaust); I found that 43.6% of workers are exposed to heat exhaust signs, and 34% of workers suffer from headache symptoms.

Table (4-5) studies population by heat-related illness (sunburn);

	Frequency	Percent
Headache	58	24.1
Swelling in the skin	3	1.2
Skin blisters	3	1.2
fever	18	7.5
non	159	66.0
Total	241	100.0

Table (4-5) shows the studies of the population about heat-related illness (sunburn). We found that 34% of workers interviewed are exposed to sunburn signs and 24.1 % and7.5%, respectively) of them complain of headaches and fever.

Table (4-6) study of the population by heat-related illness (heat cramps):

	Frequency	Percent%
Sweat	63	26.1
Pain in the muscles of the limbs	9	3.7
pain in other muscles	7	2.9
cramps	2	.8
lack of urine volume	5	2.1
non	155	64.3
Total	241	100.0

Table (4-6) shows the study of the population by heat-related illness (heat cramps). We found that 35.7% of workers interviewed were exposed to heat cramp signs, and 26.1% complained of headaches.

Table (4-7) shows the study of the population by heat-related illness (heat stroke):

	Frequency	Percent
Stop sweat	20	8.3
red skin	8	3.3
Unconsciousness	3	1.2
non	210	87.1
Total	241	100.0

Table (4-7) shows the study of the population by heat-related illness ((**heat stroke**), we found that 12.9% of workers interviewed are exposed to heat stroke signs, and 8.3% and 3.3% respectively) complain of stopping sweat and red skin symptoms.

Table (4-8) Relation between the mean of heat stress measurements (WBGT (0C) and heat stress illness

felt during the work with the following signs (heat exhaustion)		Heat stress measurements (WBGT (0C)					P. Value
		17.4	**23.7583**	**25.54**	**25.6828**	**25.913**	
Headache	Count	0	30	11	17	24	0.019
	%	.0%	36.6%	13.4%	20.7%	29.3%	
dizziness	Count	0	0	0	1	1	
	%	.0%	.0%	.0%	50.0%	50.0%	
drowsiness	Count	1	3	1	5	2	
	%	8.3%	25.0%	8.3%	41.7%	16.7%	
loss of appetite	Count	0	7	1	1	0	
	%	.0%	77.8%	11.1%	11.1%	.0%	
non	Count	1	33	23	48	31	
	%	.7%	24.3%	16.9%	35.3%	22.8%	
Feel during the work with the following signs (sunburn)							
Headache	Count	0	20	8	13	17	0.000
	%	.0%	34.5%	13.8%	22.4%	29.3%	
Swelling in the skin	Count	1	1	0	1	0	
	%	33.3%	33.3%	.0%	33.3%	.0%	
Skin blisters	Count	0	2	1	0	0	
	%	.0%	66.7%	33.3%	.0%	.0%	
fever	Count	0	5	3	4	6	
	%	.0%	27.8%	16.7%	22.2%	33.3%	
non	Count	1	45	24	54	35	
Feel during work with the following signs (heat cramps):		Heat stress measurements (WBGT (0C)					P. Value
		17.4	23.7583	25.54	25.6828	25.913	
Sweat	Count	0	21	11	15	16	0.042
	%	.0%	33.3%	17.5%	23.8%	25.4%	
Pain in the muscles of the limbs	Count	1	4	2	2	0	
	%	11.1%	44.4%	22.2%	22.2%	.0%	
pain in other muscles	Count	0	4	0	0	3	
	%	.0%	57.1%	.0%	.0%	42.9%	
cramps	Count	0	2	0	0	0	
	%	.0%	100.0%	.0%	.0%	.0%	
lack of urine volume	Count	0	3	0	1	1	
	%	.0%	60.0%	.0%	20.0%	20.0%	
non	Count	1	39	23	54	38	
	%	.6%	25.2%	14.8%	34.8%	24.5%	
Feel during the work with the following signs (heat stroke)							0.690
Stop sweat	Count	0	8	2	6	4	
	%	.0%	40.0%	10.0%	30.0%	20.0%	
red skin	Count	0	4	0	3	1	
	%	.0%	50.0%	.0%	37.5%	12.5%	
Unconsciousness	Count	0	0	1	0	2	
	%	.0%	.0%	33.3%	.0%	66.7%	
non	Count	2	61	33	63	51	
	%	1.0%	29.0%	15.7%	30.0%	24.3%	

Table (4-8) Relation between the mean of heat stress measurements (WBGT (^{0}C) and heat stress illness, I found a significant association between heat stress (WBGT) and heat stress in all symptoms of heat stress illness except the signs of heat stroke p = (0.690)

Acclimatize with work		Frequency	Percent%
	Yes	202	83.8
	No	39	16.2
	Total	241	100.0
additional work			
		Frequency	Percent
	Yes	34	14.1
	No	207	85.9
	Total	241	100.0
food meal provided to the worker during his work		Frequency	Percent
	Yes	134	55.6
	No	107	44.4
	Total	241	100.0
trained to work in hot areas			
	Yes	42	17.4
	No	199	82.6
	Total		
Task duration		Frequency	Percent
	Less than 8 hours	34	14.1
	8 hours	103	42.7
	More than 8 hours	104	43.2

Table (4-9) shows the population distribution studied by the workers' activity to avoid exposure to extreme heat; we found that about 16.2% did not acclimate to work. Regarding the additional work, We found that 14.1% of the workers have other work, also, we found that 44.4% of workers have no food meals during work.

We noticed that 82.6% were not trained to work in hot areas. For the task duration, we found that 43.2% and 42.7% of workers completed their tasks in more than 8 hours and 8 hours, respectively, while 14% completed their tasks in less than 8 hours.

Table (4-10): Distribution of study population by activity of preventing heat illness

premedical check-up		Frequency	Percent
	Yes	95	39.4
	No	146	60.6
	Total	241	100.0
last medical examination		Frequency	Percent
	One year ago	153	63.5
	Two years ago	8	3.3
	Other	80	33.2
	Total	241	100.0
Training in heat stress protection		Frequency	Percent
	yes	21	8.7
	no	220	91.3
	Total	241	100.0
Knowledge about heat stress risk at work		Frequency	Percent
	Yes	73	30.3
	No	168	69.7
	Total	241	100.0

Table (4-10) **shows the distribution of the study population by activity of preventing heat illness. About 60 % of workers did** not receive a medical check-up.

Regarding the last medical check-up, we noticed that 63.5 % of workers had a medical check-up one year ago. We noticed that 91% of workers do not receive training in heat stress prevention. Regarding knowledge of heat stress risk at work, we found that 69.7% of workers did not know about heat stress risk at work.

Table (4-11) Effort of company (employer) to protect workers from heat stress.

Companies take any measures to protect workers.		Frequency	Percent
	yes	120	49.8
	no	121	50.2
Periodic exposure measure			
	yes	22	18.3
	no	98	81.7
Supplement with cold water			
	yes	111	92.5
	no	9	7.5
appropriate clothing			
	yes	72	60.0
	no	48	40.0
Vacations set in relatively cool places			
	yes	97	80.8
	No	23	19.2
Workers stop working when they feel heat stress symptoms.			
	yes	41	34.2
	no	79	65.8

Table (4-11) shows that, in terms of the effort of the company (employers) to protect workers from heat stress, we found that 50% of employers do not take any measures to protect workers. Referring to periodic exposure measurement, we noticed that 81% of workers do not take rare exposure measures in the workplace. Regarding supplementing with calm water, we found that 7.5% of workers do not increase with cold water. According to appropriate clothing, we found that 40% of workers do not provide appropriate clothing.88u

Regarding the vacation period (rest period), we found that 19.2%of workers are not set relatively in cool places. We noticed that 65.8% of workers did not stop working when they felt heat stress symptoms.

5. DISCUSSION

This study was an attempt to assess the impact of thermal stress and work-related stress on workers, with the aim of possible mitigating measures for its removal or reduction, taking into consideration the hot climates of Sudan, in different industrial sectors in Omdurman, to improve working conditions. This study covers food industries, oils and soap, iron and metals, plastic, cement, and derivatives. Ninety-two different factories in various industrial sectors were visited to collect data on the workplace and individuals (241 workers and their health status were surveyed for possible heat stress exposure {name, age, sex, occupation, work duration, shift, working hours, and habits related to smoking, etc.}).

Other factors were considered, including the effects of heat exposure on workers, such as heat exhaustion, heat cramps, and heat strokes.

5.1. Assessment of thermal stress on studied factory workers:

In this study, in 3 sectors (plastics, foods, iron, and metal), the mean Wet Bulb Globe Temperature (WBGT) heat stress was 25-25.9 Cº. In the other industries (oil and soaps), the mean WBGT was at 23.7 Cº.

This study also indicates that plastic factories have a 43.50 Cº level above the standard WBGT level, followed by food and iron factories with 34.50 and 33.30Cº over the heat stress level standards.

The rest of the factories (oils and cement factories) have 25.10 levels without showing heat stress level standards. These findings agree with many previous studies, Al-Jallab A.M,Summan, A.S., and Balkhyour, which pointed out that plastics factories are exposed to heat stress levels with high permissible exposure limits.(18) On the other hand, the previous study conducted by Bolghanabadi indicated that in food factories, the heat stress level exceeds the national and internationally acknowledged heat limits.(19)

A study conducted by Jafari also showed that in iron factories, the WBGT index was higher than the recommended threshold(20). My observations indicated a lack of engineering controls and that most factories lacked ventilation. On the other hand, these factories had several general ling hot areas, such as ;(cookers, roasters, and boilers in the food industry, and melting and roughing processes in plastic and iron factories.

5.2. Heat-related illness:

This study's findings show that 43.60% of workers are exposed to heat exhaustion signs, and 34% suffer from headache symptoms. This finding might be justified by factors such as the fact that most of these factories, especially the engineering services, did not apply occupational health and safety measures.

This is affirmed by Seng's study, which indicated that the highest WBGT levels were recorded in the rice manufacturing factories. These levels were above the recommended permissible WBGT levels, with a high-risk exposure.(21)

On the other hand, our current study indicates that 34% of workers interviewed were exposed to sunburn signs; the others suffered headaches and fever (24.1% and 7.5%, respectively). This result may be referred to as poor training in heat stress prevention, which pointed out that 91% of workers did not receive training in heat stress prevention. An earlier study by Griggs indicated that diminished performance is associated with increased core temperature, premature fatigue, and the potential for heat-related illnesses(22).

The study indicated that 35.70% of interviewed workers were affected by heat cramps, and 26.10 % complained of headaches. This finding might be justified by workers having less knowledge about heat stress risk, which means that 69.70% of them did not have sufficient knowledge about heat stress risk at work. Our current study documents that 12.90% of interviewed workers were exposed to heat stroke signs. Others complained of stopping sweat and red skin symptoms, 8.30% and 3.30%, respectively. This might refer to shortages in protective measures, and this study found that 50%of employers did not maintain any protective measures.

World climate change may have contributed to heat strain, which results in heat stroke cases. The earlier study by Yamamoto indicated that the association of climatic factors led to future heatstroke risks in Tokyo.(23)

5.3. Prevention of heat illness by workers themselves:

The study documented that 16.20% of workers are not acclimatized. The earlier study by Vesic indicated that acclimatization influences stress hormone concentration in serum during heat stress.(24)

On the other hand, this study also illustrates that 44.40% of workers do not have meals during the workday. This agrees with the earlier study by Yeghiayan, which maintained the beneficial effect of a protein-free, high-carbohydrate meal on rat coping behavior and neurotransmitter levels during heat stress.(25)

Consistent with the current study is the clear finding that 82.60% of the workers did not have training for working in hot spots. The present study showed that 43.20% completed their tasks in more than 8 hours, while 42.70% completed their tasks in 8 hours, and 14.00% completed their tasks in less than 8 hours. These findings could point to the employer's inattention to social services in the workplace, which could be one of the causes of high work-related stress in the workplace. The earlier study also agrees with our finding in some respects: Jackson clarified the importance of workers' training to avoid heat illness.(26)

5.4.1 Prevention of heat illness:

This study noted that 60% of workers were not subjected to pre-medical check-ups and that 63.50% had a medical check-up one year earlier. It was also noted that 91% of the workers had not received training in heat stress prevention, and 69.70% did not have information about heat stress risk at work.

The lack of follow-up and inspection from Khartoum's Occupational Health and Safety department might justify these findings. Workplace laws have not been abided by, and heat stress illness at work may also support these findings. The earlier study of Godderis indicates the effectiveness of periodic medical examination in preventing work-related ill-health(27) This study indicates that 50% of employers did not take any measures to protect workers, and 81% of the workers did not follow periodic exposure measures at the workplace. We also found that 7.50% of the workers had no regular cold water supply.

In addition to the above, this study found that 40% of the workers were not provided with appropriate clothing and that 19.2% were not set up in relatively cool working spots. The findings also show that 65.80% of the workers did not cease work when affected by heat stress symptoms. In my view, all these findings documented the bad situation performance regarding worker protection at the workplace, with workers suffering from heat stress and the consequences of heat stress symptoms. In the earlier study, Chan suggested introducing anti-heat stress clothing for construction workers in hot and humid weather.(28)

6.CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study assesses the impact of thermal stress and proposes mitigating measures for its removal or reduction. It covers various industrial estates in the Omdurman area. Factories included in this study are Food, Oil and Soaps, Iron and metals, Plastic, and Cement derivatives; it comprises about 92 factories in different sectors. The study sought to collect a database to target workers in those factories. This study covered a sample of (241 workers), considering health status (heat exhaustion, heat cramps, heat strokes) that may result in heat stress exposure. In addition to collecting personal information such as age, sex, occupation, work shift- duration, and hobbies, it included questions about smoking or another hygienic lousy habit. A questionnaire was conducted among 241 workers to assess workplace performance evaluation.

Factors contributing to heat stress in 92 industrial sectors were also examined, along with the factories suffering from higher heat levels than TLV and others with heat stress boundaries. It examined heat stress illness resulting from exposure to high heat levels, especially in industries with records above (TLV). It also examined factors predisposing to stress among the 241 workers, such as the Socio-demographic data of workers, to determine whether there was a significant relationship.

Conclusions Related to Findings

This study pinpoints several findings of how thermal stress affects the workers that indicate an upper limit of heat stress and heat stress illness, and also highlights the different conclusions of heat stress in industrial sectors such as Plastic, Food, Iron and Metal, and Cement derivative) ...

The study also indicates that half the workers are exposed to heat exhaustion signs and that more than a third (34%) suffer from headache symptoms. Our study also suggests that more than one-third of workers interviewed had sunburn signs.

Our study documented that one-eighth of the interviewed workers were exposed to heat stroke signs. This study showed that 16.20% of workers did not acclimatize to work and that 44.40% did not eat during the workday. This study clarifies that 60 % of the workers were not subjected to medical check-ups. It is documented that 91% of workers had not received heat stress protection training, and 69.70% had no previous knowledge about heat stress risks at work. The study also clarifies that half of employers did not take any measures to protect the workers; in this regard, it was found that 7.50% of the workers had no access to cold water.

In addition to the above finding, it was revealed that 40% of workers were not provided with proper clothing, 19.2% were not set up in relatively cool spots, and 65.80% did not stop working when they felt heat stress.

6.2 Recommendations:

6.2.1: For the Sudan Government:

I participated in the occupational health and safety workshop conducted by Dr.Mona Ebrahim Mohamed, representative of MonazaamatEltanmiahAlamrania, to prepare for it and suggest a framework for the issues involved. I was also a core person involved in recommending sectors and partners.

I presented a paper at the workshop that addressed some problems related to my present research in the Sudan, generally titled "The guideline recommendation for upgrading occupational health and safety in the Sudan. (See appendix). It includes the following issues:

- Discussing the organization chart of occupational health and safety administration.
- Planning policy and legislation for occupational health and safety.
- Removing the overlapping between occupational health and safety sectors.
- Presenting the situational analysis of occupational health and safety.

The significant recommendations are:

- Strengthening of laws and legislations of occupational health and safety.
- Removal of opposing Laws.
- Continuous training of occupational health and safety personnel.
- Acquiring and completing occupational health and safety devices for risks and hazard assessment.

Considering the results of this study, it is recommended the following:

Given the results of our research, we recommended the following:

1-Prevention of heat illness:

Sudan falls short of the occupational health and safety guidelines, so we recommend conducting an OSHAD technical measure to protect it from heat. An OHS team will carry out this guideline in the high-temperature Omdurman environment.

Recommendations for employers:

Employers should take the following steps to protect employees against heat stress

1. Schedule hot areas maintenance and repair works during the months of cooler weather.
2. Schedule hot jobs for the cooler weather during the day.
3. Acclimatize employees by gradual exposure for progressively more extended periods in the working environment.
4. Reduce excessive physical demand on employees.
5. Use reliable employees or engage extra employees for physically demanding jobs.
6. Provide cool water and other liquids to employees.
7. Avoid drinks with caffeine, alcohol, and high sugar content.
8. Schedule rest –breaks with water and liquid bereaves;
9. Provide cool areas for use drink break periods.
10. Monitor employees who are prone to heat stress;
11. Provide heat stress training, including directives about employee risk, symptoms, prevention, personal protective equipment, and treatment.

Recommendations for employees:

1- Avoid exposure to extreme heat, sun exposure, and high humidity if- exposure is unavoidable.
2- Employees should follow these steps to avoid heat stress:
1- Wear light-colored, loosely fitting, and breathable clothing, like cotton;
2- Avoid synthetic clothing in the gradual build-up of complex jobs.
3- Schedule demanding tasks for the more excellent parts of the day.
4- Take extra breaks in boiling and humid conditions.
5- Take breaks in the shady, cool area when possible;
6- Take frequent drinks of water to avoid thirst;
7- Avoid drinks with caffeine, alcohol, or significant sugar content.
8- Be aware that protective clothing or personal protective equipment may increase the risk of heat stress and;
9- Monitor the physical conditions of self and co-workers.

REFERENCES

1. Garde, A.H., Hansen, J., Kolstad, H.A., Larsen, A.D. and Hansen, Å.M., 2016. How do different definitions of night shift affect the exposure assessment of night work? Chronobiology International, 33(6), pp.595-598.
2. Zhu, Y., Ouyang, Q., Cao, B., Zhou, X. and Yu, J., 2016. Dynamic thermal environment and thermal comfort. Indoor air, 26(1), pp.125-137.
3. Lucas, R.A., Epstein, Y. and Kjellstrom, T., 2014. Excessive occupational heat exposure: a significant ergonomic challenge and health risk for current and future workers. Extreme physiology & medicine, 3(1), pp.1-8.
4. Gagge, A.P. and Gonzalez, R.R., 2010. Mechanisms of heat exchange: biophysics and physiology. Comprehensive physiology, pp.45-84.
5. Erbas, O., 2021. Investigating factors affecting thermal performance in a coal-fired boiler and determining thermal losses by energy balance method. Case Studies in Thermal Engineering, 26, p.101047.
6. Ken, Parsons(2006).Heat Standard ISO7243 and its Global Application. Industrial Health: (396-379)
7. ISO 10551 (2005), Ergonomics of the Thermal Environment: Assessment of the influence of the thermal environment using subjective judgment scales, Geneva: International Standards Organization.
8. Sadhra SS, Rampal GK (1999). Occupational hazards types and their characteristics. In: Occupational Risk Assessment. Hong Kong: Black Well Science: 78.
9. Lundgren, K., Kuklane, K., Gao, C. and Holmer, I., 2013. Effects of heat stress on working populations when facing climate change. Industrial Health, 51(1), pp.3-15.
10. Khazaradze, K.R., 2017. Comparative Analysis of Mean-Daily Value of Air Equivalent-Effective Temperature in Tbilisi and Kojori.
11. Mitz, C., Thome, C., Thompson, J., Manzon, R.G., Wilson, J.Y. and Boreham, D.R., 2017. A method to transform a variable thermal regime to a physiologically equivalent practicaltemperature. Journal of thermal biology, 65, pp.21-25.
12. Heidari, H., Golbabaei, F., Shamsipour, A., Forushani, A.R. and Gaeini, A., 2018. Consistency between sweat rate and wet bulb globe temperature for assessing heat stress of people working outdoors in arid and semi-arid regions. The International Journal of Occupational and Environmental Medicine, 9(1), p.1.
13. Pourmahabadian, M., Adelkhah, M. and Azam, K., 2008. Heat exposure assessment in the working environment of a glass manufacturing unit. Journal of Environmental Health Science & Engineering, 5(2), pp.141-147.
14. Patel, T., Mullen, S.P. and Santee, W.R., 2013. Comparison of methods for estimating wet-bulb globe temperature index from standard meteorological measurements. Military medicine, 178(8), pp.926-933.
15. Brocherie, F. and Millet, G.P., 2015. Is the wet-bulb globe temperature (WBGT) index relevant for exercise in the heat? Sports Medicine, 45(11), pp.1619-1621.
16. Louis J (1999). Handbook of Occupational Safety and Health. Awiley. Interscience Publication. New York.
17. ISO 14505-3(2006). Ergonomics of the thermal environment-environment-Evaluation of thermal environments in vehicles. Part 3: Test method for thermal comfort assessment using human subjects. Geneva: International Standards Organization.
18. Al-Jallab, A.M., Summan, A.S. and Balkhyour, M.A., 2021.Occupational exposure to Noise and Heat in Plastic Factory in the Industrial City of Jeddah.
19. Bolghanabadi, S., Mohammadi, A., Kohnavard, B. and Delkhosh, M., 2019. The relation between heat strain and hydration status in the food industry employees in Mashhad, 2014.Polish Annals of Medicine, 26(1).
20. Jafari, M.J., AssilianMahabadi, H., Khodakarim, S. and Teimori, G.H., 2016. Heat stress in an open-pit iron ore mine and its relationship with physiological strain. Health and Safety at Work, 6(4), pp.51-62.
21. Seng, M., Ye, M., Choy, K. and Ho, S.F., 2018. Heat stress in rice vermicelli manufacturing factories. International Journal of Occupational and Environmental Health, 24(3-4), pp.119-125.
22. Griggs, K.E., Stephenson, B.T., Price, M.J. and Goosey-Tolfrey, V.L., 2020. Heat-related issues and practical applications for Paralympic athletes at Tokyo 2020.Temperature, 7(1), pp.37-57.
23. Yamamoto, M., Kasai, M., Okaze, T., Hanaoka, K. and Mochida, A., 2018. Analysis of climatic factors leading to future summer heatstroke risk changes in Tokyo and Sendai based on dynamical downscaling of pseudo-global warming data using WRF. Journal of Wind Engineering and Industrial Aerodynamics, 183, pp.187-197.
24. Vesic, Z., Jakovljevic, V., Turnic, T.N., Vukasinovic-Vesic, M., Bolevich, S. and Radakovic, S., 2021. The influence of acclimatization on stress hormone concentration in serum during heat stress.Molecular and Cellular Biochemistry, pp.1-11.
25. Yeghiayan, S.K., Georgelis, J.H., Maher, T.J. and Lieberman, H.R., 2004. Beneficial effects of a protein-free, high carbohydrate meal on rat coping behavior and neurotransmitter levels during heat stress. Nutritional neuroscience, 7(5-6), pp.335-340.
26. Jackson, L.L. and Rosenberg, H.R., 2010. They are preventing heat-related illness among agricultural workers. Journal of agromedicine, 15(3), pp.200-215.
27. Godderis, L., Steel, J. and Luyten, J., 2018. 1702d Effectiveness of periodic medical examination to prevent work-related ill-health.
28. Chan, A.P., Guo, Y.P., Wong, F.K., Li, Y., Sun, S. and Han, X., 2016. Developing anti-heat stress clothing for construction workers in hot and humid weather. Ergonomics, 59(4), pp.479-495.

****