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Wet Bulb Globe Temperature (WBGT) among Solid Waste Collection Workers at Al Leith Municipal

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Abstract: *Background: Predicted changes in air temperatures and/or humidity as part of local climate change have been forecasted to cause occupational health and work productivity concerns.*
Solid waste collectors are exposed to serious health risks, the most important of which is the risk of thermal stress, while the nature of the climate in the city of Al-Leith is geographically related to it.
Material and method: This study is a cross-sectional descriptive study. To assess the heat stress (WBGT) in the work environment of waste collection workers and identify the use of personal protective devices among solid waste collectors and assess the knowledge, attitudes and practices towards health and safety. The study population, workers of solid waste collection in El-Leith Municipality. All workers were covered 50 workers. For environmental measurements (WBGT) 21 points were selected in the systematic system of random sampling (from April 8th, 2018 to April 9th, 2018. A questionnaire was used to collect information on the use of PPE and the duration of work and other personal information. A personal interview was also conducted with the Solid Waste Manager at the Municipality of Al-Leith. Results: The results of the measurements showed high readings of thermal stress parameter (WBGT). The results showed a mean reading of the WBGT and a minimum value and a maximum value (mean ± SD = 30.0±0.70; Min = 26.1; Max =31.2), 39% of workers do not use personal protection tools. 56% of solid waste collectors were exposed to injuries. Conclusion: The study found that all solid waste collectors in the municipality of Al leith were exposed to heat stress and exposed to various types of preventable hazards inherent in their jobs because of their work. 56.0% of the workers suffer from injuries. The qualitative data revealed that 30.0% of workers were not protected, and 30.0% of workers do not take training or health education programs on the dangers of solid waste. Recommendations: Implemented rest/work regime for workers. Training and health education programs should be provided to all workers since the beginning of work. Workers should be given appropriate training and training at the beginning of their work.

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I. Introduction

Human performance is influenced by a vast range of environmental factors in working systems. Heat stress is one of these factors. Since the internal body temperature should be kept around 37 °C, heat exchange between human body and surrounding environment seems to be essential. Body must reach thermal equilibrium by dissipating excess heat transferred to the body and produced in the body. Failure to remove excessive heat will cause an increase in the deep body temperature. Consequently, heat induced physiological strain may lead to health impairments such as heat stroke, heat exhaustion, heat cramps, heat collapse, heat rashes, and heat fatigue. Furthermore, there are two types of external human responses to the increased internal temperature including: behavioral responses, and cognitive responses [1].

Thermal comfort is very difficult to define. This is because we need to take into account a range of environmental and personal factors when deciding on the temperatures and ventilation that will make feel comfortable. The best that we can realistically hope to achieve is a thermal environment which satisfies the majority of people in the workplace, or put more simply, ‘reasonable comfort [2].

Humans can tolerate a vast range of thermal environments using both physiological and behavioral strategies. however, from a clinical perspective, body – core temperature (Tc) must be held within a very narrow range, and it is normally regulated at approximately $36.7\pm30.3\,^{o}c$. If Tc varies by more than $2\,^{o}c$ either in side of $37\,^{o}c$, then one can assume that thermal balance has been lost, or thermoregulatory failure to has occurred. In this state, the regulation of body temperature has been transiently compromised, resulting in either hypothermia (<35

^{o}c) or hyperthermia (>39^{o}c), with the possibility of death accompanying a Tc reduction of about 10 ^{o}c , or an elvation of only 5 ^{o}c [3]

Different factors including type of task, duration of the exposure, intensity of the stressor, and operators' skill level are key variables influencing the extent that thermal conditions influence the performance. However, it had been shown that simple tasks are less affected by heat stress, comparing to the complex tasks such as tracking, monitoring, and multiple tasks [1].

A number of studies point to a growing concern over increasing heat stress in the 21st century as a result of human-caused global warming, particularly when moisture, as well as temperature, effects are considered. [4] found that the greenhouse gas induced increases in heat index, or apparent temperature, substantially exceed the increases in temperature alone, particularly in humid regions of the tropics and subtropics [5].

Heat stress is the overall heat load to which an employee may be exposed from the combined contributions of metabolic heat, environmental factors (i.e. air temperature, humidity, air movement, and radiant heat), and clothing requirements. Heat stress occurs when the body's means of controlling its internal temperature starts to fail. [6].

The American Conference of Government Industrial Hygienists [7] defines heat stress as "the net heat load to which a worker may be exposed…" Heat strain is defined as "the overall physiological response resulting from heat stress."

The existence of extreme hot conditions in many work environments may have a serious negative effect on the health and safety of employees [8].

Heat stress indices: A Wet Bulb Globe temperature index (WBGT) was invented more than 50 years ago and is now the most widely used index in assessing heat stress. It was in vented and first used during the 1950s as one element in an imaginative and successful campaign to control heat illness in training camps of the US army and marine corps [9]. One of the most consequential future impacts of long-term climate warming could be the impact of heat stress on humans. Various approximate measures of heat stress have been developed in the medical and human health communities [5].

It is important that the index incorporate variables that are related to heat loss mechanisms used by humans to stay in thermal equilibrium. This includes variables such as air temperature (Ta), natural ventilated wet bulb (Tnwb), globe temperature (Tg) and air movement (m.sec-1). The WBGT heat stress index incorporates all the mentioned variables and is also currently the most user friendly index available in industry. The index proved also to have good correlations with physiological reactions at high temperatures [10].

The WBGT, wet bulb temperature, and dewpoint temperature all include both temperature and moisture influences on heat stress, similar to the heat index or apparent temperature indices [11]. The WBGT, wet bulb temperature, and dewpoint temperature are indices which, as they approach the human body skin temperature, signify increasing difficulty for the body to cool itself down. The apparent temperature or heat index is, in contrast, a "feels-like" index, where the temperature index is elevated above the regular air temperature to reflect the effect that moisture has in making the temperature feel hotter than it actually is [5].

The WBGT index is by far the most widely used heat 189 stress index throughout the world. The heat effects are dependent upon not only air temperature, but also humidity, air movement, radiated heat, clothing, individual ability to sweat and the workers' physical activity level (metabolic rate) [12].

This index has also been recognized by other organizations for setting limits in industrial plants [13], approved by the ISO organization as an international standard for heat load assessment [14] and as a safety index for workers in different occupations [15].

Heat Stress Effects: Heat stress can affect individuals in different ways, and some people are more susceptible to it than others. Typical symptoms are: An inability to concentrate; Muscle cramps ; Heat rash ; Severe thirst - a late symptom of heat stress ; Fainting ; Heat exhaustion - fatigue, giddiness, nausea, headache, moist skin ; Heat stroke - hot dry skin, confusion, convulsions and eventual loss of consciousness. This is the most severe disorder and can result in death if not detected at an early stage [6].

Factors That Contribute to Heat Stress: To prevent heat stress, employers and employees must be able to recognize and understand source of heat and how the body removed excess heat. The most commonly used indicator of heat stress is air temperature. However, air temperature alone is not a valid or accurate indicator for heat stress. It should be always considered in relation to other environmental and personal factors [5].

the key environmental factors affecting human heat stress include ambient temperature, the amount of radiation (e.g., direct sunlight adds to heat stress), environmental humidity, and windspeed [5].

Control of Heat stress: When possible, schedule hot jobs for the cooler part of the day (early morning, late afternoon, or night shift).; Alter the work/rest schedule to permit more rest time.; Increase workers' water intake on the job.; Reduction of work time (reduce work day, increase rest time, restrict double- shifting) and planned times.; A heat stress training program should be in place for all who work in hot environments and their supervisors.; Recognition of the signs and symptoms of the various types of heat-related illnesses— such as heat cramps, heat exhaustion, heat rash, and heat stroke—and in administration of first aid; The proper care and use of heat-protective clothing and equipment and the added heat load caused by exertion, clothing, and personal protective equipment [16].

II. Aims of Research

To evaluate the WBGT among solid waste collectors at Al Leith municipal.To evaluate the risk of heat stress among solid waste collectors at Al Leith municipal. To assessment Knowledge, Attitudes and Practices (KAP) towards heat stress among solid waste collectors at Al Leith municipal.

III. Methodology

This is a descriptive cross-sectional study, the sample for the study constituted of (50) solid waste collectors selected through convenient random sampling technique.

Sampling (sample size & sample technique): 21 points were selected in the systematic system of random sampling in four main streets (east - west) at a rate of 4 points for each street with a total of 20 points and one point outside these streets as a background point.

Data collection method: Field studies were conducted during the summer time in Al leith (March-July 2018). Fifty outdoor workers worked at solid waste collection were randomly selected. All workers had the same pattern of work and rest regimen. The mean of subject workload (metabolic rate) (according ISO-9920) and thermal insulation of cloths (according ISO-8996) were estimated 300 to 415 W and 0.78 clo, respectively [12].

The participants were informed of the purpose and the procedure of the study. Their participation was on a voluntary basis and the participants can withdraw any time as they desired.

Environmental measurements: We measure WBGT, HSI, Ta, Tn.wb, Relative Humidity RH, Dewpoint, Air velocity, measurements were made during normal working hours, The number of locations WBGT measurements was taken in each workplace varied depending on the work intensities of the workers and potential heat exposure zones in the work place, the days when the measurements were performed are:

- April 8th, 2018;
- April 9th, 2018.

Measurement of WBGT:

This index has also been recognized by other organizations for setting limits in industrial plants [13], approved by the ISO organization as an international standard for heat load assessment [14].

The WBGT provides an index of the environmental conditions which contribute to heat stress. It is influenced by air temperature, radiant heat, air movement and humidity. Once a monitoring plan is developed (refer to previous section), WBGT can be determined in either of the following two ways :

a) Measurement using a 'heat stress monitor' – this device automatically calculates WBGT based on the measurement of: air temperature (i.e. dry bulb temperature), radiant heat (i.e. using black wet bulb thermometer), and the cooling effect of evaporation caused by air movement (i.e. using a wet bulb thermometer); or

b) Individual measurement of air temperature, radiant heat and air movement and calculation of WBGT using the following formula:

- Where there is direct exposure to sunlight: WBGT out = 0.7 Tnwb + 0.2 Tg + 0.1 Tdb
- Where there is no direct exposure to the sun: WBGT in = 0.7 Tnwb + 0.3 Tg

Where, Tnwb = natural wet bulb temperature (in co) Tg = globe temperature (in co) Tdb = dry-bulb (air) temperature (in) (Sun Safety at Work Canada 2016)

The WBGT (C∘) is an index of heat stress imposed on the human body by the thermal environment. It is a combination of dry bulb temperature, air current speed and relative humidity of air and radiation. The WBGT can be calculated using a correlation proposed by ISO-7234 standard for the outdoor conditions (in the presence of solar radiation).

Thermal condition of the working environment was evaluated using global wet temperature, as recommended by [7] accordingly, measurements of this index were done by a WBGT meter (WBGT SD Datalogger, model 800037, Sper Scientific, USA). In this sense, dry temperature, wet temperature, globe temperature and wet bulb glob temperature were measured in each workstation, in three heights including ankle, abdomen, and head. The weighting for spatial variation is given by:

$$WBGT = \frac{WBGT\ neck + 2WBGT\ abdomen + WBGT\ ankles}{4}$$

Since climate conditions change during the shift, these measurements have been performed several times (08:00am, 12:00 pm and 05:00 pm).

These data were used to calculate a WBGT heat index value for the exposure.

To assess heat stress we used WBGT index and corrected it for cloth thermal insulation. It means that not only measured WBGT was used in this study, but also effective WBGT was estimated by correction for clothing adjustment factor (CAF), as well as activity level or metabolic rate, two important personal parameters, which should be considered when individual heat stress exposure assessment is necessary. The clothing adjustment factor and metabolic rate were estimated according to ISO-9920 and ISO-8996, respectively for all of 50 participants and then corrections were made to achieve effective WBGT, if necessary this done also in previous studies [12].

Workers' work intensity was judged by a trained Industrial Hygienist according to American Conference of Governmental Industrial Hygienists [7] guidelines for evaluating Metabolic Rate Categories and the Representative Metabolic Rate with Example Activities [17]. ACGIH WBGT permissible heat exposure threshold limit values (TLV) were also used to evaluate the risk of heat stress and the corresponding WBGT under which continuous work during an hour could be safely undertaken [18] Workers in evaluated areas wore work clothes (long sleeve shirt and pants) or cloth (woven material). Accordingly, no WBGT correction factor for clothing was used in the current study [17].

Measurement Air velocity (m/s) was monitored using Kestrel 3000 Weather Meter Relative humidity: was monitored using Kestrel 3000 Weather Meter . Relative humidity is the ratio between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can hold at that air temperature. Relative humidity between 40% and 70% does not have a major impact on heat stress. In workplaces which are not air conditioned, or where the weather conditions outdoors may influence the indoor heat environment, relative humidity may be higher than 70%. [6].

Environmental conditions during solid waste collection activities were monitored using conventional Kestrel 3000 Weather Meter digital to record ambient air temperature, Dewpoint, Relative Humidity temperature, and air speed. We take reading of 21 points in the frist day and then we repeat this reading in same points in second day for all parameters (WBGT. ….), and then we calculate results. A questionnaire: Data for the study was collected through structured questionnaire on Al leith solid waste collectors workers to collect data solid waste hazards, protective equipment, duration of exposure, and other personal information. Interviews were held with the solid waste manager in Al leith municipality. Face to face interviews were conducted with workers using questionnaire to determine socio-demographic information, daily activities and health status of the workers. A personal interview: A personal interview was also conducted with the Solid Waste Manager at the Municipality of Al-Leith. Data analysis: Responses were analyzed using descriptive statistics of frequency counts, percentages and tables. The data are analyzed using SPSS software version 23. Independent t-test was used for data analyzing. In addition, correlation of heat stress with other factors was examined by Pearson Correlation Test. P-value less than 0.05 was considered statistically significant.

IV. Results and Dsicussion

Table (1): Socio-demographic characteristics of the solid waste collectors in Al leith municipality, Al leith, Saudi Arabia 2018 (N=50).

Characteristics	Frequency	Percent %
Age (years)		
20 – 30	25	50.0
31 – 40	15	30.0
41 - 50	10	20.0
Gender		
Male	50	100
Female	0	0.0
Social status		
Married	31	62.0
Not married	19	38.0
Nationality		
Bangladesh	26	52.0
Indian	19	38.0
Pakistan	3	6.0
Nibal	2	4.0
Work shift		
Morning	15	30.0
Night	11	22.0
Together	24	48.0

Table (2): Mean and standard deviation of environmental parameters (WBGT (co); HSI%; Ta (co)) of studied occupational outdoor environments Al leith, Saudi Arabia 2018.

Time	Environmental Parameter

	WBGT (co)			Ta (co)		
	Mean ± SD	Min	Max	Mean ± SD	Min	Max
8:00 am	28.1±0.66	26.7	29.3	30.6±1.36	28.6	33.8
1:00 pm	30.0±0.70	28.1	31.2	34.1±1.36	31.6	36.6
5:00 pm	27.0±0.59	26.1	28.3	30.8±0.84	29.4	32.4

Table (3): Mean and standard deviation of environmental parameters (RH%; Air velocity (m/s); Dewpoint (co)) of studied occupational outdoor environments Al leith, Saudi Arabia 2018.

Time	Environmental Parameter								
	RH%			Air velocity (m/s)			Dewpoint (co)		
	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max
8:00am	72.6±4.27	63.7	84.3	3.1±1.83	1.0	6.5	25.8±0.34	25.4	26.6
1:00pm	60.3±3.71	53.7	66.9	2.9±1.59	1.2	6.5	25.6±0.64	23.7	26.7
5:00pm	72.8±3.70	65.0	78.6	2.6±1.81	0.8	7.1	25.1±0.28	24.2	25.8

Figure (1): WBGT1 parameter measurement at 8.00 am of studied occupational outdoor environments Al leith, Saudi Arabia 2018.

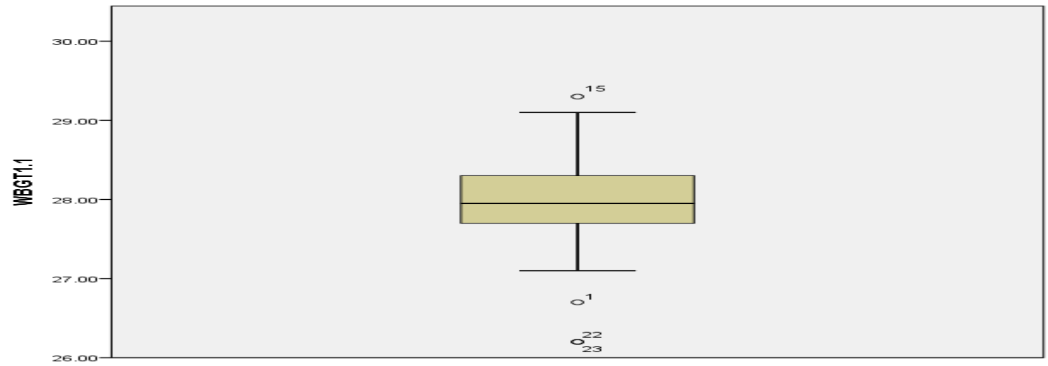


Figure (2): WBGT2 parameter measurement at 1.00 pm of studied occupational outdoor environments Al leith, Saudi Arabia 2018.

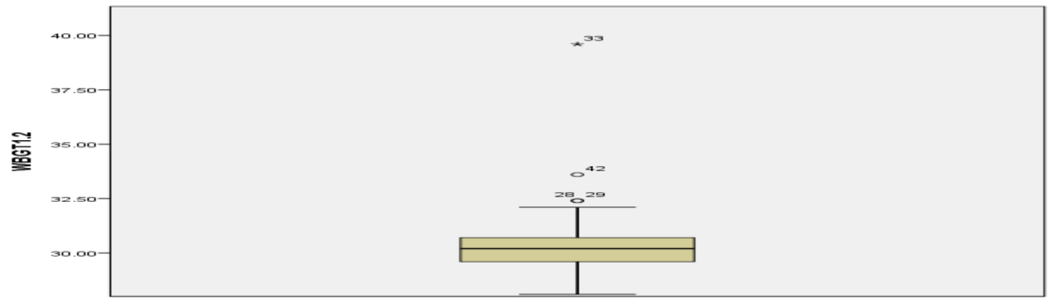


Figure (3): WBGT3 parameter measurement at 5.00 pm of studied occupational outdoor environments Al leith, Saudi Arabia 2018.

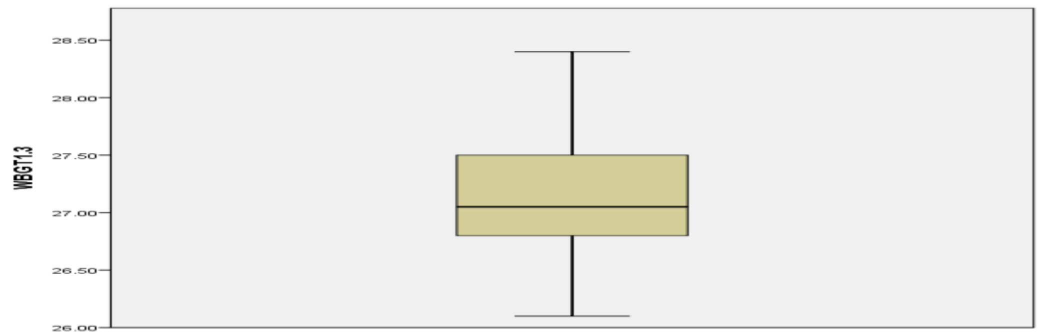


Figure (4): The usage of Personal Protective Equipment (PPE) among solid waste collectors in Al leith municipality, Al leith, Saudi Arabia 2018 (N=50).

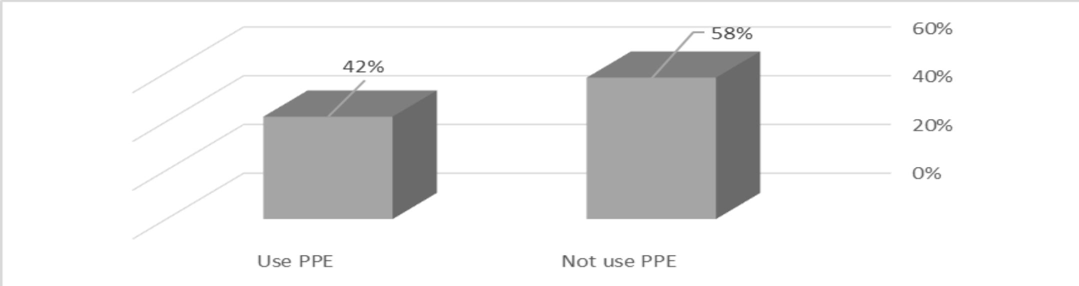


Table (4): Knowledge about thermal stress among the solid waste collectors in Al leith municipality, Al leith, Saudi Arabia 2018 (N=50).

Knowledge about thermal stress	Frequency	Percentage
Yes	5	10
No	45	90
Total	50	100

Table (5): Correlation between the Knowledge about thermal stress risk and The usage of Personal Protective Equipment (PPE) among the solid waste collectors in Al leith municipality, Al leith, Saudi Arabia 2018 (N=50).

Pearson Correlation			
Pearson Correlation = - 0.144 weak negative		Full body clothing covers	Risk
The usage of Personal Protective Equipment (PPE)	Pearson Correlation	1	-.144
	Sig. (2-tailed)		.370
Risk	Pearson Correlation	-.144	1
	Sig. (2-tailed)	.370	

rp = -1.44 (weak , negative)

Figure (5): Training on Solid waste hazard among solid waste collectors in Al leith municipality, Al leith, Saudi Arabia 2018 (N=50).

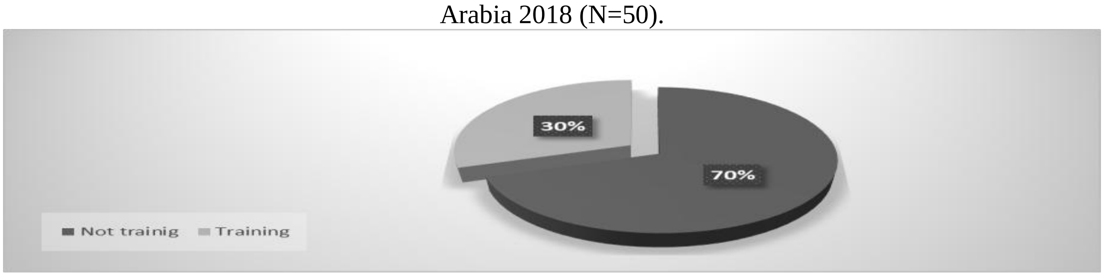


Figure (6): Solid waste collectors responses on injuries in Al leith municipality, Al leith, Saudi Arabia 2018(N=50).

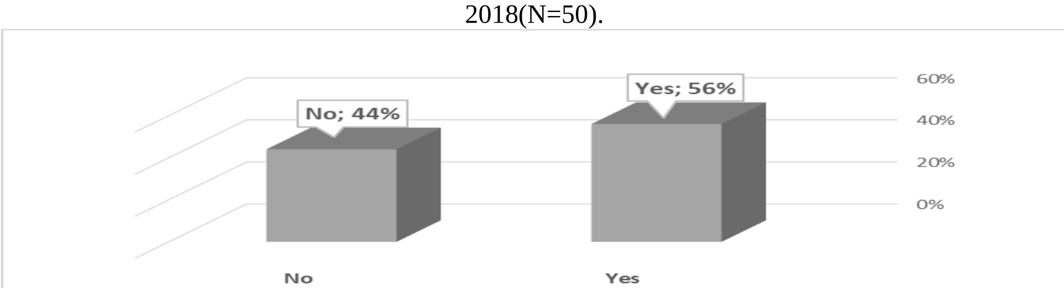
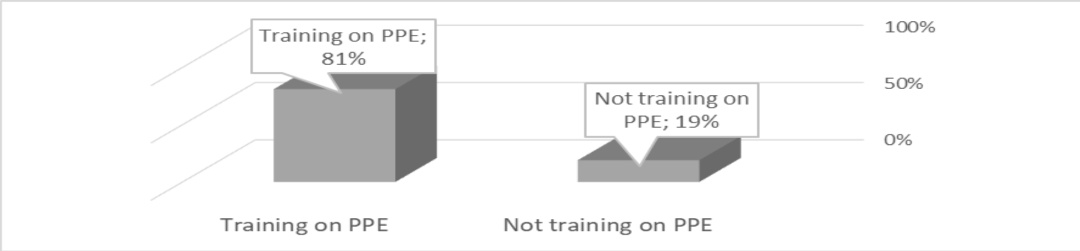


Figure (7): Training on Personal Protective Equipment (PPE) among solid waste collectors in Al leith municipality, Al leith, Saudi Arabia 2018 (N=50).



One hundred and eighty questionnaires were prepared and about 50 were collected and analyzed giving a response rate of 27.8%. The response rate of this study was not similar with studies like 97.9% [19], 92% [20] and 95% [21]. Majority of the respondents were aged between 20 - 30 years (50.0%), followed by ages 31 - 40 (30.0%), the age range of 41- 50 years (20.0%).

The measured values of WBGT, Air temperature, Air velocity, relative humidity and Dewpoint of the air in the test period have given the mean±SD, Minimum and Maximum values reported in Table 1;Table 3: From the measurements performed in this period, the air temperature is always higher than 29.4°C.The high values of the air temperature can cause serious health problems of the workers especially in the event of prolonged exposure. The relative humidity measured is between 53.7% and 84.3%, has been reached the saturation of the air and this has not allowed to reduce the risks associated with the high air temperature. Table 1 shows the mean values of the WBGT (30.0±0.70) calculated with the measured values from 1: 00p.m. for each day of measurement severe hot because were more than limit established by ACGIH.

In general, the search results allow to affirm that, under the climatic conditions, during the summer season (late April-mid June) the workers are in the presence of a situation of thermal discomfort and they are subjected to thermal stress since the WBGT was found to be always higher than the limit established by ACGIH.

The total workers examined in the current study had direct heat exposures that included direct sun. WBGT and ambient temperature (TA) from the 21examined workplaces are shown in Tables 2 and 3 and WBGT profiles alone are illustrated in Figurers 1; 2 and 3. 100% of the workers were exposed to WBGTs higher than the recommended TLV as per ACGIH guidelines.

Depending on the WBGT value, the ratio of the work to the rest should be different below 38 °C for maintaining the internal body temperature. The allowed time for heavy work was less than 1 h, and this time decreased by 4 or 5 min as WBGT value increased 1 °C [22]. Based on the previous studies, one can conclude that WBGT values over 25 °C, and conducting solid waste collection work in these environmental conditions has negative influence on efficiency and productivity as well as health and safety of the workers. The excessive thermal strain by the workers is predicted, and it would reach to the threshold limit value [23] [24]. If human thermal equilibrium is disturbed as a result of increasing temperature in the workplaces, workers may be at risk of heat stress [25] [26]

Wearing Personal Protective Equipment (PPE) among Al leith solid waste collectors was higher than previous studies done in Addis Ababa 39% [19] and 37.6% [27]. This might be due to supplying PPEs for waste collectors. A study done in Hebron and Bethlehem reveals that most of the solid waste collectors did not use PPE i.e. 98.6% of them do not use face mask; 78.9% do not use rubber boot; 45% do not use protective gloves; and 85.5% do not use over all protective materials [21]. A study done in Addis Ababa revealed that, only 43.6% of the solid waste collectors were using PPE while they are on duty and of these, only 22.5% of them reported as not using it consistently while they are on duty. Not having access (83.7%), discomfort (25.6%) and to save time (12.8%) were the main reasons mentioned by them for not using the PPE [19]. The results revealed that there is weak correlation between the knowledge about thermal stress risk and the usage of Personal Protective Equipment (PPE) among the solid waste collectors in Al leith municipality, Al leith, Saudi Arabia.

The percentage of waste handlers who had received training before engaging to this line of work in this study was 70% which is greater when compared with other studies 6% [27] and a research done in Addis Ababa revealed that, only 20.8% of the solid waste collectors had training before starting the waste collection job [19].

Workers having satisfactory level of knowledge about the hazards associated with their work in the present study (10%) were less than the carpenters studied by Bolaji in Nigeria (15.4%) [28]. This difference might be due to 70% workers received training on solid waste hazard. Further, work-related injuries during the past year, were reported in 56% solid waste collectors were highly exposed to occupational accidents (injures) because of the nature of their work which oblige them to work in the open environment [29] Which might be explained by the direct contact with wastes while using no protective devices. A research done in Addis Ababa revealed that only 42.0% of the solid waste collectors were using personal protective equipment (PPE) all the time while they were on duty which might result in increasing the probability of occupational health risks [19]. A study done in Port Hartcourt Metropolis in Nigeria about the attitude of solid waste collectors towards safe occupational practice revealed that, 76.3% agreed that they had sustained injuries from sharp objects in the course of packing refuse with bare hands and 26.2% agreed that their PPE were of the right quality and suitable to the task [30].

V. Summary and Recommendations

The calculation of the indices, brought in accordance with the safety standards, has allowed us to assess the degree of risk of heat stress they are subjected to the workers worked in solid waste collection in Al leith. The research data showed the presence of situations of heat stress risk because the calculated WBGT Index exceeds the threshold established by the legislation. The result of this study revealed that the magnitude of safe occupational health practice among solid waste collectors was very low while the overall level of knowledge and attitudes were high/moderate. The variables which had significant influence on the practice of workers about occupational health hazards were years of education, received training about the job-associated hazards and duration of work and job satisfaction. These variables should be taken into consideration in any program addressing occupational health and safety issues.

In order to reduce this risk, the workers were required to: Provide appropriate clothing; Check the exposure times with programming breaks to spend in areas. Al leith solid waste management office should provide occupational health and safety training on occupational health and safety to reach full coverage. Policy makers should enforce training occupational health and safety before engaging to waste collection job for every waste collector. We conclude that this working group of solid waste collectors should be treated as a vulnerable group that needs a special care.

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