THERMAL EXPOSURE AND RELATED HEAT ILLNESS SYMPTOMS AMONG WORKERS IN MARA GOLD MINES

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By

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A Dissertation Submitted in (partial) Fulfillment of the Requirements for the Degree of Master of Science in Environmental and Occupational Health of the

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CERTIFICATION

The undersigned certifies that he has read and hereby recommend for acceptance by Muhimbili University of Health and Allied Sciences a dissertation entitled: ***‘‘Thermal Exposure and Related Heat Illness Symptoms among Workers in Mara Gold Mines’’,*** in (partial) fulfillment of the requirements for the Master of Science (Environmental and Occupational Health) degree of Muhimbili University of Health and Allied Sciences.

Dr. Stephen Kishinhi
(Supervisor)

Date

DECLARATION AND COPYRIGHT

I, **Eugene Benjamin Meshi**, declare that this **dissertation** is my own original work and that it has not been presented and will not be presented to any other university for a similar or any other degree award.

Signature: ……………………………… **Date**:……………………………….

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Last but not least I'm thankful to the University of Dodoma (UDOM), my employer for supporting me financially throughout my Msc Programme.

DEDICATION

This dissertation is dedicated to the family of Mr. and Mrs. B. Meshi for being the source of inspiration, love, support and encouragement that has been an invaluable tool throughout the period of this academic endeavor.

ABSTRACT

Background: Working in humid and hot environment expresses the unique challenges to occupational health and safety in tropical countries. Tanzania being in the region experiences high ambient temperature that can exceed 30°C. The high temperature expose mining workers to heat related injury and illness and hence reduce productivity.

Study Objective: This study was undertaken to assess heat stress exposure and associated heat illness symptoms among gold mine workers at Mara region.

Materials and Methods: A cross section study was conducted where the Similar Exposure Groups (SEG) of study participants were selected based on their risk to extreme heat environment. The Wet Bulb Globe Temperature (WBGT) index was used to assess the heat load while the change in core body temperature, blood pressure and pulse rate of miners presented the heat strain indicator. Data were analyzed using IBM SPSS software version 20. Chi-square test and Pearson correlation were used as a measure of association, while t-test and one way ANOVA were used to check the significant differences between the variables. The p values of < 0.05 were considered significant.

Results: Results showed that the averaged wet bulb globe temperature at the mining workplace was within the ACGIH TLV of 28.5°C. However, 78.4% of underground miners and 69.6% of open cut miners reported to have moderate heat illness. Moreover high body temperature and hot and dry skin were the highly reported heat illness symptoms among miners. Open cut mine workers were under much greater heat strain than underground mine workers with the mean core body temperatures of 38.4 ± 0.5°C and 37.3 ± 0.5°C respectively (p-value = 0.000). Approximately 80% of workers in open cut miners indicated high core body temperature above ISO 7933 threshold of 38.0°C for safety. Majority of workers under contractor were found to consume less water prior to work shift commencement.

Conclusion and recommendation: Occupational setting at the mining area presents the potential exposure to thermal condition that can contribute to heat illness symptoms. Therefore effective strategies like hydration program and breaks must be implemented to enhance workers safety in mines.

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LIST OF ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienist
AIOH	Australian Institute of Occupational Hygienists
ANOVA	Analysis of Variances
BMI	Body Mass Index
EMP	Environmental Management Planning
GDP	Gross Domestic Product
ISO	International Organization for Standardization
MRT	Metabolic Rate
NEMC	National Environment Management Council
NIOSH	National Institute for Occupational Safety and Health
OHS	Occupational Health and Safety
OSHA	Occupational, Safety and Health Authority
SEG	Similar Exposure Group
SPSS	Statistical Package for the Social Sciences
TLV	Threshold Limit Value
TWA	Time weighted Average
WBGT	Wet Bulb Globe Temperature
WCF	Workers Compensation Fund

DEFINITION OF TERMS

Heat exhaustion: Physiological changes caused by failure of cardiovascular system to simultaneously supply adequate blood flow to the vital organs, working muscles and the skin.

Heat stress: is the net heat load on the body with contributions from both metabolic heat production, and external environmental factors including temperature, relative humidity, radiant heat transfer and air movement, as they are affected by clothing**.**

Heat strain: refers to the acute (short-term) or chronic (long-term) consequences of exposure to environmental heat stress on a person's physical and mental states. The overall physiological response resulting from heat stress

Heat Stroke: condition caused by overheating body, usually as a result of prolonged exposure to or physical exertion in high temperature. The most serious form of heat stroke occurs when the body temperature rises to 40° C or higher

Similar Exposure Group (SEG):means a group of employees who experience hazard exposures similar enough that monitoring exposures of any representative sub group of employees in the group provides data useful for predicting exposures of the remaining employees;

Mining site: Location where mining operations are undertaken, it can be underground or open cut.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Mining and quarrying industry contribute to 105,561 (0.5 %) employment opportunities out of 19,678,259 persons who are in other labor activities in Mainland Tanzania. The industry alone contributes 3.3% in Gross Domestic Product (1). Production in mining industry is accompanied with high percentage of risk to the safety and health of the workers, among them being heat related illness from hot environment exposures. Several epidemiological studies have shown the contribution of extreme hot environment to the morbidity and mortality within the community as a result of climate change (2–4). Working and activities in thermal operations such as in mining industry and steel mills subject the workers to the risk of heat stress (5,6). The increases of global temperature as a result of climate has and will continue to exacerbate workplace heat (7)

Generally, the body should maintain a core temperature within + 1°C of the normal 37°C core body temperature (8). The environmental heat stress (air temperature, humidity, radiant heat) combined with physical work and clothing is accountable for heat strain within occupational setting. Heat strain is defined as "the physiological impact of heat stress on the body, as expressed in terms of changes in core body temperature and compensating changes in the activity of physiological systems (heart rate, sweat rate, skin blood flow)" (9).

Heat stress as an aspect of the physical work environment has directly affected the human health, safety , sense and subtly changed interpersonal interactions and thus productivity (10) and have also a significant economic burden in compensation claims. The effects include muscle cramps, heat exhaustion and heat stroke. Muscle cramps are a painful involuntary muscle contraction thought to occur due to either dehydration and electrolyte depletion, or neuromuscular fatigue. The more severe forms of heat illness include heat exhaustion and heat stroke. Signs and symptoms of heat exhaustion include headache, nausea or vomiting, weakness and fatigue, dizziness, clammy skin, rapid heart rate and breathing, and irritability.

Dehydration and loss of electrolyte balance as a result of high sweat rates are key factors in the experience of heat exhaustion (11).

In underground mines, virgin rock temperature increases with depth (geothermal gradient), air temperature increases with depth due to increase air pressure (auto compression), groundwater and mine water transfer heat to the air by evaporation and increase the humidity, energy consumed by mining machines and equipment is liberated as heat. These account for hot and humid environment within deep underground mines.

The extent of heat stress and associate heat related illness has been experienced in different part of the world. A study by Hunt (2008), on heat strains, hydration status and symptoms of heat illness in 91 surfaces mine workers of Australia, found that 87% of workers reported at least one symptom of heat illness over a 12-month period, with fatigue, headache, high body temperature being the most reported symptoms. In Washington State from 1995 to 2005, the economic burden associated with heat related illness were $895,196 from workers' compensation claims and 1564 lost time days (12).

In Africa, a one year study in South Africa underground mines, the incidence of heat exhaustion for three mines operating above 1200m depth was 43.0 cases/million man-hours, while from two mines operating between 1200m and 1800m depth it was 58.3/million man-hours (13).

In Tanzania, employee is legally entitled to safe and healthy workplaces. However, despite standards formulated and enforced by Occupational Health and Safety (OHS) Act 2003, there are still reports on injuries and death from the accidents within the workplace. Occupational factors make an important contribution to the global burden of diseases, but the reliable data on occupational diseases are much more difficult to obtain (14). Since the extent of excessive heat exposure in mining industry is not well documented in Tanzania (15), then the need to develop research based evidence is highly warranted. This study therefore aims at creating empirical evidence so that sustainable intervention will be implemented to prevent heat stress and reduce health and safety effects from the exposure.

1.2 Problem Statement

Tanzania is the fourth-largest gold miner in Africa behind South Africa, Mali and Ghana. The mining industry makes a significant contribution to the country economy (16). It provides job for over one million people, majority being employed in artisanal mining operations. Mining activities have a lot of environmental and health impacts, where the health cost of mining sometimes outweigh the benefits gained. Thus promoting safety and protect the health of workers in mining industry is of great importance, not only to the employee or employer but to the country at large.

Nevertheless, workers in mining industry encounter multiple exposures from several hazards, heat stress being among them. The hot and humid temperature from climate change, radiant heat energy from machines and equipment and workload severity increases the susceptibility of workers to heat stress injury and illness. Moreover, mine workers are equipped with PPE such as long-sleeved cotton jumpsuit, rubber or leather boots, hard hat with lamp, safety glasses, and self-contained-self-rescue apparatus that increase the insulation and prevent excessive heat loss (17). To protect workers from thermal exposure, ILO, ISO 7933 and ACGIH have set measures which include; limiting work permission when workers core body temperature exceed 38°C, improving ventilation practices and promoting hydration practices (7,18,19).

Despite this, there are still reported cases of heat illness in mining industry. Hunt *et al* (2012), observed heat illness symptoms among 87% and 79 % of surface and underground mine workers respectively (11). Mara region has annual high ambient temperature of 28.4˚C and relative humidity (> 58.2%). Mine workers in Mara goldmines are increasingly susceptible to heat-related injuries and illness given the ambient temperature in this region can be greater than 30˚C WBGT for extended periods.

Globally there are few available data on the contribution of occupational factors on the global burden of diseases (14) This situation has received little attention in Tanzania as well (15). This study will therefore create empirical evidence on whether hot environmental exposures contributes to heat related illness and suggest effective strategies to enhance workers safety and health.

1.3 Problem Analysis Diagram

Exposure to extreme thermal environment that lead to heat stress depends on environmental and personal factors. Air temperature, radiant temperature, air velocity and the humidity within the workplace make the environmental factors, while clothing insulation and metabolic heat constitute the Personal factors.

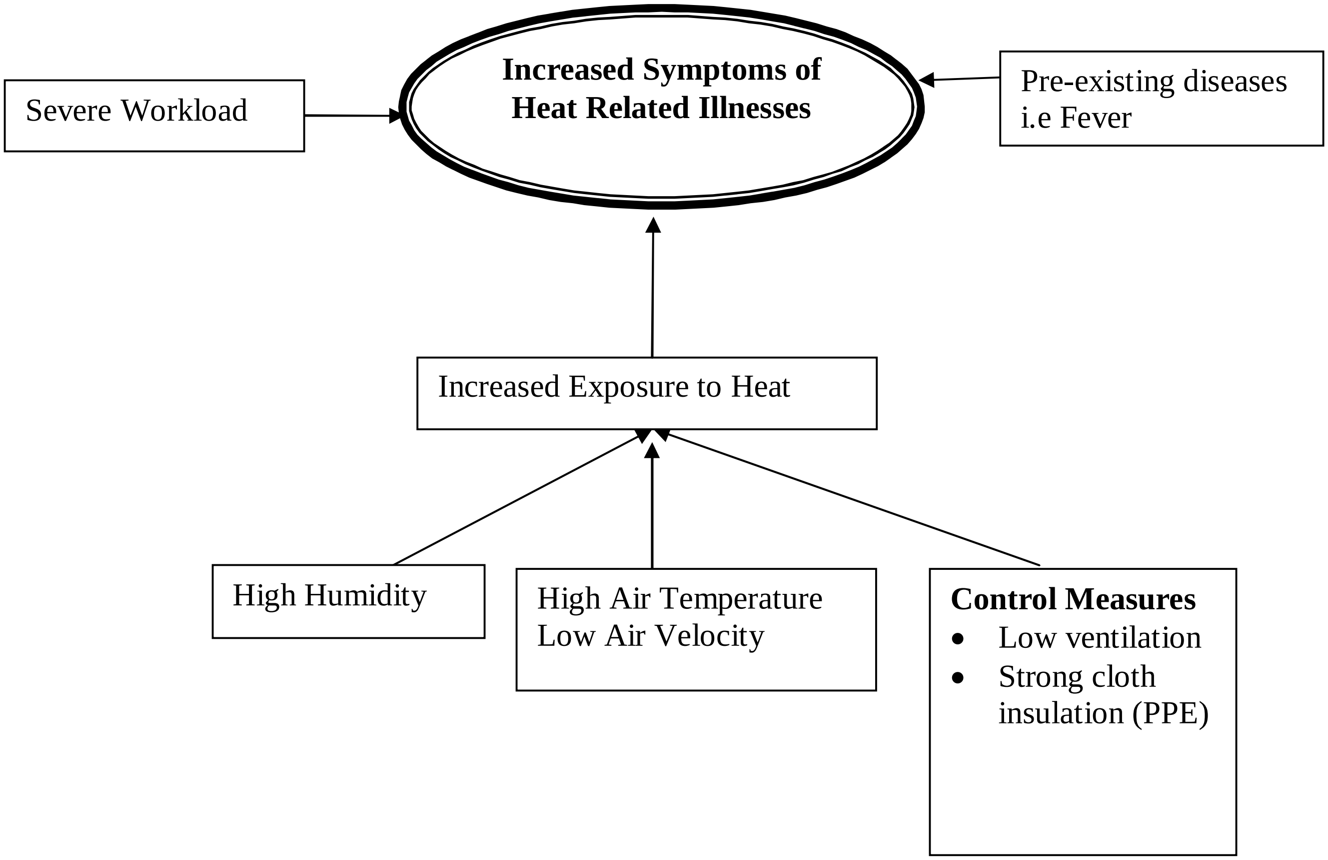

Figure 1: Problem Analysis Diagram

There are several other factors that put miners at an increased risk for heat strain symptoms and heat related illness after the exposure: pre-existing disease hypohydration, age, gender, ability for heat acclimatization, body size and increased Body Mass Index (BMI).

1.4 Significance of the Study

Reported studies in mining industries focused on dust, physical injuries and chemicals as occupational hazards that have ill effect to health and safety of workers, forgetting heat stress as one of the major contributing factor. The results from this study will shed light on the following:

- Provide evidence-based information on the extent of heat stress in underground and open cut mining in Tanzania, to influence the promotion of preventive measure against exposure to extreme hot environment within workplaces.
- Provide exposure data which are necessary inputs for mining industries in suggesting ways to minimize levy (compensation tariff) from WCF by implementing preventive measures and at the same time protect safety and health of workers.

1.5 Research Questions

1. What is the proportion of workers with the symptoms of heat illness in Mara goldmines?

2. Are the gold miners' heat strain indicators associated with the Wet Bulb Globe Temperature (WBGT) index within occupational environments in Mara gold mines?

3. What are the heat stress control measures available within Mara gold mines?

1.6 Objectives

1.6.1 Main Objective

To assess heat stress exposure and associated heat illness symptoms among gold mine workers at Mara region.

1.6.2 Specific Objectives

1. To determine the proportion of mine workers with heat related illness symptoms at gold mine in Mara region.
2. To ascertain the association between WBGT indices and heat strain indictors for workers at open cut and underground gold mine in Mara
3. To determine the availability of heat control measures and the way they help workers at Mara gold mines.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Proportion of miners with heat related illness

Heat is a common problem in the mining industry. Surface miners are frequently exposed to high temperature especially during hot days. Underground miners are vulnerable to heat accumulation as the result of high heat flow from the earth, heat from virgin rock, and additional safety equipment (20).

Heat illness has been suggested to occur along a continuum of ailments because relatively minor symptoms can quickly progress into more serious and life-threatening cases if appropriate actions are not taken to alleviate the condition (11). Its occurrence is from relatively minor heat rash (milliaria rubra) and heat cramp, to the serious heat exhaustion and severe heat stroke, heat illness can present with headache and nausea, fatigue, dizziness, confusion and disorientation, irrational or aggressive behaviour, loss of consciousness, and in extreme cases death. These symptoms are caused by the effects of dehydration, an excessive rise in body temperature, or a combination of both. These three factors (heat strain, hydration status and heat illness) are key aspects affecting the health and performance of individual required to work in the heat (21).

Study done in three mines site across Australia found that 87% of surface miners and 79% of underground workers reported experiencing at least one symptoms of heat related illness. A higher proportion of underground miners experienced heat rash, whereas surface miners proportionately experienced more moist skin, hot and dry skin and high body temperature. The mean number of symptoms reported for surface workers were higher as compared to underground workers; however the difference was not statistically significant. The mean number of symptoms reported did not differ between job category for surface mine worker. More than half of the surface miners workers were classified as experiencing minor heat illness (11,22)

Fatalities from occupational heat exposures often occur in occupations in which workers are performing tasks in hot environments, causing them to build metabolic heat faster than their bodies can release heat and cool down.

A report from Global health action (2007), showed that in South Africa goldmine with greater than 200,000 underground miners there were about 3.3 deaths/1,000miners/year due to fatal heat stroke when wet bulb temperature (Twb) exceeded 34˚C; 0.7deaths/1,000 miners/year when Twb was between 31˚C and 33˚C (3). According to Donoghue , (2004), there were 23 cases of heat exhaustion and 32 cases of heat cramps in underground miners from South Africa deep underground goldmine during 1990 (20).

In the same workplace, depend on the available heat stress control measures, the heat stress can varies between workers who are under different management. A study by Donoghue found that contractors' employees had a higher incidence of heat illness than operators' employees for all major categories of mining operations; underground operations, surface mining, and mills/preparation plants (20).

2.2 WBGT index and Physiological measures of workers in gold mine

Assessment of personal's thermal environment involves several factors which can be grouped into two categories, the environmental and personal factors. Environmental factors include; air temperature, radiant temperature, air velocity and humidity, while personal factors include clothing insulation, metabolic heat and hydration status (23).

The above factors are considered in a three-tiered approach to assessment of heat exposure in different range of scenarios. These include basic assessment which is qualitative, undertaken as part of walk-through survey. Thermal assessment using heat stress index- the wet bulb globe temperature (WBGT) index which is a portable heat stress meter to measure heat condition and determine how long a person can safely work or remain in a particular hot environment, Table 1 and Table 2. Studies (24–26) have reported the use of WBGT as the indirect heat stress indices and the primary indicator of the thermoregulatory stress in occupational settings.

Thirdly is the physiological monitoring based on an individual’s reactions to the thermal stress to which they are being exposed. These direct measurements take into account the variables such as core body temperature, pulse rate, blood pressure, urine specific gravity, urine production and color (23).

Working in hot underground mines frequently requires miners to complete job task in environments that combine high ambient temperatures, and relative humidity with radiant and conductive loading leading to an increased potential of inducing heat illness (27,28). A study conducted in Australia mines identified the surface air temperature, virgin rock temperature, high and hot humidity as the major risk factors for heat stress while human metabolism, oxidation processes, explosive blasting and rock movement as less important source of heat. It was found that the mean core temperature of the workers were below the ACGIH TLV with only five cases exceeded 38.0˚ C. Based on air velocity of < 1.5 m/s the mean average WBGT was above recommended limit. Low proportion of workers had a heart rate greater than 100 beats/min (13).

Thermal conditions prevailing on the surface have been linked in contribution of heat stress to workers in mining industry. A study by Donoghue on the risk of heat exhaustion at deep underground metalliferous mine in relation to surface temperatures found that; the three surface temperature variables were significantly higher on those days on which heat exhaustion occurs. The relative risk of heat exhaustion on days when the 24-h mean WBGT was in the range between 26.0°C to 28.0°C was 4.82 (21). Studies by other researchers (24,29,30) indicated that, when measured WBGT was above the allowable ACGIH TLV then the workers were exposed to the heat stress and were in risk of developing heat illness.

Another study conducted in German coal mines to determine the physiological strain of miners at hot working places found the recorded environmental measures were above ACGIH TLV as the average WBGT was 28.2˚C and dry bulb temperature 31.2˚C. The average pulse rate were 102.8 beats/min while the mean rectal temperature was 37.7˚ C and the intermediate increase in body temperature lead to an increase basic level of heart rate (31).

This indicates that surface temperature data could be used at the mine workplace to warn the miners on the risk of heat stress.

Heat strain can results into excessive cardiac strain hence affect heart rate. A study by Lien (2003), in steel industry between two group of workers who performed different task found that, the heart rate at pre- and post work were 73.1±11.9 and 76.8±11.8 beats/min and 74.0±12.1 and 78.3±11.2 beats/min respectively (24).

A study on occupational heat strain in a hot underground metal mine found that most (98%) miners' median core body temperature were measured below the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for hyperthermia (38˚ C). However the average dry bulb temperature in the working-level underground shaft was above the ACGIH wet bulb globe temperature for moderate workload 28°C (17).

2.3 Control measures for heat illness within open cut and underground gold mines

Heat hazard must be well anticipated prior to the launching of mining operations. It is during planning and designing stage where effective methods of hazard control can be thought of. The basics factors that defined an individual's thermal environment must be considered during design phase. These factors include environmental factors such as air temperature, humidity and air velocity; and personal factors such as hydration status.

Mines are generally designed to provide a specified workplace air temperature, determined in accordance with criteria that relate to worker health, safety, productivity and comfort, legal and regulatory requirements, as well as engineering constraints which invariably entail financial considerations (18). Current interventions used to reduce the development of a heat stress related illness in miners include; setting the upper limit on body temperature during work to 38.5˚ C, limiting the work time in hot ambient conditions according to heat stress indices, improving ventilation practices, wearing cooling garments and educating workers on importance of fluid replacement (19). Table 1 show the ACGIH wet bulb globe temperature TLV under difference various workload in hot environment.

Janse van Rensburg has indicated that formal controls in the form of structured heat stress management (HSM) programme are required where the wet-bulb temperature (T_{wb}) reaches 27.5˚ C. It has also been recommended that routine work should not be permitted where T_{wb} exceeds 32.5˚ C or the dry bulb temperature (T_{db}) exceeds 37˚ C. To achieve this, there is a need to design for and attain workplace wet-bulb temperature not greater than 27.4˚ C (Table 1) and dry bulb temperature not greater than 37.0˚C so as to minimize the risk of heat illness and enhance labour productivity.

Dehydration is another factor that can lead to heat illness following thermal exposure. Hypohydration commonly occurs where workers are exposed to high environmental temperatures for prolonged periods, hence reducing their productivity and placing them at increased risk of accidents and injuries (32).

Table 1: ACGIH Wet-bulb Globe Temperature TLVs at various workloads

Work/rest regimen	**Work Load**		
	Light	**Moderate**	**Heavy**
Continuous work	30.0˚ C	26.7˚ C	25.0˚ C
75% Work, 25% rest , each hour	30.6˚ C	28.0˚ C	25.9˚ C
50% Work, 50% rest , each hour	31.4˚ C	29.4˚ C	27.9˚ C
25% Work, 75% rest , each hour	32.2˚ C	31.1˚ C	30.0˚ C

Table 2: Recommended WBGT TLVs for various workload and air velocity

Workload	**TLVs. WBGT for**	
	Air velocity < 1.5 m/s	**Air velocity > 1.5 m/s**
Light	30.0 ˚ C	32.2 ˚ C
Moderate	27.8 ˚ C	30.6 ˚ C
Heavy	26.1 ˚ C	28.9 ˚ C

2.3.1 Engineering Controls

Control measures are in place to reduce worker's exposure from excessive heat. A study by Giahi *et al* (2015) showed that the installation of heat absorbing system in the furnace and reflective aluminum barrier in the workstation reduces MRT and WBGT indexes by 26.5˚ C and 5.2˚C respectively (33).

2.3.2 Administrative controls

During designing stage, when setting protocols for working in the heat environment, the ability of mine workers to replace fluid lost must be thought of since dehydration has been associated in 50% of all heat stroke cases in South African miners (34). Studies have shown that dehydration of 1 to 2% of body weight results in a 6 to 7% reduction in physical work rate while dehydration of 3 to 4% of body weight results in a 22% to 50% reduction in work rate for moderate and hot environment respectively (35).

One of the consequences of environmental heat stress is heat illness. Maintaining adequate hydration is the single most important strategy to counteract the effects of thermal stress. A study by Miller on hydration status of outdoor workers at mine sites found that higher proportions of workers were inadequately hydrated. Most were found to be hypohydrated at the commencement of the shift and their fluid intake were, in general, well below those required to replace fluid losses. The WBGT were in excesses of 30˚C in all locations (32).

The administration should not overlook the perception of people on the available water within the workplace as several studies have indicated that the perceived color and taste of water influence the hydration behavior. A study by Carter to determine the; hydration knowledge, perception and behaviors, hydration status and needs and perceived taste of portable water found that, majority of workers were aware and had knowledge on the effect of dehydration but were found to be dehydrated. He further reported that most rated unfiltered water as tasting significantly worse than the bottled water or the filtered water (36).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Design

A cross sectional study was conducted at gold mine in Mara region to determine the extent of heat related illness based on the symptoms and heat stress experienced by workers.

3.2 Description of Study Area

The study was conducted in a goldmine located in the Tarime district of the Mara region, northern of Tanzania with the coordinates 01° 28' S 034° 31' E (Figure 2). The gold deposits in the study area are situated in the Mara Musoma greenstone belt. The mine is a combined open cast and underground operations as shown in Figure 3 and Figure 4. Surveying, mining activities (drilling, blasting, and hauling) and plant activities (crushing, milling, inline and cyanide leaching and smelting) constitute the major operations in the mining.

The mine has a medical center which is open 24 hours /day, 7 days/week and undertakes the emergency retrieval and treatment of all workers in the event of illness or injury.

Table 3 shows the division of gold mine's operation into different departments such as mining and technical services, with several sections depending on specific task performed. The Similar exposure groups (SEG) in these sections provide a subgroup to make study population. The participants were selected based on their risk of exposure to extreme environmental condition.

Table 3: Similar Exposure Group in study area depending on their task and job section

DEPARTMENT	SECTION	SEGs (Operators)
Mining	Production (Surface)	Dozer, Excavator, Grader, Truck and Wheel Dozer operators Flag Personnel Quality Controller Offsiders
	Production (Underground)	Bogger, Grader, Truck, Jumbo and IT operators Nippers, Charge up crew Jumbo Offsiders
Technical Services	Geology	Geologists, Geo-technicians, Exploration geologist, Geology data clerks
	Mining Engineering	Mining engineers, drilling and blast engineers
	Survey	Surveyors and survey assistants

3.3 Study Population

Workers in Gokona underground mine and Nyabirama open cast mine within the gold mine composed a target population from which the representative sample were selected to form the study population.

3.4 Study Variables

3.4.1 Dependent Variables

1. Symptoms of heat related illness :

Table 4: Symptoms of heat illness

Symptoms of Heat Illness	Heat Illness
Painful spasm of muscle in the arms, legs or abdomen	Heat Cramps
Headache, Nausea, Vomiting, Weakness and Fatigue Dizziness or Light-headedness, Moist and Pale Skin Rapid heart rate and breathing, Irritability	Heat Exhaustion
High Body Temperature, Hot and Dry Skin , Confusion or Disorientation, Loss of consciousness Seizures, Irrational behavior	Heat Stroke

3.4.1.1 Classification of heat illness

Heat illnesses were classified as minor and heat illness, based on the self-reported number of symptoms. Table 4 shows the symptoms of heat illness that were used in questionnaire.

- **Minor heat illness:** Experiencing more than once [either less than four out eight heat exhaustion symptoms and/or less than three out of seven heat stroke symptoms]
- **Moderate heat illness:** Experiencing more than once [either four out of eight heat exhaustion symptoms and/or three out of seven heat stroke symptoms]

3.4.2 Independent Variables

1. **Personal Factors :** Hydration practices ,work severity and work-rest regime
2. **Environmental factors:** Air temperature, radiant temperature, heat energy from machines and equipments, air velocity and humidity.

3.5 Sample Size Estimations

Procedure for selecting homogeneous group of workers or Similar Exposure Group (SEG) as stipulated in Occupational Exposure Sampling Strategy Manual (OESSM) given by NIOSH was used to determine sample size (37). Sample size ‘n’ was drawn from SEG of size ‘N’ using NIOSH sample size determination table as stipulated on Table 5. Two SEGs was selected from open cast and two SEGs from underground. Half of the sample size ‘n’ for each SEG was repeated to account for source of variability within and between workers. A total of 60 research samples were selected for the study, 37 from underground mine and the remaining 23 from open cut mine.

Table 5: Sample size determination by NIOSH

Size of Group ‘N’	**Number of Samples ‘n’**
8	7
9	8
10	9
11-12	10
13-14	11
15-17	12
18-20	13
21-24	14
25-29	15
30-37	16
38-49	17
k50	18

Table 6: Sample size determination for the SEG - Underground operation

Similar Exposure Group	Number of Population 'N'	Number of Sample size 'n'	Number of repeated samples 'n'	Total number of samples
Jumbo offsiders	16	12	6	18
Service/Charge up Crew	20	13	6	19

Table 7: Sample size determination for the SEG- Open cut operation

Similar Exposure Group	Number of Population 'N'	Number of Sample size 'n'	Number of repeated sample 'n'	Total number of sample
Offsiders	10	9	5	14
Quality Controllers	6	6	3	9

3.6 Sampling Procedure and Technique

Multistage sampling was used to select study subjects. At first stage, workers were grouped into clusters of those who performed a specific task with similar thermal environment exposure to form the Similar Exposure Group (SEG). Then two SEGs from open cut (Quality controllers and offsiders) and two SEGs from underground mine (Jumbo offsiders and Charge up crew) were selected to make four SEG groups. From the four selected SEGs, NIOSH sample size determination table was used to get the study participants

Within each SEG, three physiological study parameters were observed. The core body temperature, pulse rate and blood pressure. Data collection involved two measurements for each parameter before work and eight hours after commencing work, making a total of three hundred and twenty four measurements.

Table 8: Number of samples to be collected from SEG during data collection

SEGs	Type of Data	Sampling Frequency	No. Days	No. Subject (n)	Total Measurements
Underground					
Jumbo offsiders	Core body temperature	2	1		36
	Pulse Rate	2	1	18	36
	Blood Pressure	2	1		36
Charge up crew	Core body temperature	2	1		38
	Pulse Rate	2	1	19	38
	Blood Pressure	2	1		38
Open cut					
Quality Controller	Core body temperature	2	1		18
	Pulse Rate	2	1	9	18
	Blood Pressure	2	1		18
Offsiders	Core body temperature	2	1		28
	Pulse Rate	2	1	14	28
	Blood Pressure	2	1		28
Total					**324**

3.7 Inclusion and Exclusion Criteria

3.7.1 Inclusion Criteria

All underground and open cut miners with employment record of more than one year and once requested treatment from the mine's medical center for symptoms of heat related illness were considered for inclusion.

3.7.2 Exclusion Criteria

Workers who had shortly returned from inter break/leave and not acclimatized.

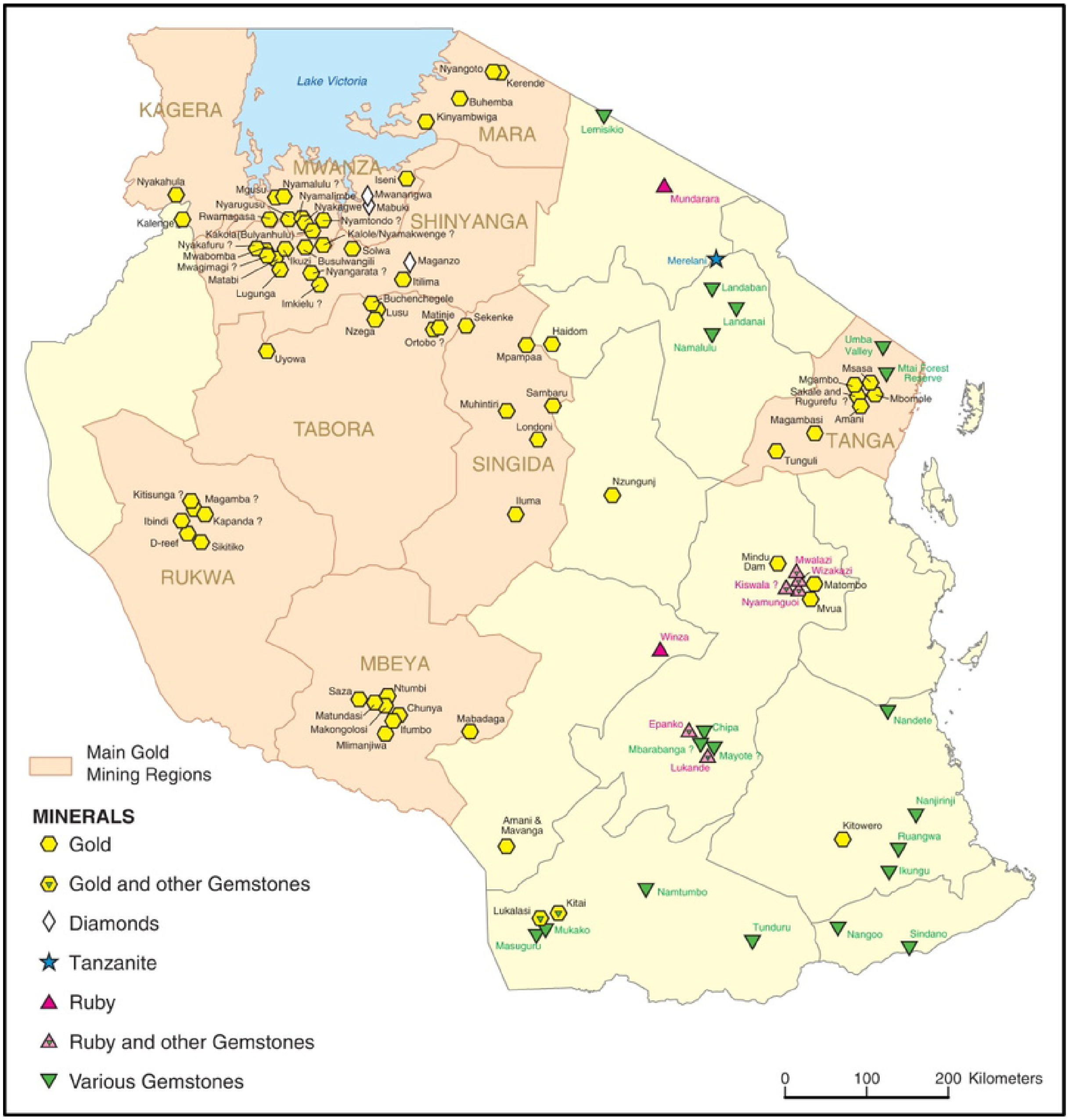

Figure 2: The map of Tanzania showing Mara region: Source (Google Map)

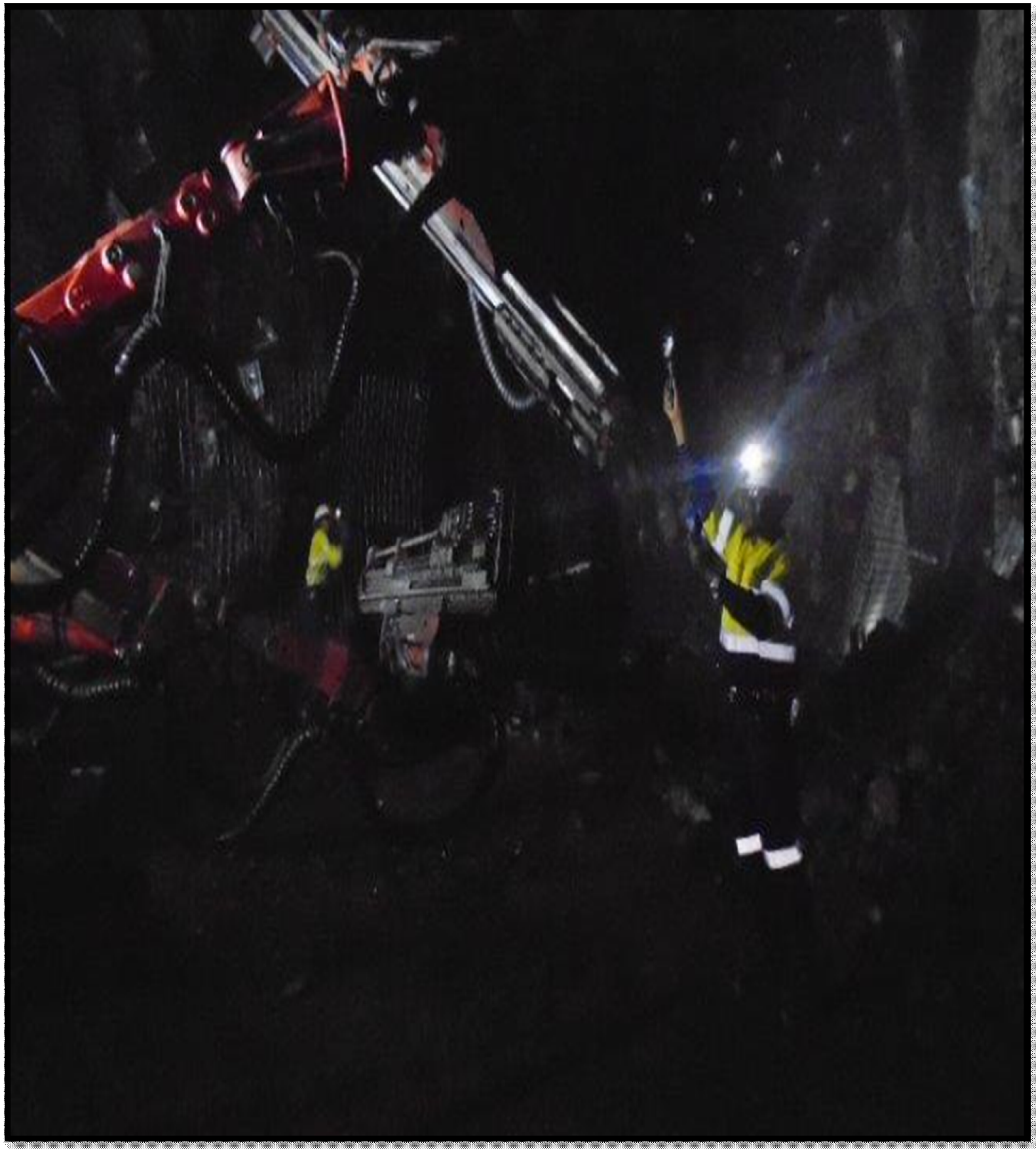

Figure 3: Underground gold mine in Mara region

Figure 4: Open cut gold mine in Mara region

3.8 Data Collection Methods and Procedure

3.8.0 Plan for Data Collection

The study was conducted at open cut and underground mines and involved the OHS representatives from both section and medical personnel from the medical center within the workplace. Since the goldmine had its established system on environmental monitoring then data collection were in line with the established schedule at the study area. In underground operation, the dayshift begins at 0600hrs and end at 1700hrs. Prior to the beginning of the day shift, management used to have tool box meeting and the first measurements were recorded at this time.

For open cut operations, dayshift begins at 0700hrs with the tool box meeting and end at 1700hrs. The first study measurements were taken during tool box meeting. In both mine locations, the second the measurements were recorded at eight hours after work commencement.

3.8.1 Walk through Survey

A preliminary evaluation of the work sections in gold mines was conducted during a work through survey. A developed checklist was used to collect information regarding control measures for heat stress which were available in the study area (Appendix 5).

3.8.2 Interviewer Administered Questionnaire

An interviewer administered questionnaire was used by Principal Investigator (PI) to obtain information from study subjects on the factors that influence heat stress. A closed ended structured questionnaire was used as a tool during data collection. The instrument was adapted from interviewer administered questionnaire in 2011 study conducted by Hunt from Queensland University of Technology due to the similarities in approach and research topic.

The questionnaire comprised of four sections. Section one contained questions on demographic information, including age, gender, height, weight and type of job/task performed. Section two addressed questions on work environment and hydration practices, including frequency and volume of fluids consumption during work and the type of fluid consumption during break. In section three, study subjects were asked to indicate if they had experienced any symptoms of heat illness in the past 12 months. This included muscle cramp, fainting, headache, nausea, vomiting, weakness, fatigue, dizziness, clammy/moist skin, irritability, hot and dry skin, high body temperature, confusion, irrational behavior, low coordination, loss of consciousness, and convulsions/seizures. These are most common symptoms experienced during heat exhaustion and heat stroke as explained in literature review in Chapter Two. This list of symptoms was also in agreement with the conditions as outlined by the scientific and occupational hygiene communities including, the Australian Institute of Occupational Hygienist Heat Stress Standard and review articles on environmental thermal stress and industry. Other information on this section included the frequency of symptoms occurrence and as well as the work shift. Section four focused on information regarding medical conditions and prescribed medications.

3.8.3 Measurements of core body temperature

To measure the pyrogenic change in body's temperature , a medical digital thermometer (Geratherm® clinic GT-2038)was used**.** The measurement range of thermometer is 32° C to 43.9° C and accuracy of ± 0.1° C

3.8.3.1 Procedure for measuring core body temperature

With the help from medical personnel from the gold mine health center, the thermometer was placed in the mouth under the tongue so that it rests to the root of the tongue for two minutes before taking temperature measurements. The temperatures were measured before starting of work and eight hours after commencing work. Each study subject was provided with his/her own clinical thermometer by the researcher for core body temperature measurement.

3.8.4 Measurements of wet bulb globe temperature

3.8.4.1 Details of the Questemp instrument

- Type: QUESTemp° 46 (Waterless Wetbulb sensor and relative humidity sensor)
- Measurement accuracy:
  - Dry Bulb and Globe Temperature: ± 0.5° C between 0° C and 120° C
  - Waterless Wet Bulb Temperature: Expanded measurement uncertainty of 1.1° C between 0° C and 80° C
  - Relative humidity: ±5% between 20 to 95%
- Serial Number TSN080015-1 C€
- Instrument Operating Temperature: $-5^\circ C \leq T_{amb} \leq +60^\circ C$

The waterless wet bulb sensor and relative humidity sensor QUESTemp˚ 46 was used to both measure and automatic calculate the dry bulb, wet bulb, globe, WBGT indoors, WBGT outdoors, relative humidity and heat index.

- Wet-bulb thermometer - the natural wet-bulb temperature was obtained by waterless wetted sensor which was exposed to natural air movement and unshielded from the radiation
- Globe thermometer- a thin walled, blackened copper sphere 15 cm in diameter with a temperature sensor at its center .The globe thermometer depends upon the transfer of radiant energy between the thermometer and the surrounding surfaces.
- Dry-bulb thermometer- this was used to obtain air temperature. The thermometer is always shielded from radiation without restricting airflow around the bulb

The QUESTemp˚ 46 was placed in the work area in safe location approximately 1 meter off the ground. Before taking the measurements the sensor was left for 10 minutes to stabilize to a new environment.

3.8.5 Measurements of Pulse rate and Blood pressure

The pulse rate was measured before start of work and eight hours after start of work. The Automatic Blood pressure monitor model SLD 3-107 of Suresign make was used to measure both blood pressure (Systolic and diastolic) and pulse rate simultaneously. The measurement range of the BP monitor is 0 to 299mm/Hg for pressure and 40 to 180 beats/min for pulse rate with the accuracy of ± 3mm Hg and ± 5% of reading for pulse rate and oscillometric measurement method

3.9 Pre -Testing the Questionnaire

Prior to the commencement of data collection, the developed and modified questionnaire was distributed to occupational health and safety staff and few representatives from each job section for pre-testing. This included the representative from underground and open cut mining area. Purposively it aimed at checking the clarity of the questions which were to be asked, and estimate the time to be used during data collection. Feedback information from pre-testing was used to update and enhance the questionnaire so as to suit the workplace environment without compromising the quality of research.

3.10 Data Management

Principle investigator supervised the filling of questionnaires during interview sessions and ensured the questions were well understood and only correct data were collected from interviewer.

The collected data were verified for completeness, before coding and entering them into computer. Data cleaning to ensure no information missing was done by computer software IBM SPSS Statistics version 20 prior to data feeding.

3.11 Data Analysis

Data were analysed using IBM SPSS Statistics Version 20. Table 9 shows how different analysis techniques were used for each specific objective. Descriptive statistics were used to analyse the description of sample population and relevant proportions, in frequency tables and cross tabulations between independent and dependent variables. Categorical data were summarized as counts and percentages while continuous data were presented as means and standard deviation. The independent sample t-test was used to determine the difference in mean environmental measures between surfaces and underground mines. Bivariate analysis and simple linear regression (Pearson co-relation coefficient [r] and coefficient of determination [r^2]) were used to analyze the association between environmental measures and physiological measures.

3.12 Data Analysis Plan

Each specific objective had its own technique of data analysis based on the type of data collected.

Table 9: Data analysis techniques

No:	Research Objective	Data Analysis Technique
1	To determine the proportion of mine workers with heat related illness symptoms	• Frequency and Percentage
	• Demographic characteristics of study subjects	• Frequency and Percentage • Mean and Standard Deviation
	• Relationship between heat illness symptoms and (Job category, mines location and employment status	• Cross tabulation (Pearson Chi-square)
2	To determine the environmental (WBGT index) and physiological measures of workers in open cut and underground gold mines environment	• Mean and Standard Deviation
	• Relationship between environmental measures and mines location	• Independent sample t-test
	• Relationship between physiological measures and (job category and mining location)	• Independent sample t-test and One way ANOVA
	• Association between environmental measures and physiological measures	• Bivariate analysis • Simple linear regression
3	To determine available heat control measures in open and underground gold mines	• Frequency and Percentage • Cross tabulation (Pearson Chi-square)

3.13 Ethical Considerations

The study was conducted following the ethical clearance which was granted from the Muhimbili University of Health and Allied Sciences (MUHAS) Ethical Committee. The study considered ethical guidelines. Respondents were informed on the aim of the study for purposes of understanding and providing voluntary consent to participate in the study. Throughout the course of the study, confidentiality of the respondents was maintained.

CHAPTER FOUR

4.0 RESULTS

4.1 Demographic and anthropogenic characteristics of study population

This cross sectional research study was carried out at Tarime District, Mara region from 01st to 25th of May 2017. A total of 60 workers were involved in the study. Table 10 and 11 detailed the general characteristics of the study subjects. Majority of study participants were male 55(91.7%), and the age group 20-29 had maximum number of workers 31 (51.7%) followed by age group 30-39 with 25(41.7%) and the last age group 40-50 had only 4 (6.7%) workers. Thirty one workers (51.7%) were overweight while 25 (41.7%) had normal weight, 3 (5.0%) participants were obese and 1 (1.7%) was underweight.

Table 10: Demographic and anthropogenic characteristics of mine workers

Characteristics	Frequency	Percent (%)
Gender		
Male	55	91.7
Female	5	8.3
Age Group (Years)		
20-29	31	51.7
30-39	25	41.7
40-50	4	6.7
BMI Group (kg/m^2)		
Underweight < 18.5	1	1.7
Normal 18.5 - 24.9	25	41.7
Overweight 25 - 29.5	31	51.7
Obesity > 30	3	5.0

Table 11 shows that the mean ages of workers were 30.1 ± 6.4 years and 30.5 ± 5.1 years for underground and open cut mines respectively. The corresponding means height for workers in underground and open cast were 171.41 ± 8.51m and 173.83 ± 5.81m. There was no significant difference between open cut and underground mines observed for age (p = 0.512), height (p = 0.459), body mass (p = 0.058) and BMI (p = 0.526).

The results on employment status of workers showed that 43 (71.7%) of study participants were under main operator while the remaining 17 (28.3%) were under contractor employment scheme as indicated on Figure 5.

Table 11: The mean and standard deviation of anthropogenic data of mine workers

Anthropogenic Data	**Underground (n = 37)**	**Open Cut (n = 23)**	***P*-Value**
Age (years)	30.11 ± 6.41	30.52 ± 5.19	0.512
Height (m)	171.41 ± 8.51	173.83 ± 5.81	0.459
Body Mass (kg)	74.2 ± 6.7	76.1 ± 8.3	0.058
BMI (kg/m^2)	25.4 ± 2.8	25.1 ± 2.2	0.526

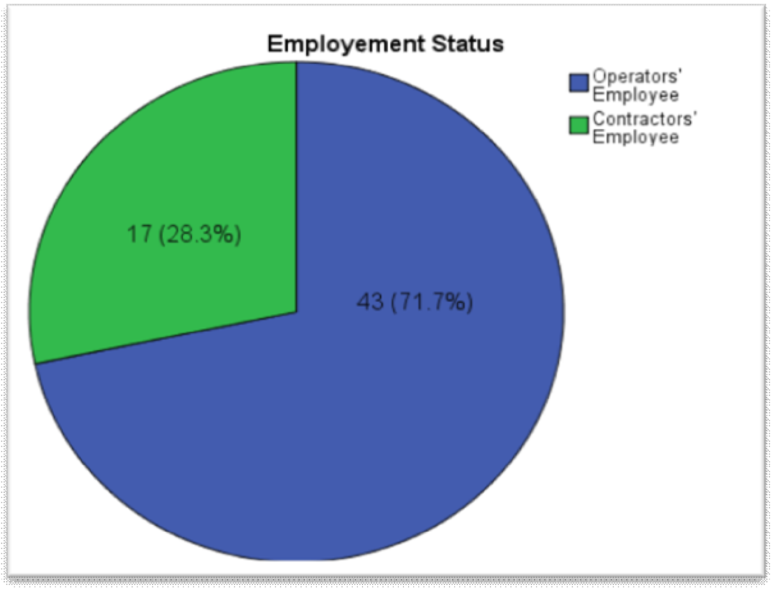

Figure 5: Employment status of mine workers

4.2 Heat illness symptoms among workers in open cut and underground gold mines

This part gives the results of the reported heat illness symptoms among miners within the twelve months period while in workplaces. It presents the proportion of heat illness among the study participants based on the main mining operation at the gold mine, open cut and underground mining operation

4.2.1 Proportion of heat illness symptoms among gold mine workers

Heat illness symptoms experienced by workers are presented on Table 12. Workers at open cut and underground gold mines reported at least one symptoms of heat illness. Overall, high body temperature was the mostly (95%) reported heat illness symptoms followed by hot and dry skin (90%).

In almost all instances there were no significance association between the reported heat illness symptoms and the location of mining site as most of the recorded *p*-values were above the significance level ($p > 0.05$).

Table 12: Reported Heat Illness Symptoms among Open cut and underground miners

Heat illness symptoms	Open cut (n=23)	Underground (n=37)	Chi-Square	*p*-value	Rate Ratio (Surface/Underground)	Total n=60
Muscle cramp	7 (30.4)	15 (40.5)	0.624	0.430	0.8	22 (36.7)
Headache	15 (65.2)	25 (65.6)	0.035	0.851	1	40 (66.7)
Nausea	2 (8.7)	0	-	-	_	2 (3.3)
Vomiting	2 (8.7)	0	-	-	_	2 (3.3)
Weakness	13 (56.7)	22 (59.5)	0.50	0.822	0.9	35 (58.3)
Fatigue	15 (65.2)	24 (64.9)	0.001	0.978	1	39 (65.0)
Dizziness	2 (8.7)	2 (5.4)	-	-	1.6	4 (6.7)
Moist skin	19 (82.6)	34 (91.9)	1.186	0.276	0.9	53 (88.3)
Irritability	7 (30.4)	13 (35.1)	0.141	0.707	0.9	20 (33.3)
Hot and dry skin	21 (91.3)	33 (89.2)	0.071	0.791	1	54 (90.0)
High body temperature	21 (91.3)	36 (97.3)	1.072	0.300	0.9	57 (95.0)
Confusion	6 (26.1)	13 (35.1)	1.212	0.271	0.7	19 (31.7)
Irrational behavior	8 (38.4)	7 (18.9)	1.904	0.168	2.0	15 (25.0)
Low coordination	1 (4.3)	1 (2.7)	-	-	1.6	2 (3.3)
Loss of consciousness	1 (4.3)	1 (2.7)	-	-	1.6	2 (3.3)

Values summarize count and percentage (%) of workers reporting each symptoms

4.2.2 Relationship between heat illness and potential confounding factors

Since ambient environmental conditions varied between open cut and underground mines, and the study participants were performing different job task, then to control for confounders, the proportion of workers with heat illness were compared based on their job category, mining site and employment status.

4.2.2.1 Relationship between heat illness and mining sites

Twenty nine (78.4%) underground mine workers were classified with moderate heat illness, with the remaining 8 (21.6%) as minor heat illness (Table 13). Similar for the open cut mine, the proportion of workers with moderate and minor heat illness were 16 (69.6%) and 7(30.4%) respectively. Notably, there was a difference in proportion of miners with moderate heat illness as compared to those with minor heat illness between the two mines location. The difference, however, was not significant ($x^2 = 0.588$, $p = 0.443$).

Table 13: Heat illness by potential confounding factors

	Heat Illness		**Chi-Square**	***p*-value**
Potential Confounders	Minor Heat Illness	Moderate Heat Illness		
Mine site				
Underground	8 (21.6)	29 (78.4)	0.588	0.443
Open Cast	7 (30.4)	16 (69.6)		
Job Category				
Jumbo Offsiders	8 (25.0)	24 (75.0)	0.055	0.973
Charge up /service crew	5 (26.3)	14 (73.7)		
Quality controller	2 (22.2)	7 (77.8)		
Employee's status				
Operators' Employee	8 (18.6)	35 (81.4)	3.311	0.069
Contractors' Employee	7 (41.2)	10 (58.8)		

Values summaries count and (row percentage)

4.2.2.2 Relationship between heat illness and job category

The proportion of moderate heat illness varied considerably between job category and was notably high for quality controller (77.8%) followed by Jumbo Offsiders/ offsiders (75%) and lastly Charge up/service crew (73.7%). The similar variation was also encountered for the prevalence of minor heat illness between job categories, where higher proportion of minor heat illness was found within charge up/service crew (26.3%). The proportion of miners in either minor or moderate heat illness categories did not differ between the mentioned job categories ($p = 0.069$).

4.2.2.3 Relationship between heat illness and employment status

Table 13 show the proportion of workers with different level of heat illness based on employment status. For employee working under main operator, 35 workers (81.4%) had moderate heat illness while8 (18.6%) experienced minor heat illness. Employee under contractor had 10 (58.8%) and 7 (41.2%) workers with moderate and minor heat illness respectively. In both groups the proportion of workers with moderate heat illness were consistently higher than those with minor heat illness, however the difference was not significant ($p > 0.05$).

4.3 Association between WBGT index and physiological measures

This part gives the results of the measured environmental parameters and physiological parameters of miners. It shows how physiological parameter varies between workers in different mining operation and those who performed different tasks.

4.3.1 WBGT and physiological measures within Open cut and underground mines

The average dry bulb temperature for both underground and open cast mines was 30.8 ± 1.9° C with the minimum and maximum values of 27.24° C and 34.46° C respectively. The recorded minimum, maximum and the average wet-bulb globe temperature for both mines locations were 25.30° C, 31.16° C and 27.7 ± 1.8° C, respectively (Table 14)

During the study period, core body temperature was measured before and eight hours after starting work. The mean core body temperature of workers before commencing work was lower (36.1 ± 1.4˚ C) compared to 37.8± 0.7˚C which was recorded eight hours after commencing work, while the mean rise in core body temperature was 1.4± 0.79˚C. The mean rise in pulse rate was 25.2 ± 16.0 beats/min

For systolic blood pressure, the corresponding mean before starting and eight hours after commencing of work were 128.7 ± 11.6 mmHg and 146.10 ± 13.6 mmHg respectively. The maximum rise in systolic blood pressure was 38 mmHg (17.35 ±7.8).

Table 14: Miners' Physiological parameters and thermal environmental measures

Parameters	**Mean ± SD**
Core body temperature before (˚ C)	36.1 ± 1.4
Core body temperature after (˚ C)	37.8 ± 0.7
Rise in Core Body Temperature (˚ C)	1.4 ± 0.79
Pulse rate before (beats/min)	74.9 ± 14.6
Pulse rate after (beats/min)	100.4 ± 19.5
Rise in Pulse Rate (beats/min)	25.2 ± 16.0
Systolic blood pressure before (mmHg)	128.7 ± 11.6
Systolic blood pressure after (mmHg)	146.10 ± 13.6
Rise in systolic blood pressure (mmHg)	17.35 ± 7.8
Average WetBulb Globe Temperature (˚ C)	27.7 ± 1.8
Average Dry Bulb Temperature (˚ C)	30.8 ± 1.9

4.3.1.1 Relationship between thermal environmental measures and mining sites

Table 15 shows the results from independent sample t-test analysis. The average wet-bulb globe temperature in open cut was higher (28.92 ±1.87˚ C) compared to underground (27.09 ± 1.51˚ C). Similar to average dry bulb temperature, the open cast value (31.9 ± 2.1) was higher than the underground (30.1 ± 1.4). The difference in temperature values from both mine sites were statistically significant (p < 0.05).

Table 15: Thermal environmental measures in underground and Open cut mines (N=60)

Parameters	**Underground (37)** **$\bar{x}$ ± SD**	**Open cut (23)** **$\bar{x}$ ± SD**	***p*- value**
Average WBGT (˚ C)	27.09 ± 1.51	28.92 ±1.87	0.000*
Average Dry Bulb Temperature (˚ C)	30.1 ± 1.4	31.9 ± 2.1	0.000*
Average Relative Humidity (%)	69.1 ± 7.8	40.72 ± 9	0.000*

* Significant at $p < 0.05$. Data presents mean ± SD

4.3.1.2 Relationship between miners physiological measures and job category

Table 16 shows the results from one way ANOVA on measured core body temperature, pulse rate and blood pressure based on job category. The rise in core body temperature varied between the groups, with miners from quality controller experienced high rise in core body temperature (Mean 1.81 ± 0.7˚ C). The difference on rise in core body temperature between job categories was found to be statistical significant (p < 0.05). The rise in pulse rate among jumbo offsiders was higher compared to the other job categories. However the observed difference was not significant (p > 0.05). The variation in systolic blood pressure before work across the job category was statistical significant with miners from quality controller having higher value (138.3 ± 7.9 mmHg).

Table 16: Physiological measures of miners by job category (N= 60).

	Job category of miners				
Physiological factors	**Offsiders (n=32)** $\bar{x}$ ± SD	**Charge up crew (n=19)** $\bar{x}$ ± SD	**Quality controller (n=9)** $\bar{x}$ ± SD	**F**	***p*-value**
Core body temperature before (˚ C)	36.25 ± 0.5	35.8 ± 2.3	36.68 ± 0.69	1.283	0.285
Core body temperature after (˚ C)	37.8 ± 0.7	37.34 ± 0.6	38.5 ± 0.5	9.510	0.000*
Rise in Core Body Temperature (˚ C)	1.63 ± 0.8	1.01 ± 0.5	1.81 ± 0.7	5.284	0.008*
Pulse rate before (beats/min)	75.84 ± 14.4	66.78 ± 10.5	89 ± 11.7	9.119	0.000*
Pulse rate after (beats/min)	104.18 ± 17.3	89.94 ± 20.1	109.5 ± 17.6	4.884	0.011*
Rise in Pulse Rate (beats/min)	27.71 ± 14.6	23.15 ± 19.2	20.55 ± 13.6	0.920	0.404
Systolic blood pressure before (mmHg)	127.34 ± 10.2	126.57 ± 13.3	138.3 ± 7.9	4.004	0.024*
Systolic blood pressure after (mmHg)	143.4 ± 10.64	144.57 ± 16.04	158.88 ± 11.4	5.435	0.007*
Rise in systolic blood pressure (mmHg)	16.06 ± 6.3	18 ± 9.9	20.55 ± 7.1	1.271	0.288

* Significant at $p < 0.05$

4.3.1.3 Physiological parameters in underground and open cut gold mine

Table 17 shows the recorded physiological measures based on mining sites. The mean rise in core body temperature for workers in open cut was 1.9 ± 0.8° C while in underground was 1.1 ± 0.6° C. Mean rise in pulse rate for workers in open cut was 28.30 ± 17.0beats/minute, while in underground was 23.2 ± 15.3 beats/minute. The independent sample t-test conducted showed that, for systolic blood pressure, the mean rise for open cut mine and underground workers were 19.7 ± 6mmHg and 15.8 ± 8.4 mmHg, respectively. Observed changes in physiological parameters in open cut were higher as compared to underground, however the difference were significant only for the mean rise in core body temperature (*p* <0.05).

Table 17: Physiological parameters of workers in underground and open cut gold mine

Parameters (n = 60)	**Underground(n = 37)**	**Open cut (n = 23)**	
	$\bar{x}$ ± SD	**$\bar{x}$ ± SD**	***p*- value**
Core body temperature before (° C)	35.9 ± 1.7	36.5 ± 0.5	0.151
Core body temperature after (° C)	37.3 ± 0.5	38.4 ± 0.5	0.000*
Rise in Core Body Temperature (° C)	1.1 ± 0.6	1.9 ± 0.8	0.000*
Pulse rate before (beat/minute)	70.9 ± 14.6	81.35 ± 12.4	0.007*
Pulse rate after (beat/minute)	94.7 ± 19.5	109.65 ± 15.9	0.003*
Rise in Pulse Rate (beat/minute)	23.2 ± 15.3	28.30 ± 17.0	0.241
Systolic blood pressure before (mmHg)	128.4 ± 11.7	129.3 ± 11.5	0.773
Systolic blood pressure after (mmHg)	144.2 ± 13.8	149 ± 12.9	0.195
Rise in systolic blood pressure (mmHg)	15.8 ± 8.4	19.7 ± 6	0.066

* Significant at *p* < 0.05, Data summarizes mean ± SD

4.3.2 Association between environmental factors and physiological change

To understand the influence of ambient thermal environments on workers physiology, Pearson correlation between the WBGT and the changes in physiological parameters of study participants was conducted

4.3.2.1 Association between average WBGT and physiological change

Table 18 shows relationship between wet-bulb globe temperature and average dry bulb temperature with miners' physiological parameters. Bivariate analysis revealed the existence of positive correlation between them except for rise in pulse rate. The correlation between WBGT and rise in core body temperature was found to be significant with r = 0.410 and p = 0.001. Figure 6 show a plot from linear regression analysis which suggest that average WBGT predict the rise in core body temperature by 16.8% ($r^2 = 0.168$), and for a unit change of average WBGT then we predict a corresponding average change of 0.174℃ of core body temperature.

Table 18: Pearson correlation between environmental factors and physiological parameters

Environmental Factors	Rise in Core Body Temperature	Rise in Pulse Rate	Rise in systolic blood pressure
Average Dry Bulb Temp	0.503*(*p* = 0.00)	0.006 (*p* = 0.962)	0.096 (*p* = 0.466)
Average WBGT	0.410* (*p* = 0.001)	-0.051(*p* = 0.701)	0.033 (*p* = 0.801)

* Correlation is significant at the 0.01 level (2-tailed).

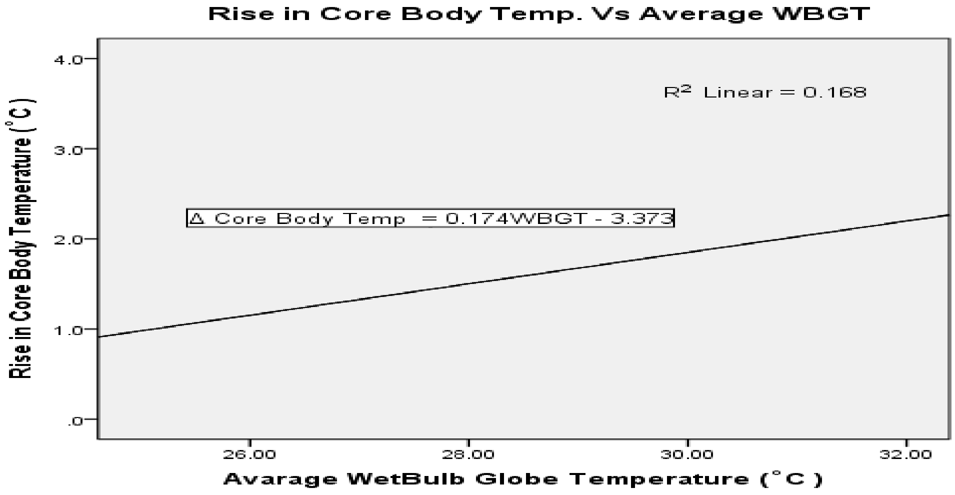

Figure 6: Correlation between WBGT and rise in core body temperature

4.3.2.1 Association between average dry bulb temperature and physiological change

The data on table 18 indicates a positive correlation (r) between dry bulb temperature and rise in core body temperature, pulse rate and systolic blood pressure r = 0.503, 0.006, 0.096 respectively. The rise in core body temperature had a fair positive, statistically significant correlation with dry bulb temperature (r = 0.503, p = 0.000). The coefficient of determination (r^2 = 0.253) from Figure 7 indicate that the average dry bulb temperature predict the rise in core body temperature by 25.3%. For a unit change of average dry bulb temperature then we predict a corresponding average change of 0.205°C of core body temperature.

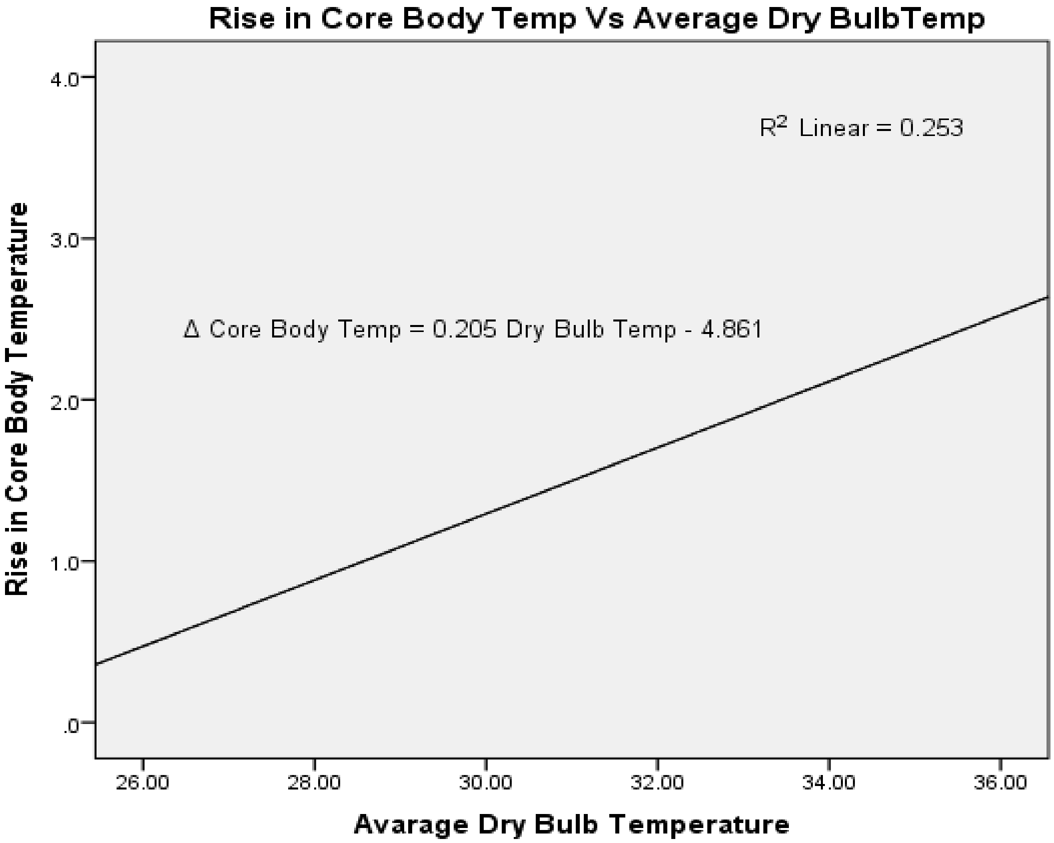

Figure 7: Correlation between dry bulb temperature and rise in core body temperature

4.4 Heat stress control measures within goldmines

This part gives the estimated amount of water consumed by study participant before commencing work and during work shift in order to determine their hydration status as shown on Table 19.

4.4.1 Hydration practices and characteristics

Majority 41(68.3%) had a free accessibility to safe and clean water (bottled water), whereas 19 (31.7%) could not get such access and had to either buy or drink the tap water at workplace. Most of the workers (41.7%) do not drink water before commencing work, and only 35% take less than 250mls, while 8% consume 250 - 500mls. During daily shift more than half (56.7%) consume 3000mls of water, while 40% take greater than 3000mls

Table 19: Hydration practices among mine workers

Hydration characteristics	**Frequency (%)**	**Chi-square**	***p*-value**
Accessibility to free drinking water			
Yes	41 (68.3)	8.067	0.005*
No	19 (31.7)		
Fluid intake before commencing work			
None	25 (41.7)	36.33	0.000*
< 250 ml	21 (35.0)		
250-500mls	8 (13.3)		
500-1000mls	5 (8.3)		
>1000mls	1 (1.7)		
Fluid consumption during shift			
1500mls	2 (3.3)	26.800	0.000*
3000mls	34 (56.7)		
> 3000mls	24 (40.0)		

* Significant at $p < 0.05$

4.4.1.1 Relationship between hydration practices and heat illness

The results from Table 20 show the output from cross tabulation analysis. Overall the higher proportion of heat illness was observed among participants who did not drink any water prior to beginning of work shift, followed by those who consume less than 250 mls.

Table 20: Heat illness by hydration practices among miners

Fluid intake before Commencing work	Heat Illness		Total
	Minor Heat Illness	Moderate Heat Illness	
None	7 (28.0)	18 (72.0)	25 (41.7)
< 250 ml	6 (28.6)	15 (71.4)	21 (35.0)
250-500mls	0	8 (100)	8 (13)
500-1000mls	2 (40)	3 (60)	5 (8.3)
>1000mls	0	1 (100)	1 (1.7)

4.4.2 Work rest regime

Results from Table 21 indicated that most of the workers break once per shift and that is during lunch time. Proportion of workers who do not spend time in cooling environment was higher (83.3%) than those who spent some of their time and half of their time in cooling environment, and the difference was statistically significant ($p < 0.01$).

Table 21: Work rest regime

Factors of work-rest regime	Frequency	Chi-Square	*p*-value
Number of breaks during shift			
One Shift	60 (100)	-	-
Time spent at air condition during work			
None	50 (83.3)	26.667	0.000*
Some of the time	10 (16.7)		
Type of roster			
5 Days Day shift, 5 Days Night Shift, 5 Days Off	37 (61.7)	3.26	0.071
7 Days day shift, 7 days night shift, 7 days off	23 (38.3)		

*Significant at $p < 0.05$

4.4.2.1 Relationship between heat illness and work-rest regime

Table 22 give the estimate of heat illness based on the exposure to cool environment during day working shift. Proportion of workers with moderate heat illness were higher (78%) among the category who do not spend time in cooling environment as compared to those who spend some of their time in cooling environment (60%). The difference however was not significant ($p > 0.05$).

Table 22: Work-rest regime and heat illness

Time spent in cooling environment	Heat Illness	
	Minor Heat Illness	Moderate Heat Illness
None	11 (22)	39 (78)
Some of the time	4 (40)	6 (60)

CHAPTER FIVE

5.0 DISCUSSION

This study determined the level of thermal exposure and associated heat illness within workers in open cut and underground gold mine at Mara region. Workers from different job categories as well as different employers were involved in the study.

Proportional of miners with heat illness symptoms

The finding on this study show that majority of miners from both open cut and underground mine reported to experience at least one symptoms of heat illness. The prevalence of moderate heat illness was 78.4% for underground miners and 69.6% for open cut miners.

Based on employer category, this study found that the prevalence of moderate illness were 81.4% and 58.8% for miners under operator and contractor respectively. This observation differ from the results of other scholars where miners under contractors had higher incidence of heat illness as compared to those under operator (20). The variation in observed prevalence in different studies could in part due to the difference in behavior pattern among miners who were involved in our study. Despite being provided with adequate and safe bottled water, workers under operator were observed to sell some of the bottled water to the nearby shops. This could increase their risk to dehydration and heat illness.

High body temperature is seen to be the most prevalent (98%) heat illness symptoms followed by hot and dry skin 90%. These findings are in agreement with the study done by Hunt in Australia mining. Hunt reported high body temperature and hot and dry skin being among the prevalent heat illness symptoms (11).

WBGT indices and heat strain indicator among study participants

Environmental factors that were hypothesized to contribute to heat illness include the thermal condition on the surface (wet bulb globe temperature, dry bulb temperature), ventilation, source of heat and humidity. Results from this study revealed a fairly positive correlation between some of the thermal conditions on the surface and change in physiological parameters in workers that are indicator of heat illness.

The increase in average dry bulb temperature and average wet bulb globe temperature on the surface lead to the corresponding increase in the core body temperature of workers ($r = 0.503$ and 0.410 while p-value <0.01, respectively). This result reveals the existence of an exposure-response relationship between the surface temperature and change in core body temperature. This is consistent with the observation made by Donoghue where the relative risk of heat exhaustion was reported to increase with increasing averaged WBGT and averaged dry bulb temperature (21)

However this results were in contrast with the study done by Kalkowsky where heart rate and rectal temperature did not increase with climatic load (31).

The reasons for this dissimilarity could be due to the work-rest regime set by the administrative within the two mine workplaces. In German mines, when climatic stress increase, workers are allowed to reduce their work load or take a work break and reduce their energy expenditure (self pacing) to keep their sensation of strain at an appropriate level. The walk through survey conducted during this study showed that the management did not schedule the short break for self pacing during the working shift, open cut miners break once for lunch and it is during this time blasting was done, so they had at least more than one hour break within the shift. Similarly the underground miners break once for lunch but had short time as compared to open cut miners

Results from this study indicate that the overall averaged wet bulb temperature was 27.7 ±1.8° C. Comparison of measured WBGT indices to allowed level according to ACGIH TLV indicate the value of 27.09±1.51° C for underground and 28.92 ±1.87° C for open cut mine respectively. The observed difference in WBGT was statistically significant ($p < 0.05$). The values of WBGT on underground operation were within the American Conference of Governmental Industrial Hygienists threshold limit value (ACGIH TLV) of 28 ° C for moderate work. For the open cut operation the averaged WBGT was above the ACGIH TLV, this could likely explain the observation on heat illness between the groups, where the proportions of miners with minor heat illness in underground and open cut were 21.6% and 30.4% respectively.

Moreover, the rise in core body temperature for underground miners was 1.1 ± 0.6° C, while for open cut miners was 1.9 ± 0.8° C and the observed difference was statistically significant ($p < 0.05$). The present findings seem to be consistent with other studies (24,29,30) which reported the significant difference in WBGT index calculated for groups.

Another important point to be noted is that, 78.3% of the open cut miners had the core body temperature above 38.0°C during their working shift. The core body temperature of 38.0°C is the ISO 7933 threshold for safety for acclimatized personnel. The finding is similar with the study by Hunt (22), where the core body temperature of more than 50% of the surface mine workers exceeded 38.0°C. Again the existence of an exposure-response relationship between the surface temperature and change in core body temperature for open cut miners workers could likely be explained the Pearson correlation coefficient which was fairly positive ($r = 0.410$).

Therefore the current study conclude that ambient environmental conditions such as wet bulb globe temperature and dry bulb temperature are potential predictive of heat disorders. Their values can be used as the early warning to the risk of heat illness in mining industry.

Heat stress control measures available at the study area

Maintaining of adequate hydration in mining industry is among the most important strategy to counteract the effects of thermal stress. The finding from this study indicated that 41.7% of workers do not drink water before commencing work while 35% take less than 250mls. During the work shift more than half of the workers consumed about 300mls of water. This shows that majority of workers start the shift while dehydrated. Our finding is similar to the work of other researchers (22,26) who reported that many of the surface mine workers were dehydrated on commencing work and tend to remained so for the duration of the shift. Moreover, further results from this study indicated that, the high proportion of heat illness was observed among miners who reported not to consume water prior work commencement.

The dehydration status of workers in our finding could likely be associated with the accessibility to adequate safe water at all times in the working environment. Further results in our study showed that 31.7% of workers did not have access to adequate and safe water, most of them were under contractor employment scheme. Though they had access to treated tap water but most perceived them to be unfit for consumption.

Several studies have indicated that perceived taste of water influence hydration behavior. A study by Carter (36) on hydration knowledge, perception and behaviors, hydration status and needs reported that majority of workers rated unfiltered water as tasting significantly worse than bottled water. To promote hydration behavior the administration must be advised on provision of water that is safe by regulatory standard and perceived aesthetically fit by the consumers. Surprisingly enough, the remaining 68.3% of workers who had accesses to adequate and safe bottled water, some of them used to sell it to their nearby shops.

Therefore this study concludes that hydration program is one the suitable single mechanism to prevent heat stress under the exposure to extreme thermal environment as most of those reported to be dehydrated were from underground and under contractor. The management should not overlook the perception of workers on the portable tap water which is provided by the contractor, as it direct influence the hydration behavior and determine the amount of water consumed by workers before and during the shift.

5.1 Strength and limitation of the study

5.1.1 Strength of the study

To the best of my knowledge and in our setting so far, this was the first study carried to assess the thermal environment and monitoring the physiological parameters in order to determine the level of heat stress in the gold mine. Furthermore this is the first study that employed both the open cut and underground mining operation during assessment.

The study used multiple methods during data collection to ensure that the necessary thermal environmental and physiological parameters are collected for an assessment

5.1.2 Limitation of the study

The study used cross sectional, descriptive study to give the snap shot of the existing ambient environmental condition and heat strain of workers in the gold mine. Being a cross sectional study, the data were collected on in one season (ending of rain season). The results can not reflect the annual ambient thermal condition at the mining site. Moreover, the design could not give the exactly causal - effect relationship between the thermal environmental condition and the heat stress illness. However, the study was able to monitor the heat strain of workers and established heat load of the working environment as well as determined the proportional of workers with self reported heat illness symptoms. The established thermal environmental data could be used in mine workplace as warning on the risk of heat stress.

For the accurate measurement of a continuous core body temperature, the following methods are suggested

- Having the subject swallow a radio -tele thermometer that can transmit data to the outside (Ingestible core body temperature sensor)
- Rectal measurement by inserting a thermometer to the rectum

The mentioned methods generally meets with resistance from study participants and their cooperation is difficult to get. To overcome this the study used the digital clinical thermometer with measurement accuracy of ± 0.1° C and measurement range of 32° C to 43.

The suggested gold standard for the measurement of hydration status is urine specific gravity (USG) as it give the mass of urine sample compared to the mass of an equal volume of water.

Self reported urine production and color and amount of water consumed before and during work shift are the other available methods for measuring hydration status. Despite being subjective indicator, when closely monitored they give a presentable and estimated measure on hydration status. This study used method that measured the amount of water consumed before and during work shift to estimate the hydration status of study subject

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The overall averaged wet bulb globe temperature at the mining workplace was within the ACGIH TLV of 28°C, however the mean core body temperature of open cut miners were above ISO 7933 threshold of 38°C for safety. Heat stress is a forgotten potential health problem in gold mine. Study indicates high body temperature and hot and dry skin were among highly reported heat illness symptoms. Moderate heat illnesses were also observed among underground and open cut miners. Despite the presence of hydration program as intervention to reduce development of heat stress related illness, workers under contractor were found to consume little water prior to work commencement and did not have break.

6.2 Recommendations

The results from this study recommend the following

i. Miners should encourage on early reporting of heat illness symptoms and ending work when worse condition occurs during work shift.

ii. The OHS department should conduct the periodic monitoring on the ambient thermal condition at the mining area and communicate the results to the workers and management

iii. Administration should ensure that all workers get an access to adequate and safe water are at all times while in workplace

iv. Administration must establish the policy that allows workers to self pacing, slowing the work or resting more often in worse condition

v. Miners should be informed on the detrimental health effects that may occur following hypohydration prior to the commencement of shift.

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APPENDICES

Appendix 1: Study Questionnaire (English Version)

MUHIMBILI UNIVERSITY OF HEALTH AND ALLIED SCIENCES (MUHAS)

SCHOOL OF PUBLIC HEALTH AND SOCIAL SCIENCES (SPHSS)

P.O. BOX 65001 DAR ES SALAAM TANZANIA

A STUDY ON THERMAL EXPOSURE AND RELATED HEAT ILLNESS SYMPTOMS AMONG WORKERS IN MARA GOLD MINES

Questionnaire No:........................... **Date: ....**

GENERAL CHARACTERISTICS

1. ID ....
2. Age .... years
3. Gender Male ☐ Female ☐
4. Height .... cm
5. Weight .... kg
6. What mine site do you work at? ....
7. How long have you been employed in your current role ....years .... months
8. What is your job category?
   Nippers ☐ Charge up crew ☐
   Quality controller ☐ Flag Personnel ☐
9. What type of Roster do you work? ....
10. What is your normal shift length? .... hours
11. How many breaks do you have on your shift?
    1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

WORK ENVIRONMENT

12. How much time at work do you spend in air-conditioning?

(Either inside a building or in a motor vehicle E.g A truck cabin)

None ☐ Some of the time ☐ Half of the time ☐ Most of the time ☐

All of the time ☐

13. What is your fluid intake between waking and commencing work?

None ☐ <250ml ☐ 250 - 500mls ☐ 500 - 1000mls ☐

> 1000mls ☐

14. Is drinking water freely accessible during work?

Yes ☐ No ☐

15. How often do you drink during your shift ? .... Times per shift

16. How much do you consume during your shift ?

None ☐ <250ml ☐ 250 - 500mls ☐ 500 - 1000mls ☐

1500mls ☐ 3000mls ☐ >3000mls ☐

17. What type of drink do you consume most often during work ?

Water ☐ Tea/Coffee ☐ Soft drinks eg. Coke ☐ Other ☐

....

18. What type of drink do you consume most often on breaks ?

Water ☐ Tea/Coffee ☐ Soft drinks eg. Coke Other ☐

19. How often do you urinate during your shift ? .... times per shift

SYMPTOMS OF HEAT ILLNESS

20. Have you experienced any of the following symptoms at work in the past 12 months?

{Please tick "Yes" or "No" beside each symptoms in the table below. If "Yes", please also tick the other boxes in that row to show how often you have had this symptom (once or more than once), and on what type of shift you were working at the time (day or night).}

S/N	**Symptoms of Heat illness**	**Occurred**		**How Often**	
		No	**Yes**	**Once**	**More than Once**
I	Red rash on skin	☐	☐	☐	☐
II	Muscle cramp	☐	☐	☐	☐
III	Fainting	☐	☐	☐	☐
IV	Headache	☐	☐	☐	☐
V	Nausea	☐	☐	☐	☐
VI	Vomiting	☐	☐	☐	☐
VII	Weakness	☐	☐	☐	☐
VIII	Fatigue	☐	☐	☐	☐
IX	Dizziness	☐	☐	☐	☐
X	Moist skin	☐	☐	☐	☐
XI	Irritability	☐	☐	☐	☐
XII	Hot and dry skin	☐	☐	☐	☐
XIII	High body temperature	☐	☐	☐	☐
XIV	Confusion	☐	☐	☐	☐
XV	Irrational behaviour	☐	☐	☐	☐
XVI	Low coordination	☐	☐	☐	☐
XVII	Loss of consciousness	☐	☐	☐	☐

MEDICAL CONDITIONS AND PRESCRIBED MEDICATION

21. Have you been diagnosed with any of the following medical conditions?

(Please tick al that apply.)

Diabetes ☐ High blood pressure ☐ Kidney disease ☐

Anemia ☐ Skin disorder ☐ Respiratory disorder ☐

Circulatory disorder ☐ Other ....

22. Are you on any medications ?

No ☐

Yes, prescribed ☐ Yes, non prescribed ☐

What is the medication (s) you are currently taking;

....

....

....

23. How long have you been taking this medication?

3 months ☐ 6 months ☐ 1 year ☐ 3 years ☐

5 years ☐ 10 years ☐ Permanent prescription ☐

Thank you for completing this questionnaire

Appendix 2: Study Questionnaire (Swahili Version)

CHUO KIKUU CHA AFYA NA SAYANSI SHIRIKISHI MUHIMBILI (MUHAS)

SLP 65001 DAR ES SALAAM -TANZANIA

DODOSO LA UTAFITI JUU YA KIWANGO CHA JOTO NA DALILI ZA MAGONJWA YASABABISHWAYO NA JOTO KUBWA MIONGONI MWA WAFANYAKAZI KATIKA MIGODI YA DHAHABU MKOANI MARA

Namba ya Dodoso : .... **Tarehe: ....**

TAARIFA BINAFSI

1. UTAMBULISHO ....
2. Umri:Miaka ....
3. Jinsia Mwanaume ☐ Mwanamke ☐
4. Kimo: sm.........................
5. Uzito kilogramu.........................
6. Ni mgodi upi unachofanyia kazi? ....
7. Una muda gani katika kitengo chako cha sasa?miaka .... na miezi ....
8. Eneo lipi,kitengo cha mgodi unachofanyia kazi ?
   - Jumbo offsiders ☐ Charge up crew ☐
   - Wahakiki wa Ubora ☐ Flag Personnel ☐
9. Unafanya kazi katika zamu ipi ? Kutwa ☐ Usiku ☐
10. Je urefuwa zamu yako ya kawaida kazini ni upi? masaa ....
11. Unapumzika mara ngapi katika zamu yako?
    1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

MAZINGIRA YA KAZI

12. Ni mara ngapi uwapo kazini unakuwa sehemu yenye kiyoyozi? (Aidha kwenye jengo au chombo maalumu cha kupooza hewa mfano Motokaa)

    Situmii ☐ Mara mojamoja ☐ Nusu ya muda wa kazi ☐

    Mara nyingi ☐ Muda wote ☐

13. Je unakunywa kiasi gani cha maji/ au kimiminika chochote toka unapoamka hadi muda wa kuanza kazi ufikapo ?

    Situmii ☐ < ml 250 ☐ ml 250 - 500ml ☐

    ml 500 - 1000ml ☐ > ml 1000 ☐

14. Je maji ya kunywa hupatikana bure wakati wakazi?

    Ndio ☐ Hapana ☐

15. Ni mara ngapi hunywa kimiminika wakati wa zamu yako? Mara ....kwa zamu nzima

16. Je unakunywa kiasi gani wakati wa zamu yako?

    Situmii ☐ < ml 250 ☐ ml 250 - 500ml ☐

    ml 500 - 1000ml ☐ > ml 1000 ☐

17. Ni aina gani ya vinywaji unavyotumia mara kwa mara ukiwa kazini?

    maji ☐ chai/kahawa ☐ vinywaji baridi mfano soda ☐

    vingine ....

18. Je unajisaidia haja ndogo mara ngapi ukiwa kazini? mara ....kwa shifti

DALILI ZA MAGONJWA YATOKANAYO NA KIWANGO KIKUBWA CHA JOTO SEHEMU ZA KAZI

19. Ulishawahi kuwa na dalili yoyote kati ya zilizohorodheshwa hapo chini katika kipindi cha mieazi 12 iliyopita?

{Tafadhali weka alama ya Pata kwenye kisanduku cha NDIO au HAPANA pembeni ya kila dalii iliyotajwa. Kama NDIO weka alama ya Pata kuonyesha ni mara ngapi umepata dalili hizo kwenye sehemu inayofuata na onyesha ni muda gani unaingia kazini (kutwa au usiku}

S/N	**Dalili za ugonjwa**	**Ugonjwa ulitokea**		**Mara ngapi**	
		Hapana	**Ndio**	**1**	**>1**
I	Vipele vidogovidogo vyekundu katika ngozi	☐	☐	☐	☐
II	Kubanwa misuli	☐	☐	☐	☐
III	Kuzimia	☐	☐	☐	☐
IV	Maumivu ya kichwa	☐	☐	☐	☐
V	Kichefuchefu	☐	☐	☐	☐
VI	Kutapika	☐	☐	☐	☐

VII	Kuko sanguvu	☐ ☐	☐ ☐
VIII	Uchovu	☐ ☐	☐ ☐
IX	Kizunguzungu	☐ ☐	☐ ☐
X	Ngozi kuwa na unyevunyevu	☐ ☐	☐ ☐
XII	Ngozi kuwa na joto na kavu	☐ ☐	☐ ☐
XIII	Joto kali la mwili	☐ ☐	☐ ☐
XIV	Kuweweseka	☐ ☐	☐ ☐
XV	Matendo yasiyo sahihi	☐ ☐	☐ ☐
XVII	Kupoteza fahamu	☐ ☐	☐ ☐

HALI ZA KITABIBU NA MATIBABU

20. Ulishawahi kugundulika na ugonjwa wowote kati ya huu ?

(Tafadhali weka alama ya pata panapo husika)

Kisukari ☐ Shinikizo kubwa la damu ☐ Ugonjwa wafigo ☐

Upungufu wa damu ☐ Ugonjwa wa ngozi ☐ Tatizo la upumuaji ☐

Matatizo ya mfumo wa mzunguko wa damu ☐

mengine ☐ ....

21. Unatumia dawa zozote wakati huu?

Hapana ☐

Ndio,nimepewa na mtaalamu wa afya ☐

Ndio, sijapewa na mtaalamu wa afya. ☐

Ni aina gani ya dawa unazotumia wakati huu

....

....

....

....

22. Umetumia dawa hizi kwa muda gani sasa?

Miezi 3 ☐ Miezi 6 ☐ Mwaka 1 ☐ Miaka 3 ☐

miaka 5 ☐ Miaka kumi ☐ Maisha yote ☐

Asante kwa ushirikiano wako.

Appendix 3: Informed Consent Form (English Version)

MUHIMBILI UNIVERSITY OF HEALTH AND ALLIED SCIENCES

DEPARTMENT OF ENVIRONMENTAL AND OCCUPTIONAL HEALTH

CONSENT TO PARTICIPATE IN A STUDY

FORM NO:

TITLE:

ASSESSMENT OF HEAT STRESS EXPOSURE AND ASSOCIATED HEAT ILLNESS SYMPTOMS AMONG WORKERS IN NORTH MARA GOLD MINES

Dear sir/madam

You are hereby invited to participate in a study conducted by Mr. Eugene B. Meshi, who is a postgraduate student at Muhimbili University of Health and Allied Sciences. Mr. Eugene B. Meshi is conducting this study for his Masters Dissertation.

Your participation in this study is entirely voluntary. Before deciding whether or not to participate in the study, Please read the information below and ask questions about anything you do not understand. You are being asked to participate in this study because you are among the workers in open cut/underground mines in North Mara.

Purpose of the study

The purpose of this study is to explore the elements in the working situations (such as individual characteristics of workers and working environments) so as to determine if these are related to the symptoms of heat illness experienced by workers. No information regarding an individual's personal information or results will be provided to an employer or external body. Summary results may be provided to your employer, MUHAS, and/or other industry groups and may contain statistical numbers and suggested actions based on the information provided.

Voluntary participation

Please note that your participation in this study is voluntary and you have a right to refuse to consent. If you consent to participate, you have the right to withdraw from the study at any time if you wish to do so.

Your participation will involve the completion of the attached questionnaire and measurements of core body temperature, pulse rate and blood pressure. The length of the time required to complete the questionnaire is approximately 10 minutes, while for core body temperature, pulse rate and blood pressure is 10 minutes.

Expected benefits

To date there is little information on the influencing factors or rate of heat related illness within the mining industry. This research will be conducted in four different work stations to compile a big picture so that mining industries can plan interventions, education, and support programs.

Risks and discomfort

There are no risks or discomforts beyond normal day to day living associated with your participation in this study. The methods for core body temperature, pulse rate and blood pressure measurements are both non invasive procedures.

Compensation for time

You will not receive any payment or other compensation for participation in this study. There is also no cost to you to participate in the study.

Confidentiality

All comments and responses are anonymous and will be treated confidentially. The names of individual persons are not required in any of the responses. Any information we use for publication will not identify your name.

Review and approval

The review and approval of the study has been done by the Ethical committee of Muhimbili University of Health and Allied Sciences (MUHAS).

Results

The results of the study will be made available to you through a planned means of research dissemination. Results of this study will also be compiled in a research paper for publication and as part of a partial fulfillment of a master's degree.

Consent to participate in the study

I confirm that I have read and understood the purpose and significance of this study. I also have understood the conditions of participation.

I therefore have no objection to take part and for the inclusion of my information in the study as long as my identity is treated anonymous.

Participant's Signature: ………………………….

Date:………………………………

Name of person obtaining authorization and consent

…………………………………………………………………

Signature: …………………………. Date:……………………………….

Contacts (MUHAS)

Please if you have questions you can contact Dr. Stephen Kishinhi; MUHAS: P.O BOX 65015, Dar es Salaam (Tel 0684 001 274) who is the supervisor of this research or the PI , Chairman of Senate Research and Publication on the address below.

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Appendix 4: Informed Consent Form (Swahili Version)

RIDHAA YA KUSHIRIKI KWENYE UTAFITI - TOLEO LA KISWAHILI

CHUO CHA SAYANSI ZA TIBA MUHIMBILI

KURUGENZI YA UTAFITI NA MACHAPISHO

IDARA YA MAZINGIRA NA AFYA MAHALA PA KAZI

NAMBA YA FOMU:

UTAFITI JUU YA KIWANGO CHA JOTO NA DALILI ZA MAGONJWA YASABABISHWAYO NA JOTO KUBWA MIONGONI MWA WAFANYAKAZI KATIKA MIGODI YA DHAHABU MKOANI MARA

Mpendwa Msahili;

Nakukaribisha kushiriki katika utafiti unaofanywa na Bw. Eugene B. Meshi kwa ajili ya shahada ya pili kutoka katika chuo kikuu cha sayansi za tiba za asili Muhimbili.

Kushiriki kwako katika utafiti huu ni kwa hiari unatakiwa kusoma taarifa zote katika fomu hii na kama kuna swali kuhusu jambo lolote ambalo halikueleweka unaweza kuuliza kabla hujaamua kushiriki au kutokushiriki katika utafiti huu. Umeombwa kushiriki katika utafiti huu kwa kuwa ni mmoja wa wafanyakazi katika migodi ya dhhabu kwenye mkoa wa Mara

Madhumuni ya utafiti

Dhumuni la utafiti huu ni kutathmini eneo la kazi katika migodi ya dhahabu kwa kuangalia kiwango cha joto na visababishi viongezavyo kiwango cha joto pamoja na taharifa binafsi za wafanyakazi ili kuweza kubaini kama ni chanzo kimoja wapo cha dalili za magonjwa yatokanayo na uwepo wa mfanyakazi katika eneo lenye joto kali sehemu ya kazi. Taharifa yoyote binafsi kutoka kwa mfanyakazi haitasambazwa au kutolewa kwa muajiri, ila mjumuisho wa taharifa hizi kwenye mfumo wa takwimu ndio utakaotolewa kama matokeo kwa wadau husika mbalimbali.

Ushiriki

Ushiriki wako katika utafiti huu ni wa hiari na una haki ya kukataa kushiriki katika utafiti. Kama umekubali kushiriki utatakiwa kuweka sahihi yako katika fomu hii nakujibu maswali utakayokuwa unaulizwa na msahili.

Ushiriki wako utahusisha mambo yafuatayo:

- kujibu maswali yaliyopo kwenye dodoso husika
- kupimwa kiwango cha joto mwilini
- kupimwa kiwango cha msukumo wa damu pamoja na mapigo ya moyo

Faida

Matokeo ya utafiti huu yatasaidia kuboresha sehemu zingine za kazi ili kuzuia ongezeko la magonjwa yasababishwayo na joto kali sehemu za kazi.

Hasara

Hakuna hasara za moja kwa moja zitakazotokana na utafiti huu.Washiriki wataulizwa maswali kwa mahojiano na msahili ambapo pia utaombwa kupimwa kiwango cha joto mwilini, mapigo ya moyo na msukumo wa damu kwa njia ambazo ni salama na rafiki.

Malipo

Hakuta kuwa na malipo yoyote kutokana na ushiriki wa utafiti huu na pia kama mshiriki hutakuwa na gharama zozote za wewe kushiriki katika utafiti huu.

Usiri

Taarifa zote zitakazokusanywa zitashughulikiwa kwa usiri wa hali ya juu na pia zinatolewa kwa ruhusa yako maalum kutokana na taratibu na sheria. Jina lako halitatumika katika taarifa zozote zitakazopatikana katika utafiti huu.

Fomu Ya Utafiti

Nakiri kwamba nimesoma maelezo yote kwa umakini na nimeelewa kila kilichoandikwa katika fomu hii.Ninaelewa kwamba ninaweza kujitoa muda wowote nitakaotaka kujitoa.

Sahihi ya Mshiriki: …………………………. Tarehe:…………………………

Jina la Msahili ……………………………………………………………………

Sahihi ya Msahili: …………………………. Tarehe:…………………………

Mawasiliano kuhusiana na utafiti huu

Kama una maswali kuhusiana na utafiti huu unaweza kuwasiliana na Dkt. Stephen Kishinhi msimamizi wa mwanafunzi katika utafiti huu kutoka chuo kikuu Muhimbili, S.L.P 165001, Dar es Salaam kwa namba (0684 001 274). Kama una maswali kuhusiana na haki zako kama mshiriki wa utafiti huu, unaweza kuwasiliana na Prof. Said Aboud, mwenyekiti wa kamati ya utafiti na uchapishaji kwa kutumia njia ya mawasiliano kwenye aya ifuatayo hapo chini.

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Appendix 5: Checklist for Data Collection During Walk Through Survey

<table>
<tr><th></th><th colspan="2">Site: Operation:</th></tr>
<tr><td>1</td><td>Does employee encounter high temperature, humidity, radiant heat, or areas of low air flow while performing physical work activity ?</td><td>Yes ☐ No ☐
If no, stop here</td></tr>
<tr><td>2</td><td>What is the source of radiant heat at work section?
Sun
Furnace, Oven, Kiln walls
Hot surfaces and machinery
Molten metals</td><td>☐
☐
☐
☐</td></tr>
<tr><td>3</td><td>Are workers required to work at high metabolic rate ?</td><td>Yes ☐ No ☐
If no, see box 3 (a)</td></tr>
<tr><td></td><td>3(a)- Example of metabolic rate categories
<table>
<tr><td><i>Categories</i></td><td><i>Example activities</i></td></tr>
<tr><td><i>Light</i></td><td><i>Sitting with moderate arm and leg movements</i>
<i>Standing, working with arms in light lifting, turning</i>
<i>Using small power tools</i>
<i>Walking slowly on level</i></td></tr>
</table></td><td></td></tr>
</table>

	surface carrying minimal weight	
	Moderate — *Rapid and/or forceful arm movements* *Walking with moderate lifting or pushing* *Walking on level surface carrying 3kg load*	
	Heavy — *Hand sawing, Shoveling light material* *Heavy whole body motions* *Intermittent heavy lifting or working with hands above head* *Walking slowly up steep grades*	
	Very heavy — *Shoveling heavy material, near continuously heavy lifting* *Walking up grades and/or carrying heavy load*	
4	**Do workers wear multiple layers of clothing or impermeable clothing that may restrict heat loss ?**	**Yes** ☐ **No** ☐ **If yes, what is clothing insulation**

	4a Insulation Clothing Value Cotton coveralls Summer light weighting clothing	
	Does the company have a program for controlling worker exposure to heat stress ?	**Yes** ☐ **No** ☐ **If Yes, what are they?**
	Shielding heat sources Ventilation Fans Air condition Reducing metabolic workload Acclimatization Work scheduling, rotation Work/rest regimen Water Personal Protective Equipment	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Appendix 6: Core body Temperature, Pulse Rate and Blood Pressure Sampling Sheet

Work Section:					**Date:**				
S/N	**ID NO:**	**BEFORE WORK**				**8 HOURS AFTER BEGIN WORK**			
		TIME	**CBT (°C)**	**PR**	**BP**	**TIME**	**CBT (° C)**	**PR**	**BP**
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									

Appendix 7: Heat Stress Exposure Data Collection Form

<table>
<tr><td colspan="6">Date:</td></tr>
<tr><td colspan="2">Thermal Environment</td><td rowspan="2">Parameter</td><td rowspan="2">Measurements (n)</td><td rowspan="2">Mean</td><td rowspan="2">Range</td></tr>
<tr><td>Total number of people in the Thermal Environment</td><td>Occupations in Thermal Environment</td></tr>
<tr><td rowspan="5"></td><td rowspan="5"></td><td>Wet bulb (WB)°C</td><td></td><td></td><td></td></tr>
<tr><td>Dry bulb (DB)°C</td><td></td><td></td><td></td></tr>
<tr><td>Globe (GT)° C</td><td></td><td></td><td></td></tr>
<tr><td>Humidity (%)</td><td></td><td></td><td></td></tr>
<tr><td>Air Velocity (m/s)</td><td></td><td></td><td></td></tr>
</table>