ADDIS ABABA UNIVERSITY COLLEGE OF HEALTH SCIENCE
SCHOOL OF PUBLIC HEALTH

Assessment of Occupational Heat Stress-Related Illness and Associated Factors among Workers in Secondary Aluminium Production Factory and Water Bottling Factory around Addis Ababa, Ethiopia

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Contents

List of Figures

List of Tables

Acronyms and Abbreviations

ACGIH American Conference of Governmental Industrial Hygienists

HOTHAPS High Occupational Temperature Health and Productivity Suppression

HRI Heat-Related Illness

MOLS Ministry of Labor and Skill

OSH Occupational Health and Safety

OSHA Occupational Health and Safety Administration

WBGT Wet Bulb Globe Temperature

PPE Personal Protective Equipment

MRT Mean Radiant Temperature

NIOSH National Institution of Occupational Safety and Health

BMI Body Mass Index

MOH Ministry Of Health

Abstract

Background: Heat-related illness is commonly observed among workers who are engaged in metal industries; it is aggravated by climate change. The effect of heat stress on workers' health has not been adequately studied in Ethiopia.

Objectives: to assess occupational heat stress, heat-related illness, and associated factors among workers in aluminium factories and water bottling factories around Addis Ababa.

Method and Materials: A comparative cross-sectional study design was employed in the aluminium factory and the water bottling factory. A stratified sampling method was employed, and the individual was selected by a simple random sampling technique. The data was collected from 408 individuals by using standardized structured questionnaires, the MICROTHERM heat stress WBGT meter, and an observational checklist. The data was entered, cleaned, and coded using EPI DATA version 3.1 and analyzed by SPSS version 2.

Results: The prevalence of heat-related illness among aluminium factory workers was 174 (85.3%), and in water bottling factory participants, it was 55 (27%) with a 95% CI. Sweating was the most reported symptom in the aluminium factory 165 (80.9%) and the water bottling factory 134 (65.7%). The least common heat-related symptoms experienced by the respondents were fainting 7 (1.7%) and muscle cramps 6 (1.5%). Workers in aluminium factories have nine times (AOR, CI = 95%, 9.98 (4.16-23.954)) the odds of developing heat-related illness as compared to water bottling factory participants. Group of industry, water availability, occupation, clothing, and water intake were statistically significant (p-value<0.05). The average TWA WBGT of the working environment temperature in the aluminium factory (31.8 ºC) was above the normal value (25 ºC) and 22.1 ºC in the water bottling factory.

Conclusions: Aluminium factory workers had a higher prevalence of heat-related illness than workers in water bottling factories. Workers in aluminium factories had higher odds of developing heat-related illnesses than water-bottling factory workers. The average TWA WBGT value in the aluminium factory (31.8 ºC) was above the recommendation (25 ºC).

Keywords: heat stress, heat-related illness, WBGT, MICROTHERM, comparative.

1. Introduction

1.1. Background of the study

Occupational heat exposure is of growing concern globally, with climate change drawing more attention to this issue. Heat stress is an important aspect of the lives of individuals working under high-temperature conditions for long hours. The thermal environment has a major impact on the occupational health and safety (OH&S) of workers **(1)**. It is known that in certain industries, of which mining, glass, and steel are proven examples, workers work in spaces where environmental temperature conditions far exceed the severity of naturally occurring climatic heat. In iron and steel manufacturing plants, the radiant heat from the furnaces and coke ovens is the fundamental factor for thermal stress **(2)**.

The steel industry is one of the most important economic industries in both developed and developing countries, involving a large population of employees in different work departments. Workers engaged in this industry are more likely to be exposed to excessive heat stress and its adverse health effects, and Heat-related disorders that range from mild to severe health problems, including heat stroke, heat syncope, unstable movement, and death **(3, 4).**

Temperatures and humidity in indoor work environments may increase during hot and humid seasons, especially in workplaces that lack adequate ventilation or air conditioning. The presence of drinking water and emergency procedures are also factors affecting workers' responses to heat exposure. Risk factors for heat stress include individual susceptibilities, such as age and gender, along with workers' hydration levels, workplace and environment temperature levels, and work rate and activities. Moreover, the effects of hot and humid working conditions may be exacerbated if workers are unaware of heat-related illnesses and their prevention **(5).**

Heat exposure has a great impact on workers' health and productivity in many industrial workplaces, especially in the steel industry, where excessive heat exposure is a major occupational problem. Sweating, headaches, muscle cramps, fatigue, dizziness or nausea, excessive thirst, itching, and skin pink or red pumps are the common symptoms seen in workers who suffer from heat-related illnesses due to frequent exposure to heat at the workplace. Some studies indicate a highly significant association between high temperatures and heat-related illness **(6–8).**

1.2. Statement of the problem

In developing countries, including Ethiopia, heat stress is often an unacknowledged occupational health hazard, and less information is available on the effects of workplace heat exposure. Excessive hot environments are usually widespread in foundries, iron and steel industries, glass manufacturing units, rubber processing, coke ovens, mining sites, and several other industrial sectors. As Ethiopia is a developing country in the phase of industrialization, steel industries employ a large number of workers. There is no nationally organized recording and reporting system for occupation-related health problems. Also, the country has no modern device that measures heat stress levels at the workplace, and occupational diseases are among the most neglected work-related health issues **(9,10)**.

In Ethiopia, aluminium and steel production factories are a rising industry as demand is growing each year with an increase in construction activities and household used utensils. Following this, the number of industrial workers is increasing from time to time. Aluminium factory workers are engaged in rigorous physical tasks near smelters and other machines that emit high temperatures that cause the operating room temperatures to increase and create an unfavourable work environment **(11).**

Although there is severe occupational heat exposure at the workplace of steel factories, in most of the factories, proper precautions are not taken to prevent heat stress. And in most industries in Ethiopia, there is no training or awareness-creation program related to the appropriate response that should be taken when there is occupational heat exposure or heat-related illness at the workplace.

In Ethiopia, some studies assessed the impacts of increased temperatures on bakery, agricultural, and public health; however, research on aluminium and steel factories is scarce. Despite the increased exposure of steel factory workers to high temperatures, less attention is given, and there is no adequate information. Further research is needed to clearly quantify the risk of heat exposure and heat-related illnesses, including production loss due to occupational heat stress and adaptation strategies to the changing temperature in aluminium factories.

1.3 1.3 Rational of the Study

Nowadays, in many factories, employees are working in hazardous working conditions, and heat stress is one of the harmful factors present in many workplaces. A steel mill plant is one of the work environments where the workers are exposed to high temperatures, which lead to production loss.

Aluminium workers are exposed to high heat during various processes such as extraction, tapping, burning of scrap, casting, and molten steel production. Despite its harmful effect on the health of workers, the attention and awareness given to this topic is low, including its coping mechanisms in developing countries, including Ethiopia.

1.4. Significance of the study

The purpose of this study is to provide adequate information about the exposure level and direct health effects of temperature on workers' health in aluminium factories and address this for concerned bodies such as labour and health policymakers, safety and health practitioners, owners of the company, including workers, and the public.

It can be helpful and provide appropriate information for researchers or other stakeholders to explore detailed information about the exposure to heat stress among aluminium factory workers. In addition to this, the study suggested possible prevention and adaptation strategies (coping mechanisms) to reduce the effect of increasing temperatures on workers' health.

2. Literature Review

2.1. Defining heat stress

A different study stated that heat stress refers to the heat received more than what the human body can tolerate, without physiological impairment. Heat stress effects can be described in three ways: internal body heat, external heat, and clothing heat from muscular physical activity, ambient environmental temperature, and body cloth heat convection and sweat evaporation respectively **(12)**.

Heat stress includes a series of conditions where the body is under stress from overheating and when the body cannot get rid of excess heat **(13)**. The human body is designed to maintain a core body temperature of 37 0c. When occupational heat exposure is high in the workplace, the worker is at risk of increased core body temperature (above 38 0c), diminished physical work capacity, diminished mental task ability, increase accident risk and other heat-related illnesses, heat stress induced by high temperature, heavy workload, and clothing inappropriate for the heat and humidity **(14)**.

Any heat gain or loss beyond the normal level generates a sense of thermal discomfort in the human body. A human sensation of feeling hot or cold in the workplace is mainly affected and expressed in terms of environmental factors (air temperature, airspeed, mean radiant temperature and relative humidity) and personal factors (clothing insulation, metabolic rate or activity level). Thermal comfort can be maintained when the heat generated by human metabolism is allowed to dissipate making a person in thermal equilibrium with the surroundings **(15)**.

2.2. Heat stress exposure of workers at the workplace

A different study showed that workers employed in the steel industry are exposed to heat stress and heat stress is also a problem for many types of workers: metal smelters, outdoor construction and law enforcement workers, plastics manufacturing workers, landscaping and recreation maintenance personnel, staff in warehouses without air conditioning, cooks and kitchen workers.

A study conducted in Iran shows the exposure of respondents to heat stress based on DI criteria. About 39 (43.3%) subjects experienced moderate and 51 (56.7%) severe levels of exposure to heat, and there was no mild level of exposure to heat stress. The workers of the melting and then production line were more than exposed to heat stress. The average allowed limit of heat exposure was 28.32±0.38°C, most subjects were exposed to heat stress and there was a significant difference between the average WBGT and the threshold limit values ($t=4.903$, $P<0.001$) **(16)**.

According to a study conducted in South India, Among the 1842 workers, nearly 85% had WBGT exposures that exceeded the recommended heat TLV limits for the various work intensity categories and clearly showed that the maximum percentage of participants were working above the safe limit in salt-pan industry and the maximum WBGTs exposure to the workers was observed in the steel industry, and A significant association between heat stress and work intensity was observed ($p < 0.0001$), about 85% ($n = 1564$) of the workers reported experiencing any one of the heat strain symptoms **(17).**

From a study conducted in china to show how working in a hot environment increases injury, The most common type of injuries observed in hot weather were 'falls, trips and slips' (55.0%), followed by other injuries (18.0%) and cutting-related injuries (13.0%). 43.8% of the workers agreed that working in high temperatures would increase the risk of accidental injury. About half (43.8%) of the respondents were concerned about the risk of heat-related injury when working in extremely hot temperatures and results showed that the majority (91.2%) of respondents agreed with more heat-related legal requirements to assure occupational health and safety in hot weather **(18)**.

2.3. Workplace heat stress and health outcome

Adverse health effects due to exposure to excessive ambient heat (termed here heat exposure) already occur in many parts of the world, not only during heat waves but also due to the need for intensive manual work in hot daily conditions. The study conducted in Malaysia to determine the prevalence of heat-related illness in palm oil mill workers who are under heat stress found Heat exhaustion (84.2%) is the highest prevalence of heat-related illness reported, followed by dehydration (76.8%), heat cramps (58.9%), heat rashes (36.8%), heat syncope (27.4%) and heat stroke (5.3%) among Palm Oil Mill Workers in Malaysia **(19)**.

A study conducted in Ethiopia showed the prevalence of heat-related illness was 83.90% and 12.6% in steel and Pepsi cola factories respectively at $P<0.001$. The most prevalent heat-related symptoms in the metal factory were thirst 203 (90.6%), sweating 170 (75.9%), exhaustion 160

(71.4%), headache 153 (68.3%), unstable movement 41 (18.3%), and fainting 16 (7.1%). Among steel factory participants (224) the highest prevalence of heat-related illness was observed in Induction Furnace 59(88.1%) compare to others Continuous Casting Machine 34 (73.9%) and Machine Shop 82 (86.3%). The prevalence of heat-related illness (at least four and above symptoms experienced) were 83.90% and 12.6% with CI=95% from steel and Pepsi cola factory respectively **(9).** In another study in Tanzania, workers at open-cut and underground goldmines reported at least one symptom of heat illness. Overall, high body temperature was the most frequently reported heat illness symptom (95%), followed by hot and dry skin (90%) **(20).**

Another study in Ethiopia conducted among sugar factory workers showed, the majority of participants 299 (74.6%) experienced four or more HRI symptoms during the harvesting season, and it was significantly greater in Harvesting 288 (64.9%) than in the Seed Cane preparation section 71 (35.1%). The heat-related symptoms that most respondents experienced were sweating (98.3%) and thirst (98%) and the least common complaint was Nausea/Vomiting (23.1%). In the same way, the prevalence was higher in Metahara 211 (80.84%) compared to Wonjishoa 88 (62.85%). The highest prevalence of heat-related illness complaints among workers when exposed to heat was heat exhaustion with a prevalence of 376 (93.8%) **(21).**

Studies have examined the heat stress associated with occupational heat-related illness. In central India, a comparative cross-sectional study of iron and steel factory by divided two groups exposed (direct production section) and non-exposed (store and administrative section) showed that the prevalence of heat stress was the workers 90% were in workers exposed group than non-exposed group 10% **(22).** In another study in a South African gold mine with >200,000 underground miners, who worked in extremely hot and humid conditions;1956-1961 About 3.3 deaths/1,000 miners/year due to fatal heat stroke when wet bulb globe temperature(WBGT) exceeded 34°C; 0.7 deaths/ year/1,000 miners when WBGT was between 31 and 33°C **(23).**

From a study conducted in china on a steel mill factory involving 220 workers and using areal measurement, WBGT index (26.5°C to 30.6°C), and self-reporting revealed a high prevalence of heat fatigue (96.8%), lethargy (90%), dizziness (82.3%), heat rashes (44.5%), muscle cramp (58.6%) and unstable movement (48.2%), Heat collapse (20%), Heatstroke (3.6%) among the steel mill plant workers **(24).** From another review of a cohort study in a French stainless-steel producing plant, cardio-vascular mortality was 10% for those workers exposed to heat than for a control group that was not exposed **(25)**.

2.4. The determinant factor of heat stress-related illness

2.4.1 Individual factor

Age is one of the major risk factors that have a greater risk of heat stress during physical activity. The ability to physiologically maintain body core temperature during heat stress becomes compromised with age. Observational reviewed studies have shown that people aged 60 years and older are among the worst affected by extreme heat. Mortality ratios (ratios of observed deaths to expected deaths) in France increased continuously with age, from 1.3 for people 35–74 years of age to more than 1.7 for those over the age of 75 **(26)**.

Some studies have shown that females have demonstrated more blunted thermoregulatory responses than males, resulting in higher body temperatures while performing similar work. In another study, in Malaysia study steel mill plant found that there are socioeconomic factors that can influence the health impact of heat stress **(27)**.

In a study conducted in china, the thermal discomfort level was 2.91 ± 1.19, which increased to 3.61 ± 0.72 after wearing PPE ($p < 0.001$). In addition, the humidity discomfort level was 0.98 ± 1.36, which increased to 3.06 ± 1.1 after wearing PPE ($p < 0.001$). Feelings of being "very hot" and "uncomfortably humid" were the most influenced by wearing PPE, increasing from 31% to 69.1% and from 9.1% to 45.7%, respectively **(28)**. In another study, Respondents reported experiencing several heat-related illness symptoms, and heat stress impaired both cognitive and physical performance. The majority of respondents stated that wearing PPE made their job more difficult **(29)**.

A systemic review study has shown that fatal heatstroke occurs 3.5 times more frequently in adults with overweight and obesity than in individuals of average body weight. The extra weight that obese individuals carry also increases the metabolic cost of weight-bearing activities, which elevates the rate of heat production, people with obesity exhibit greater elevation in core temperature than lean individuals for the same absolute workload **(26)**.

2.4.2. Environmental factors

Environmental conditions with extreme temperature are major risks to developing heat-related symptoms such as excessive sweating or thirst, tiredness, cramps, headache, nausea/ vomiting, fainting, prickly heat, or urogenital issues, the specific environmental factors causing heat stress are high air temperature, minimal movement of air, high humidity, and radiant heat. A study conducted in china assessed fatigue in electric arc melting workers (ER) and continuous casting workers (CC) in a steel plant under heat stress. 55 men participated in the study. Areal measurement was measured with a WBGT index and workers' self-report fatigue symptoms. WBGT ranged from 25.4-28.78°C and 30.0-33.28°C r the CC and ER areas, respectively. the ER group had significantly higher prevalence rates in subjective symptoms and slower response time than the CC group **(24).**

A systemic review and meta-analysis showed that Most of the 111 studies included in the systematic review suggest that working in hot conditions (WGBT >22°C for very intense work; WBGT >25°C for most occupations) increases the likelihood of experiencing occupational heat strain, with significant detrimental effects on health and productivity. Occupational heat strain is also associated with dehydration; the study analyses show that people who worked a single shift in heat stress conditions had an increase of 14·5% in urine-specific gravity compared with those who worked a shift in thermoneutral conditions **(30).**

A study showed that, compares male workers who perform their activities near furnaces (WBGT ≥28.9°C) while wearing heavy protective clothing with the control group (men who perform manufacturing activities with similar physical effort, but not near furnaces). Heat-related symptoms of illness were reported by some participants of the control group. Only self-reported excessive sweating was significantly different between groups (29% in the exposed group and 0% in the control group; $p = 0.03$) **(31).** A study conducted in Egypt observed a higher record of WBGT among the different stages of the process (the pouring operation was higher than the melting operation) in a steel foundry which was above the recommended standard. The reason is due to the huge amount of molten metal handled during pouring which emits a great deal of radiant heat **(32).**

2.4.3 Behavioral factor

A study in Florida prospective cohort study among 198 workers (self-reported) indicated drinking alcohol and smoking had a significant association with a heat-related illness **(33)**. From a comparative study of an iron foundry and bottling plant workers in Malaysia, 35% of those consuming ≤3 l of water reported experiencing muscle cramps, compared with 5% of the bottling plant workers and consuming >3 l of water 20% and 7%, respectively, for cramp sufferers among those in the two occupational groups this difference was statistically significant **(34)**.

2.4.4 Workplace factors

From a study conducted in south India, employees in locations with furnaces and other slag handling processes have continuous exposure to high radiant heat, even during breaks, owing to the lack of cooler resting areas in those work locations. Additionally, the heat load from PPE, aluminium aprons worn by the employees, is also imposed on the workers. High heat and poor working and welfare conditions at the workplace potentially make most of the employees vulnerable to the health risks of heat stress, about 79% of the workers who worked near direct heat in about 32% of the locations experienced high heat exposure, which was further aggravated by lack of ventilation in those locations **(35)**.

From a systemic review, Workers become ill every year due to exposure to working environments characterized by high temperatures. Most of these people exposed to high levels of heat develop chronic illnesses while others become allergic to heat conditions. Workers will tend to perform ineffectively when the working conditions are not favourable. Research proved that workers perform differently when exposed to diverse conditions when working in a hot environment **(12)**. A study showed the eventual occupational impacts of such increasing heat exposure are dependent on shading from trees or roofs, clothing, radiated heat and wind speed in workplaces, but it is most likely that global climate change is a threat to safe, comfortable and productive thermal working environments for a significant part of the global population **(14)**.

2.5 Coping mechanism

Some studies showed that Workers can protect themselves from dangers associated with working in hot environments by taking some measurements, including taking Rest, availability of Shade areas which can protect workers from direct sunlight exposure, drinking water, Training improving ventilation, wearing light Clothes that can also reduce heat exposure from the hot object.

Provision of cool drinking water" was the most commonly mentioned preventive measure currently adopted in Australian workplaces for reducing the impact of heat exposure, followed by "heat stress related training" (76.1%), "central cooling system or air conditioning" (70.0%), "shady rest area" (68.9%), "rescheduling work time" (67.2%), and "electric fan" (52.2%). Furthermore, 41.7% of participants recommended "the cessation of work if the temperature is extreme". A study conducted in Australia showed that, the most frequently mentioned heat prevention and adaptation barrier was “lack of awareness” (68.3%), followed by “lack of training” (56.1%), “lack of management commitment” (52.2%), “low compliance and implementation of heat stress prevention programs” (40.0%), “lack of financial resources to bring in engineering controls” (37.2%), and “lack of specific heat-related guidelines and regulations” (36.7%) **(36).**

The reviewed study, implemented a designed cool spot with double-layer insulation to reduce the WBGT and MRT levels among workers in a foundry industry, The implemented design intervention resulted in reducing the WBGT value (from 29.6 0C to 22.8 0C) and MRT value (from 43.8 0C to 28.6 0C), thereby limiting the heat stress exposure level among workers **(37).**In another study in Ethiopia, a majority of respondents recommended their workers drink water regularly and cool themselves to cope with heat stress. However, they describe, that there is no sufficient water access and water lacks quality and some of the study participants mentioned that shade was a major adaptation strategy to cope with heat stress that their workers practice especially for Seed Cane preparation workers **(21)**.

Conceptual framework

The figure below shows the conceptual framework of the study. Heat stress occurs when the body's means of controlling its internal temperature starts to fail, which happens due to different factors. Heat stress is the major cause of heat-related illness in a steel factory; factors contributing to heat-related illness are categorized as personal factors, behavioural factors, and institutional and environmental factors. The figure also shows the health outcome and coping strategies.

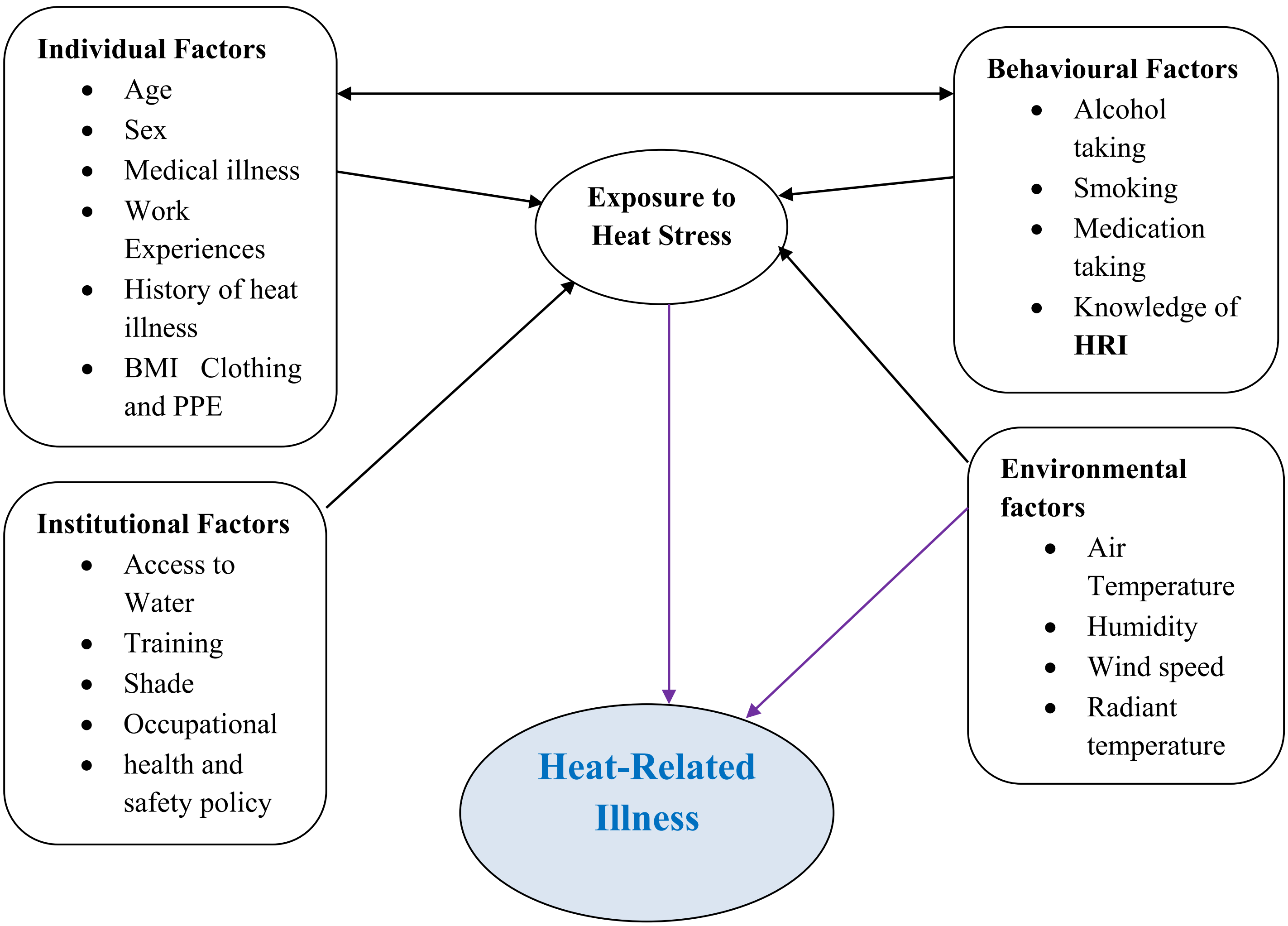

Figure1. Conceptual framework of the study, developed after extensive literature review (21, 9).

3. Objective

3.1. General objective

- To determine occupational heat stress-related illness and associated factors among workers in secondary aluminium production factories and water bottling plant workers around Addis Ababa, Ethiopia.

3.2. Specific objectives

1. To assess the prevalence of heat-related illness/symptoms among workers
2. To identify the determinant factors associated with heat-related illness
3. To measure the extent of heat stress

4. Methods

4.1. Study area

The study was conducted in Debre Birhan among aluminium and water bottling factories. Debre Birhan is a city in central Ethiopia. Located in the Semien Shewa Zone of the Amhara Region, about 120 kilometers northeast of Addis Ababa on the Ethiopian highway, the town has an elevation of 2,840 meters, which makes it the highest town of this size in Africa. It is the capital city of the North Shewa Zone in the Amhara Region of Ethiopia. Based on the CSA estimation, the town has a population of about 114,652, of whom 51,843 are men and 62,809 are women. There are about 22 large-scale factories, which are mainly involved in the production of textiles, beverages, glass, and other products.

The aluminium factory is one of the large-scale factories in Debere Birhan Town. It was established in 2007 E.C. The company is located in the western parts of Debre Birhan town. There are a total of 579 workers. There are five work departments based on the location and the activity they perform, namely the primary department (raw material sorting), circle department, utensil department, finishing department, and maintenance department. Under each work department, there are different work sections. There are three work shifts per 8 hours of work.

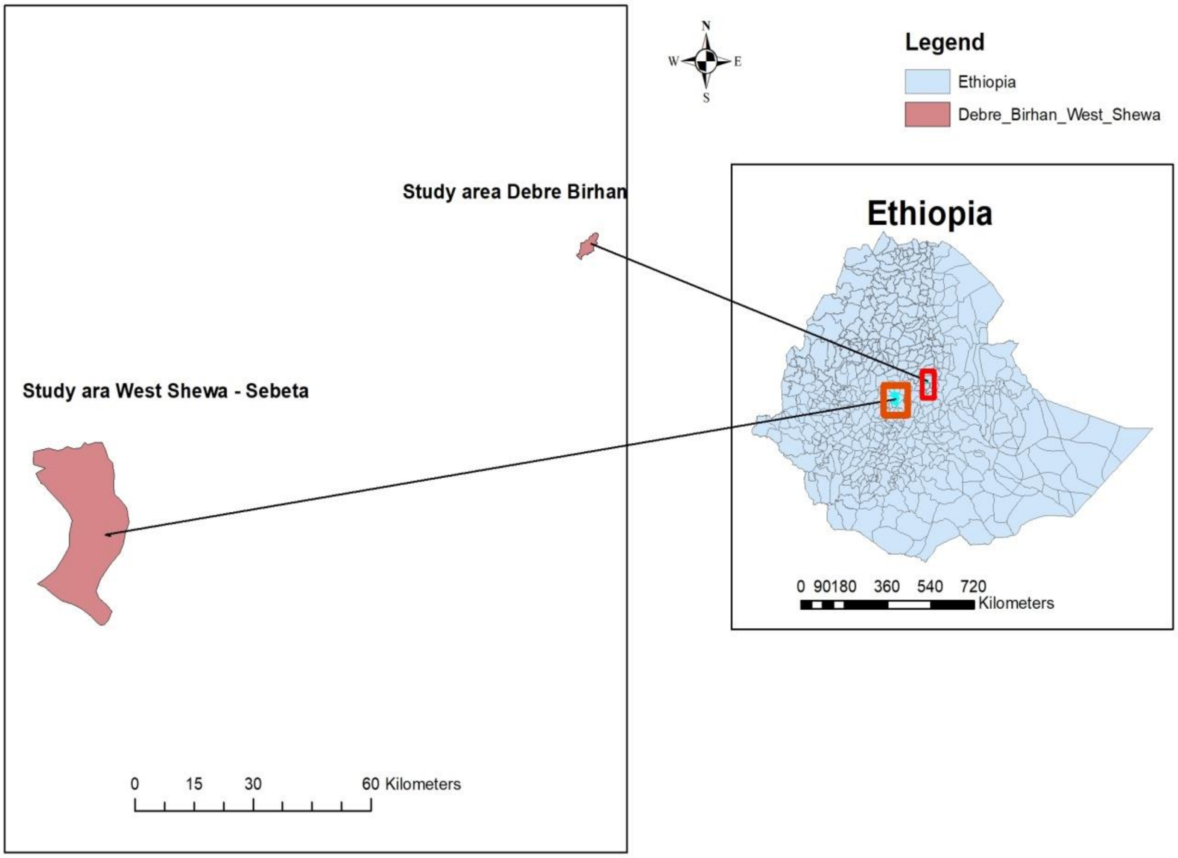

Figure2. Geographical location of study area

Table 1: Metrological, geographic, and workforce information of One water bottling factory, 2023 (38).

		One water bottling factory
Location		Oromia region, 25 km southwest of Addis Ababa
Site area		75,000 m2 of land
Name of the location		Sebeta
Temperature	Maximum	82°F
	Minimum	44°F
	Average	75°F
Annual precipitation		91.62 millimeters
Number of workers		650 workers
Production capacity		120,000 liters per hour

The study was conducted from April 2023 –Jun 2023 G.C around Addis Ababa, a secondary aluminium production factory and water bottling factory.

Secondary Aluminium Production Factory Production Process Description

The aluminium cookware production process passes through different steps; the first step is sorting raw Materials. The selected raw materials, like windows, doors, and car bodies, are directly taken to the melting furnace, and old utensils and kettles are ground by a cheriacher machine into chips and stored in a box to be taken to the melting furnace by using a forklift. The second consists of melting and casting the aluminium scrap in a melting furnace. Rolling casted aluminium and making aluminium sheets by hot rolling machine, and cutting aluminium sheets for producing utensils and kettles as per customer order by hot shearing machine.

The third step consists of three main activities: making a circle from aluminium sheets, making a circle from aluminium sheets, and cutting aluminium sheets to the required size. The fourth step is moulding a circle of metal sheet into the pot. Under the fifth step, the main tasks are making utensils and a kettle, polishing the utensil and kettle with the machine, bending the lip pot, cutting the lip pot, and cleaning the pot. The sixth step is polishing utensils with sandpaper using kerosene, arranging polished utensils, making utensil covers from the circle, cover fitting, and handle fitting. The final step is checking the quality of the product and packing different types of utensils and kettles by carton manually.

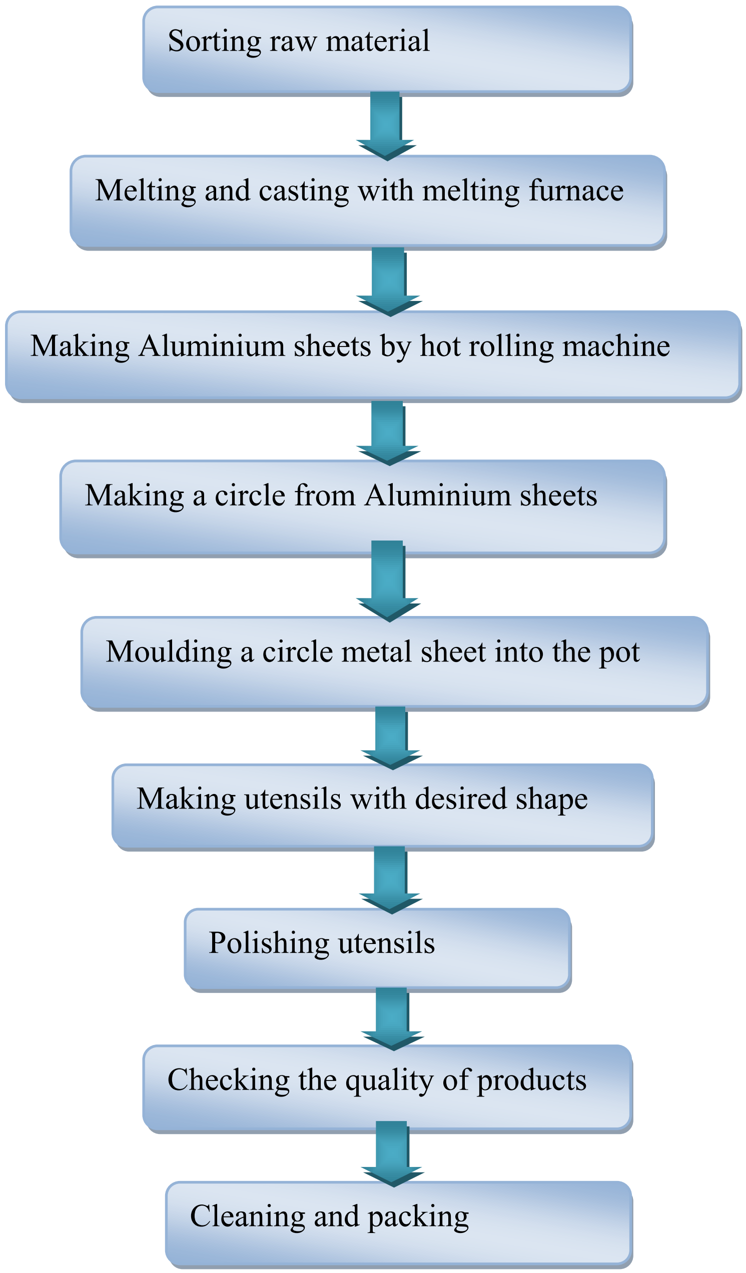

Figure 2: Production process descriptions in Aluminium factory, Debre Birhan, 2023.

4.2. Study Design and Period

An institution-based comparative cross-sectional study design was conducted among the secondary aluminium factory and the water bottling factory in 2023 GC.

4.3.1. Source population

The source populations are all employees who work in secondary aluminium production factories and water bottling factories, Debre Birhan.

4.3.2. Study Population

All employees who are production workers and randomly selected in the secondary aluminium production factory and water bottling factory

4.4. Eligible Criteria

4.4.1. Inclusion criteria: all employees who had worked at least for the last 6 months in the factory **(39)** and aged above 18 years old in the production department were eligible for the study.

4.4.2. Exclusion criteria: Workers who had chronic diseases before employment in the factory other than heat-related illnesses, like diabetes mellitus, heart diseases, and hypertension, and workers with other chronic diseases were excluded from the study.

4.5. Sample Size Determination

- **For the 1st objective (to assess the prevalence of heat-related illness/symptoms workers):**

The sample size was determined by employing the double population proportion formula. A comparative study that was done in India between iron foundry workers and ceramic workers found the highest prevalence of HRI with heavy sweating (94.1%) and (87.2%), respectively **(40).** The sample size was calculated using an open Epi sample size calculator, and a 95% confidence interval was used.

P1 = 94.1% (prevalence of heavy sweating among iron foundry factory workers)

P2 = 87.2% (prevalence of heavy sweating among ceramic factory workers)

$Z\alpha/2$ = Level of statistical significance 1.96 at a confidence level of 95%

$Z\beta$ = Desired power for 90% power

P1-P2 = Difference between proportions

$n = (Z\alpha/2+Z\beta)^{2} * (P1\ (1- P1) + (P2\ (1- P2)) / (P1- P2)^2$

n= 375

The total sample size was 750, n = 375, for each exposed and non-exposed group. By adding a 10% non-response rate, the sample size was:

375+ 37.5 = 412.5 413; the total sample size was 826.

The total population in the aluminium factory is 579, and there are 225 workers in the water bottling factory. The total population in both factories was 804. As the total number is less than 10,000, we use the finite population correction formula. By using a standard Z score of 1.96, corresponding to a 95% confidence level, it was:

n = n / (1+n/N) = 826 / (1+826/804) =408

So, the final sample size was 204 in each group. The total sample size is 408.

For the 2nd objective (to identify the determinant factors associated with heat-related illness):

The sample size was determined by employing two population proportion formulas using an open Epi sample size calculator. A comparative study was conducted in Ethiopia among steel factory and Pepsi cola factory workers. From the associated factor of HRI, the proportion of fluid intake less than three liters was 94% and fluid intake greater than three liters was 69.2%, respectively **(9).** By using a 95% confidence interval and a power of 90%, the sample size was:

n = sample size

P1= 94% (proportion of HRI among workers taking water less than 3liters) **(9)**

P2=69.2% (proportion of HRI among workers taking water greater than 3liters) **(9)**

$Z\alpha/2$ = Level of statistical significance 1.96 at a confidence level of 95%

$Z\beta$ = Desired power for 90% power

P1-P2 = Difference between proportions

$n = (Z\alpha/2+Z\beta)^{2} * (P1\ (1- P1) + (P2\ (1- P2)) / (P1- P2)^2$

n = 51, by adding the non-response rate it was 56 for each group. The total sample size is 102.

The second sample size is too small to represent the source population of the study, so we use the largest sample, n=204 for each group.

- **For the 3rd objective (measuring the extent of heat stress)**:

The environmental measurement was done by taking measurements in the work sections of the aluminium production factory. The aerial measurement was measured using the MICROTHERM heat stress WBGT (model HB3279-04) instrument. WBGT was also measured in the work environments of the water bottling factory.

Figure 3: MICROTHERM heat stress WBGT (model HB3279-04) device.

4.6. Sampling procedures

The study subjects were selected by using a stratified random sampling technique that is proportional to the number of workers in the department, taking work sections as strata. A simple random sampling technique was employed to select the participants in each work section. Both secondary aluminium production and bottling factories are selected purposively as they can show the difference between heat-exposed and non-exposed workers.

The secondary aluminium production factory is selected because the workers are engaged in rigorous activity that is performed at high room temperatures, and there is a large workforce in the factory that works at high temperatures as compared with other aluminium factories. Debre Berhan city was selected as it is located in a high-land area with low temperatures, which helps to quantify the direct occupational heat exposure of workers other than the outside temperature; in this case, it limits the confounding factors (Figure 4).

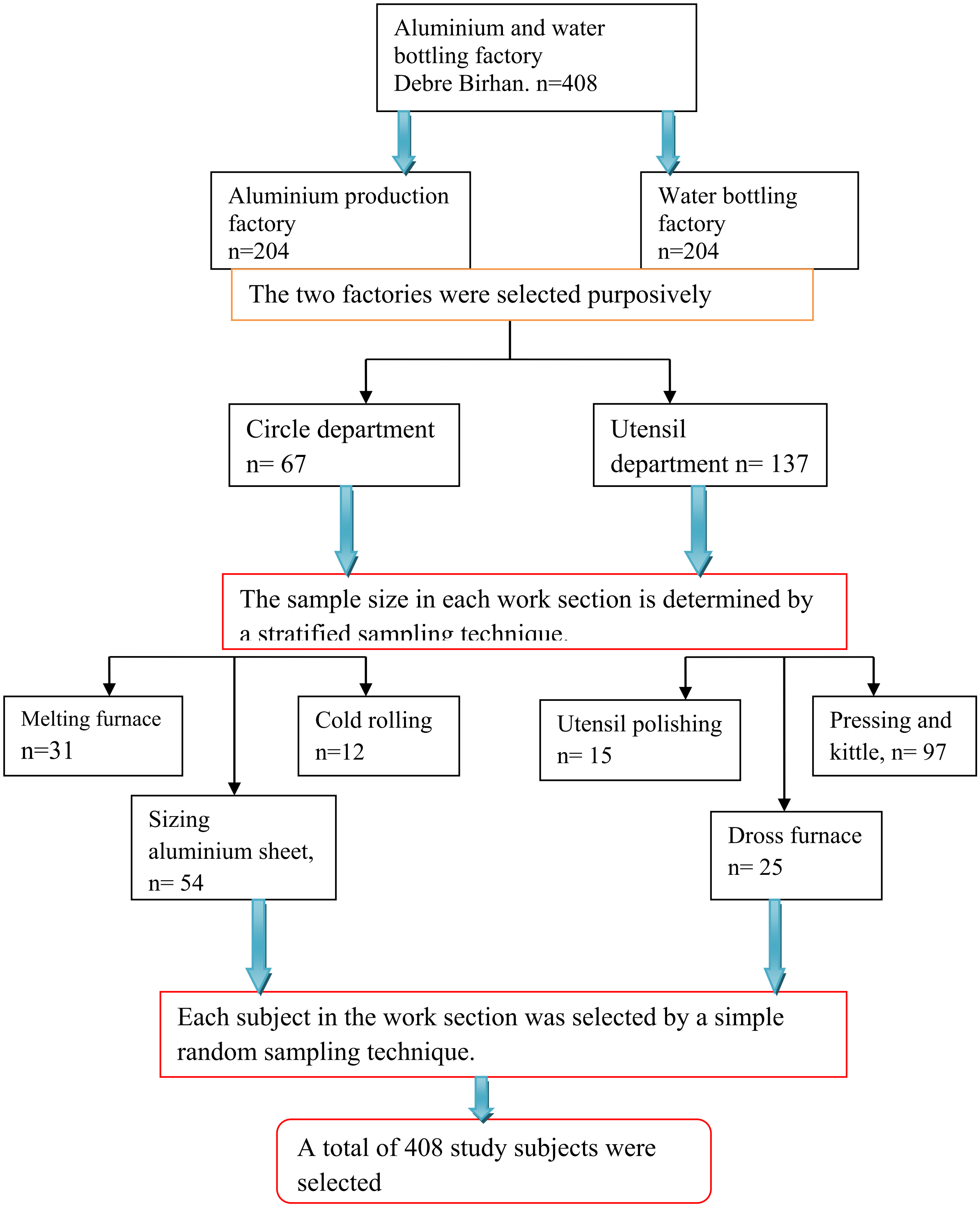

Figure 4: Sampling chart of selected factory workers, Debre Birhan, Ethiopia, 2023.

4.7. Data collection methods

4.7.1 Quantitative data

1. **Questionnaire**

Quantitative data was collected by administering a modified version of the standardized High Occupational Temperature Health and Productivity Suppression (HOTHAPS) questionnaire to workers **(41).** Four data collectors, each of whom has a bachelor's degree in the environmental field collected the data through face-to-face interviews and were supervised by two supervisors to make sure quality data was collected. Four days of training were given to data collectors before data collection to make clear the data collection tools and procedures. The questionnaire has seven parts: 1, general information 2, type of work, 3, workers' exposure to heat, 4, health impact 5, productivity impacts, 6, impacts of clothing; 7, coping mechanisms In this study, productivity loss due to heat stress was assessed by assessing loss of work day/hours or wage loss due to fatigue/exhaustion or any heat-related illness, and heat-related symptoms such as heavy sweating, thirst, fatigue, headache, irritability, clammy skin, rash, muscle cramps, vomiting, dizziness, and fainting were assessed. A person's health is considered affected by heat stress if he or she experiences at least four of the above heat-related symptoms at work.

2. **Instrument measurement (WBGT)**

For the third objective:

Heat stress exposure was assessed via environmental measurements. For measured data, one professional (a labour inspector) has measured the WBGT. The indoor work environment temperature of the aluminium and water bottling factory was measured using the Wet Bulb Globe Temperature (WBGT).

The WBGT combines the effects of the four main thermal components affecting heat stress: air temperature, humidity, air velocity, and radiation, as measured by the dry bulb, wet bulb, and globe temperatures. Globally, the WBGT index is the most commonly used heat index in heat stress assessments and is used by many international organizations for defining heat exposure thresholds or limits for workers **(42).** The WBGT was measured in the workplace for full working hours in a selected area of each department and positioned at a height of 1.1 m using a tripod stand in a representative location without any obstruction.

Figure 3: MICROTHERM heat stress WBGT (model HB3279-04) device, 2023 GC.

WBGT was calculated for the work sections as follows (as it is measured in indoor environments).

WBGT = 0.7 T w + 0.3 T g.   Where: T w = Natural wet-bulb temperature (combined with dry-bulb temperature indicates humidity) **(43)**

T d = Globe temperature

The WBGT was measured in the circle department around the melting furnace in the aluminium factory. The measurement was started at 10:50:08 AM in the morning and ended at 6:50:08 PM in the afternoon. The measurement duration was eight hours without interruption during working time. The second WBGT measurement was done in the water bottling factory and started at 8:37:12 AM in the morning and ended at 4:37:12 PM in the afternoon. The average temperature was recorded every 15 minutes during the measurement. The TWA temperature was calculated by the MICROTHERM heat stress WBGT device at the end of the measurement, and the result was directly downloaded from the MICROTHERM instrument.

4.7.2 Qualitative data

3. Observational checklist

The qualitative data was assessed by using an observational checklist. Observation was performed subjectively by the data collector by assessing air temperature, usage of personal protective equipment (PPE), working environment (ventilation), water access, and work rate, and notes from observation and supportive photos were taken.

Study Variables:

Dependent Variables: Heat-related Illness

Independent variables:

Behavioural factor

Smoking

Alcohol use

Amount of water drink daily

Personal factors

Age

Educational status

Workload

Disease History

4.8. Operational definitions

Heat-related illness: a worker who self-reported at least four and more of the following symptoms: sweating, thirst, muscle cramps, exhaustion, fainting, excessive tiredness, weakness or dizziness, headache, nausea or vomiting, prickly heat/rashes, and unstable movement **(9)**.

Heat syncope: a transient loss of consciousness resulting from a reduction of cerebral flow preceded by "short-duration fainting, headache, dizziness, and nausea" symptoms **(21)**.

Fainting: workers who had experienced a brief loss of consciousness, sweaty skin, and a normal body temperature **(21)**.

Heat rash: worker self-reported symptoms of a red cluster of pimples appearing on the neck, chest, and elbow, considered heat rasher/heat prickled **(21)**.

Acclimatization - Workers who work for more than six months are considered as acclimatized workers **(21)**.

Light workload: workers who are sitting or standing to control workers or workers performing light hand or arm work (e.g., using a table saw); occasional walking; driving **(9)**.

Moderate workload: workers who are walking with moderate lifting and pushing or pulling; walking at a moderate pace; e.g., scrubbing in a standing position **(9)**.

TWA: the employee's average heat exposure in any 8-hour work shift of a 40-hour work week, which shall not be exceeded **(44)**.

Heavy workload: workers who are engaging in picking and shovelling activities, digging, carrying, pushing, or pulling heavy loads; walking at a fast pace; e.g., carpenter sawing by hand **(9)**.

Ventilation: the process by which 'clean' air (normally outdoor air) is intentionally provided to a space and stale air is removed **(45)**.

4.9. Data Management

The primary data, which is collected through measurement, observation, and face-to-face interviews, was organized, cleaned, coded, and stored appropriately. Data completeness was checked carefully by the data collector and investigator. Supervision and necessary interventions were made by the investigator. The data was entered and coded by using Epi Data 3.1 and exported to SPSS version 21 for analysis. The documented and described data was recoded and validated as needed, and then the data was interpreted and analyzed to produce research findings and publications.

4.10. Data Analysis procedures

The imported data was analyzed using SPSS (Statistical Package for Service Solution) version 21.

For the first specific objective, the data was analyzed by using descriptive statistics with frequencies and percentages to show the prevalence of heat stress exposure and heat stress-related illness.

For the second specific objective, variables were cross-tabulated, and a bivariate logistic analysis of HRI among variables was computed. Multivariable logistic regression was computed to show the associated factors that contribute to heat-related illness; variables with a p-value < 0.20 from bivariate were taken to multivariate logistic regression analysis. A standard cutoff of $P < 0.05$ and a 95% confidence level were considered statistically significant for all analyses. The final processed data was presented in the form of tables, graphs, figures, and pictures.

For the third specific objective, the measured data by WBGT was processed and presented with maximum, minimum, and average.

4.11. Data Quality Assurance

The data collector and supervisor were selected based on their educational status, who can understand the questionnaire well, and who can conduct the exact measurement to assure the validity of the data. The data was collected by four data collectors and supervised by two supervisors. And three days of training were given to data collectors and supervisors to show how to use measurement tools and clarify the procedure, and the study participants were selected purposefully as they could be representative of the reference population.

Before the actual data collection, a pretest was conducted among 10% of the study population to check the responses of the participants and the applicability of the questionnaire. The collected data was checked for clarity, accuracy, completeness, and consistency by the supervisors. Orientation was provided by supervisors about the questionnaire.

For measurements, before the actual data collection instruments were pretested to ensure the validity of the tools, the environmental heat stress was measured by using the WBGT instrument. Before conducting measurements, the WBGT instrument was charged fully and warmed up for 15 minutes. The WBGT monitor was fixed at 1.1 meters height close to the usual workplaces where subjects spend most of the time. Distilled water was used to evaluate the relative humidity of workplaces, and the device was checked every 20 minutes for its functionality. There was strict supervision throughout the data collection. The questionnaire in the English language was translated into the Amharic language to avoid misunderstandings among participants.

4.12. Ethical Considerations

The proposal has received an ethical approval letter from the research and ethical committee of the School of Public Health of Addis Ababa University to get the desired cooperation from any concerned bodies. The data was collected after getting verbal and written consent from each participant. The participants were included in the study if they volunteered to participate in the study.

Each participant had the full right to refuse or terminate the study at any time and raise any question that was unclear related to the questionnaire. Appropriate orientation was given by supervisors and data collectors to participants if there was any misunderstanding. Participants' names were not recorded; instead, identification numbers were used. The information collected from the participants is not available to other participants to ensure data confidentiality.

4.13. Dissemination of results

The final result of the study with appropriate recommendations will be submitted to Addis Ababa University, School of Public Health, Department of Preventive Medicine, Environmental and Occupational Health Unit. And it will be disseminated to the Ethiopian Ministry of Health (MOH), the Ministry of Labour and Skills (MOLS), the Steel Factory, and other concerned bodies. It will be published to make it available at the national and international levels.

5. Results

5.1. Socio-demographic and individual characteristics of respondents

Out of 408 participants, all 408 (100%) respondents participated in this study. Among the study participants, 204 (50%) respondents were from secondary aluminium production factories, and 204 (50%) were from water bottling factories. Of the participants, 345 (84.6%) were male and 63 (15.4%) were female; from the water bottling factories, 163 (79.9%) were male and 41 (20.1%) were female; and from the aluminium production factory, 182 (89.2%) were male and 22 (10.8%) were females. The mean age of the study subjects was 25.41 ± 3.5 years. The majority of respondents were in the age group of 20–29 (92.4%) years, with a minimum age of 20 years and a maximum age of 42 years. The overall socio-demographic data was relatively similar among both factories (Table 3).

Table 3: Socio-demographic and individual characteristics of aluminium production factory and water bottling factory respondents, 2023 GC

Variable		**Aluminium factory**		**Water bottling factory**			**P-value**
		Frequency	Percent	Frequency	Percent	All (n=408)	
Sex of respondent	Male	182	89.2	163	78	345 (84.6%)	0.23
	Female	22	10.8	41	20.1	63 (15.4%)	
Age-group	20-29	191	94	186	91.2	377 (92.4%)	
	30-39	11	5.4	16	7.8	27 (6.6%)	
	Above 40	2	1	2	1	4 (1%)	0.237
Chronic illness	Yes	5	2.5	2	1	7 (1.7%)	0.419
	No	199	97.5	202	99	401 (98.3%)	
Occupation	Laborer	196	96.1	198	97.1	394 (96.6%)	0.128
	Supervisor	8	3.9	6	2.9	14 (3.4%)	
Educational status	Primary school	21	10.3	35	17.2	56 (13.7%)	0.014
	Secondary school	44	21.6	84	41.1	128 (31.4%)	
	Diploma	123	60.3	81	39.7	204 (50%)	
	University and above	16	7.8	4	2	20 (4.9%)	

Significant p-value ≤ 0.05

5.2: Behavioral and institutional characteristics of respondents

Relatively, cigarette smokers were small in number 8 (2%). About 5 (2.5%) of the aluminium production factory and 3 (1.5%) of the water bottling factory respondents were cigarette smokers. Alcohol users were higher among the aluminium production factory respondents (11.8%) than among the water bottling factory respondents (7.8%).

Water availability was highly accessible in Water bottling factory respondents 187 (91.7%) than in Aluminium production factory participants 25 (12.3%). More than half of the respondents have drunk <3 liters of water (58.8%). Of those, (33.6%) of respondents were from aluminium production factories, and (25.2%) were from water bottling factories. The average water intake of the respondents was 2.47 liters. The training was not given to any of the factory respondents about the health impacts of heat stress and heat-related illness (Table 4).

Table 4: Behavioral and institutional characteristics of aluminium production factory and water bottling factory respondents, 2023 GC

Variable	**Aluminium factory** (n=204)	**Water bottling factory** (n=204)	**All prevalence** (n=408)	**P-value**
Smoking				
Yes	5 (2.5%)	3 (1.5%)	8 (2%)	0.108
No	199 (97.5%)	201 (98.5%)	400 (98%)	
Alcohol				
Yes	24 (11.8%)	16 (7.8%)	40 (9.8%)	0.394
No	180 (88.2%)	188 (92.2%)	368 (90.1%)	
Water Intake				
<3	137 (67.2%)	103 (53%)	240 (58.8%)	.001
≥3	67 (32.8%)	101 (49.5%)	168 (41.2%)	
Water availability				
Yes				
No	25 (12.3%)	187 (91.7%)	212 (52%)	<0.001
	179 (87.7%)	17 (8.3%)	196 (48%)	
Training				
no	204 (100%)	204 (100%)	400 (100%)	
PPE				
Yes	204 (100%)	204 (100%)	400 (100%)	

Significant p-value ≤ 0.05

5.3: Work-related characteristics of respondents

About 108 (52.9%) of aluminium production factory respondents were engaged in heavy physical activity, which is higher than those in water bottling factory participants 70 (34.3%). 77 (37.7%) of the aluminium production factory and 64 (31.4%) of the water bottling factory respondents had ventilation around the working area.

Working around radiant heat was higher in aluminium production factory respondents (80.9%) than in water bottling factory respondents (60.3%). Of the participants, 115 (54.6%) of the aluminium production factory and 137 (67.1%) of the water bottling factory respondents had worked extra hours in addition to normal working hours. 8 (3.9%) of the aluminium production factory and 2 (1%) of the water bottling factory participants had asked permission due to heat when they were working. Extra breaks were never given to respondents who worked in both the aluminium factory and the water bottling factory when there was a high room temperature in the working area (Table 5).

Table 5: Work-related characteristics of aluminium production factory and water bottling factory respondents, 2023 GC

Variable	Aluminium production factory		Water bottling factory		All (N=408)	P-value
	Frequency	Percent	Frequency	Percent		
Ventilation						
Yes	77	37.7	64	31.4	141 (34.6%)	
no	127	62.3	140	68.6	267 (65.4%)	0.039
Extra hour						
Yes	115	56.4	137	67.1	252 (61.8%)	0.019
no	89	43.6	67	32.9	156 (38.2%)	
Type of work						
Light	35	17.2	53	26	88 (21.6%)	
moderate	61	29.9	81	39.7	142 (34.8%)	0.050
heavy	108	52.9	70	34.3	178 (43.6%)	
Permission due to heat						
yes	8	3.9	2	1	10 (2.5%)	
no	196	96.1	202	99	398 (97.5%)	0.081
Heat radiant						
Yes	165	80.9	123	60.3	288 (70.6%)	
no	39	19.1	81	39.7	120 (29.4%)	0.001
Work experience						
<3	103	50.5	74	36.3	177 (43.4%)	
≥3	101	49.5	130	63.7	231 (56.6%)	0.006
Work hour						
=8	204	100	204	100	408 (100%)	
Extra break						
No	204	100	204	100	408 (100%)	

Significant p-value ≤ 0.05

5.4: Prevalence of Heat-Related illness among participants

The prevalence of heat-related illness among aluminium production factory respondents was 174 (85.3%) [95%CI: 79.7-89.9], and 55 (27%) of water bottling factory respondents had heat-related illness with a CI of 95%. The most common heat-related symptom was sweating. Of this, 299 (73.3%) were from the aluminium production factory, and 134 (32.8%) were from the water bottling factory.

From all self-reported heat-related illnesses and symptoms, the prevalence was high in aluminium production factory respondents when compared to water bottling factory respondents. Heat-related symptoms that most of the respondents experienced were sweating 299 (73.3%), thirst 284 (69.6%), and tiredness 228 (55.9%), and the least common heat-related symptoms experienced by respondents were fainting 7 (1.7%), muscle cramp 6 (1.5%), and skin redness 42 (10.3%). The other symptoms were exhaustion (23.5%), dizziness (16.9%), headache (31.6%), nausea/vomiting (16.4%), and an increased heartbeat (33.1%).

Table 6: Self-reported prevalence of HRI symptoms among Aluminium production factory and water bottling factory respondents, 2023 GC

Symptoms	Aluminium factory (N=204)	Water bottling factory (N=204)	All prevalence (N=408)	P-value
Sweating				
Yes	165 (80.9)	134 (65.7%)	299 (73.3%)	<0.001
No	39 (19.1)	70 (34.3%)	109 (26.7%)	
Exhaustion				
Yes	77 (37.7%)	19 (9.3%)	96 (23.5%)	<0.001
No	127 (62.3%)	185 (90.7%)	312 (76.5%)	
Thirst				
Yes	154 (75.5%)	130 (63.7%)	284 (69.6%)	<0.001
No	50 (24.5%)	74 (36.3%)	124 (30.4%)	
Tiredness				
yes	149 (73%)	79 (38.7)	228 (55.9%)	<0.001
no	55 (27%)	125 (61.3%)	180 (44.1%)	
Dizziness				
yes	61 (30%)	8 (3.9%)	69 (16.9%)	<0.001
no	143 (70.1%)	196 (96.1%)	339 (83.1%)	
Headache				
yes	89 (43.6%)	40 (19.6%)	129 (31.6%)	<0.001
no	115 (56.4%)	164 (80.4%)	279 (68.4%)	
Nausea/vomiting				
Yes	49 (24%)	18 (8.8%)	67 (16.4%)	<0.001
no	155 (76%)	186 (91.2%)	341 (83.6%)	
Increase heart beat				
Yes	94 (46.1%)	41 (20.1%)	135 (33.1%)	<0.001
no	110 (53.9%)	163 (79.9%)	273 (66.9%)	
Skin redness				
Yes	35 (17.2%)	7 (3.4%)	42 (10.3%)	<0.001
no	169 (82.8%)	197 (96.6%)	366 (89.7%)	

Significant p-value ≤ 0.05

5.5: Results of Logistic Regression Analysis

5.5.1: Bivariate analysis for respondents' heat-related illness

The result of the bivariate analysis showed that, from socio-demographic and individual factors, age, sex of the respondent, chronic illness, and occupation were not significantly associated with the risk of developing heat-related illness ($P > 0.05$). Group of industry, educational status, and work experience were significantly associated with the risk of developing heat-related illness ($P< 0.05$). From behavioural and work-related factors, water availability, extra hours, ventilation, water intake, clothing, radiant heat, and physical activity were significantly associated with the risk of developing heat-related illness ($P< 0.05$). Smoking, permission due to heat, and alcohol were not significantly associated with the risk of developing heat-related illnesses ($P > 0.05$).

Table 7: Summary of bivariate logistic regression of HRI among study respondents in Aluminium production factory and water bottling factory respondents, 2023 GC

Variables	Categories	Heat-related illness (HRI symptoms ≥ 4)		COR (CI=95%)
		Yes	No	
Sex of respondent	Male	198 (57.4%)	147 (42.6%)	1.39 (0.812-2.38)
	female	31 (49.2%)	32 (50.8%)	1.00
Group of industry	Aluminium factory	174 (85.3%)	30 (14.7%)	15.7 (9.571-25.786)
	Water factory	55 (27%)	149 (73%)	1.00
Age-group	20-29	214 (56.8%)	163 (47.2%)	1.00
	30-39	14 (51.9%)	13 (48.1%)	1.22 (0.558-2.665
	Above 40	1 (25%)	3 (75%)	3.94 (0.406-38.213
Chronic illness	Yes	5 (71.4 %)	2 (28.6%)	1.98 (0.38-10.3)
	No	224 (55.9%)	177 (44.1%)	1.00
Educational status	Primary school	26 (46.4%)	30 (53.6%)	4.62 (1.369-15.555)
	Secondary school	66 (51.6%)	62 (48.4%)	3.76 (1.191-11.857)
	Diploma	121 (59.3%)	83 (40.7%)	2.74 (0.886-8.500)
	University and above	16 (80%)	4 (20%)	1.00
Occupation	Laborer	224 (56.9%)	170 (43.1%)	2.37 (0.781-7.206)
	Supervisor	5 (35.7%)	9 (64.3%)	1.00
Alcohol	Yes	25 (62.5%)	15 (37.5%)	1.34 (0.68-2.62)
	No	204 (55.4%)	164 (44.6%)	1.00
Water Intake	<3	169 (70.4%)	71 (29.6%)	4.29 (2.815-6.521)
	≥3	60 (35.7%)	108 (64.3%)	1.00
Ventilation	Yes	89 (63.1%)	52 (36.9%)	1.55 (1.022-6.521)
	No	140 (52.4 %)	127 (47.6%)	1.00
Extra hour	Yes	99 (63.5%)	57 (36.5%)	1.63 (1.08-2.45)
	No	130 (51.6%)	122 (48.4%)	1.00
Type of work	Light	52 (59.1%)	36 (40.9%)	1.00
	Moderate	65 (45.8 %)	77 (54.2%)	1.71 (0.999-2.931)
	Heavy	112 (62.9%)	66 (37.1%)	0.85 (0.505-1.435)
Heat radiant	Yes	184 (63.9%)	104 (36.1%)	2.95 (1.897-4.583)
	No	45 (37.5%)	75 (62.5%)	1.00
Smoking	Yes	7 (87.5%)	1 (12.5%)	5.61 (0.684-46.042)
	No	222 (55.5%)	178 (44.5%)	1.00

Significant p-value ≤ 0.05, 1.00 = reference value.

5.5.2: Multivariate logistic regression

The result from multivariate logistic regression showed groups of industry, water availability, occupation, clothing, and water intake were statistically significant (p-value<0.05).

Workers in aluminium production factories had nine times (AOR, CI = 95%, 9.98 (4.16-23.954)) higher odds of developing heat-related illness than the water bottling factory workers. Workers with a water intake of <3 liters have five times (AOR, CI= 95%, 5.08(2.786- 9.265)) odds of developing heat-related illness than workers who drank ≥3 liters of water. Workers who dressed in breathable cotton were 0.25 times (AOR, CI = 95%, 0.25 (0.14–0.459)) less likely to develop heat-related illness compared to participants dressed in thick cotton overall. Smokers have four times (AOR, CI = 95%, 4.12 (0.415–40.91)) higher odds of developing heat-related illness than non-smokers.

Being production labourers increases the odds of developing heat-related illness thirteen times (AOR, CI= 95%, 13.7 (1.974–94.65)) than supervisors. Workers who engaged in heavy physical activity were 1.7 (AOR, CI= 95%, 1.74 (0.806-3.738)) times more likely to develop heat-related illness than workers engaged in light physical activity; those workers engaged in moderate physical activity were 0.6 times (AOR, CI= 95%, 0.61 (0.313-1.172)) less likely to develop heat-related illness as compared to workers who engaged in light work.

Participants who work near radiant heat were 1.8 times more likely to develop heat-related illnesses as compared to participants who work far from radiant heat. Workers with ≥ 3 years' work experience had 1.4 times higher odds of developing heat-related illness (AOR, 95% CI, 1.43 (0.793–2.582)) than workers whose work experience was <3 years. Workers who access enough water were 0.4 times less likely to develop heat-related illness (AOR, 95% CI, 0.4 (0.175–0.917)) as compared to workers who don't access enough water. Workers who took permission due to heat had two times the odds of developing heat-related illness (2.65 (0.173–40.561)) as compared to workers who didn't take permission due to heat (Table 8).

Table 8: Summary of multivariate logistic regression of HRI among study respondents in Aluminium production factory and water bottling factory respondents, 2023 GC

Variables	**Categories**	**Heat-related illness (HRI symptoms ≥ 4)**		**COR (CI=95%)**	**AOR (CI=95%)**
		Yes	No		
Group of industry	Aluminium factory	174 (85.3%)	30 (14.7%)	15.7 (9.571-25.786)	9.98 (4.16-23.954)
	Water factory	55 (27%)	149 (73%)	1.00	1.00
Educational status	Primary	26 (46.4%)	30 (53.6%)	4.62 (1.369-15.555)	0.144 (0.018-1.163)
	Secondary	66 (51.6%)	62 (48.4%)	3.76 (1.191-11.857)	0.249 (0.034-1.839)
	Diploma	121 (59.3%)	83 (40.7%)	2.74 (0.886-8.500)	0.166 (0.023-1.173)
	University and above	16 (80%)	4 (20%)	1.00	1.00
Occupation	Laborer	224 (56.9%)	170 (43.1%)	2.37 (0.781-7.206)	13.7 (1.974-94.65)
	Supervisor	5 (35.7%)	9 (64.3%)	1.00	1.00
Water Intake	<3	169 (70.4%)	71 (29.6%)	4.29(2.815-6.521)	5.08 (2.786- 9.265)
	≥3	60 (35.7%)	108 (64.3%)	1.00	1.00
Ventilation	Yes	89 (63.1%)	52 (36.9%)	1.55 (1.022-2.358)	1.33 (0.719- 2.469)
	No	140 (52.4%)	127 (47.6%)	1.00	1.00
Extra hour	Yes	99 (63.5%)	57 (36.5%)	1.63 (1.083-2.453)	2.128 (0.524-4.621)
	No	130 (51.6%)	122 (48.4%)	1.00	1.00
Physical activity	Light	52 (59.1%)	36 (40.9%)	1.00	1.00
	Moderate	65 (45.8 %)	77 (54.2%)	1.71 (0.999-2.931)	0.61 (0.31-1.17)
	Heavy	112 (62.9%)	66 (37.1%)	0.85 (0.505-1.435)	1.74 (0.81-3.74)
Permission due to heat	Yes	9 (90%)	1 (10%)	7.28 (0.914-58.020)	2.65 (0.173-40.561)
	No	220 (55.3%)	178 (44.7%)	1.00	1.00
Heat radiant	Yes	184 (63.9%)	104 (36.1%)	2.95 (1.897-4.583)	1.88 (0.98-3.61)
	No	45 (37.5%)	75 (62.5%)	1.00	1.00
Work experience	≥3	113 (63.8%)	64 (36.2%)	1.75 (1.173-2.613)	1.43 (0.793-2.582)
	<3	116 (50.2%)	115 (49.8%)	1.00	1.00
Water availability	Yes	62 (29.2%)	150 (70.8%)	0.072 (0.044-0.118)	0.4 (0.175-0.917)
	No	167 (85.2%)	29 (14.8%)	1.00	1.00
Smoking	Yes	7 (87.5%)	1 (12.5%)	5.6 (0.684-46.042)	4.12 (0.415- 40.91)
	No	222 (55.5%)	178 (44.5%)	1.00	1.00

Significant p-value ≤ 0.05, 1.00 = reference value.

Table 9: Summary of multivariate logistic regression of significantly associated with HRI among study respondents in Aluminium factory and water bottling factory respondents, 2023 GC

Variables	**Categories**	**Heat-related illness (HRI symptoms ≥ 4)**		**COR (CI=95%)**	**AOR (CI=95%)**
		Yes	No		
Group of industry	Aluminium factory	174 (85.3%)	30 (14.7%)	15.7 (9.57-25.78)	9.98 (4.16-23.954)
	Water factory	55 (27%)	149 (73%)	1.00	1.00
Water availability	Yes	62 (29.2%)	150 (70.8%)	0.072 (0.044-0.118)	0.4 (0.175-0.917)
	No	167 (85.2%)	29 (14.8%)	1.00	1.00
Occupation	Laborer	224 (56.9%)	170 (43.1%)	2.37 (0.781-7.206)	13.7 (1.974- 94.65)
	Supervisor	5 (35.7%)	9 (64.3%)	1.00	1.00
Clothing	Breathable cotton	78 (39.8%)	118 (60.2%)	1.00	0.25 (0.14 -0.459)
	Thick cotton overall	151 (71.2%)	61 (28.8%)	3.75 (2.479-5.657)	1.00
Water Intake	<3	169 (70.4%)	71 (29.6%)	4.29 (2.815-6.521)	5.08 (2.786- 9.265)
	≥3	60 (35.7%)	108 (64.3%)	1.00	1.00

Significant p-value ≤ 0.05, 1.00 = reference value.

5.6: Heat stress level

The TWA WBGT was measured in both factories with an instrument of MICROTHERM heat stress WBGT. The maximum and minimum TWA WBGT in the aluminium production factory was 32.8 ºC and 23.9 ºC, respectively. In the water bottling factory, the maximum and minimum TWA WBGT was 24.3 ºC and 20.7 ºC, respectively. The average TWA WBGT in the aluminium production factory was 31.8 ºC, whereas in the water bottling factory it was 22.1 ºC. The overall result shows a big difference in WBGT value between the two factories. This is due to the fact that in the aluminium production factory there was heat radiant like a melting furnace, unlike that of the water bottling factory.

Table 10: the result of MICROTHERM heat stress WBGT heat stress level among aluminum production factory and water bottling factory, May 2023 GC

	WBGT TWA (℃)			**Ta (℃)**			**Tnw (℃)**			**Tg (℃)**			**RH (%)**		
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Aluminium factory	32.8	23.9	31.8	47.1	24.3	35.3	28.7	18.1	22.7	51.3	24.3	39.3	48.3%	21.1%	31.8%
Water factory	24.3	20.7	22.1	29.3	22.9	26	25.4	18.7	20.7	30	23.2	26.5	67%	50%	60.1%

5.7: Findings of Observation

Observation was done by using the standard checklist in each working area of the aluminium production factory and water bottling factory. Most of the workers in the aluminium production factory were engaged in heavy physical activity, and most of the workers performed their activity near radiant heat; unlike this, most of the workers in the water bottling factory engaged in light and moderate work.

Concerning workplace ventilation, the aluminium production factory working area was relatively well-ventilated and a smoke sucker was available, but it was not functional. An artificial ventilation system was installed in three working areas. In the water bottling factory, workers only around the door opening were ventilated, and there was no artificial ventilation system. This was due to minimizing the microbial contamination from the dust as it is a soft drink production factory.

Adequate water access for drink and showers was available for almost all workers in the water bottling factory, and it was available for twenty-four hours (24 hours), whereas in the aluminium production factory there wasn't adequate water access for drink and showers as compared to the water bottling factory, and some of the workers used to drink water by bringing water from home.

Workers in an aluminium production factory dressed in full-body suit workwear. The majority of workwear was thick cotton overall, and all workers wore thick gloves. In the water bottling factory, workers also dressed in full-body suit workwear, which was breathable cotton for most workers. All workers in the water bottling factory covered their hair with light cotton.

Figure 5: work process in Secondary aluminium factory, Debre Berhan, 2023 GC

6: Discussion

The result of this study showed that respondents from aluminium production factories had a significantly higher prevalence of heat-related illness and HRI symptoms (85.3%) than water bottling factory workers (27%). This result was supported by a previous study conducted in Ethiopia on steel mill industry workers with a prevalence of heat-related illness (83.90%) **(9)**. It is also consistent with a study done in India on a steel factory where the prevalence of heat-related illness among the workers was (96%) **(35).**

From heat-related illness symptoms, in an aluminium factory, most participants experienced sweating (80.9%), followed by thirst (75.5%), tiredness (73%), and an increased heartbeat (46.1%). The least common symptoms were muscle cramps (2%) and fainting (2%). In the water bottling factory, most of the respondents reported sweating (65.7%), thirst (63.7%), tiredness (38.7%), and headaches (19.6%). The least common symptoms were muscle cramps (1%) and fainting (1.5%). The result from another study found that the prevalence of heat-related illness symptoms among sugar factory workers was sweating (98.3%), exhaustion (96%), and tiredness (84.5%), with the least common symptoms of muscle cramps (12%) and nausea/vomiting (27%) **(21)**. The reason behind this might be that most of the participants in the aluminium factory were exposed to high environmental temperatures for a longer duration, as most of them were worked near the furnace with a WBGTTWA of 31.8 ^{o}C and engaged in heavy type of work as compared with the water bottling factory. In addition, training related to occupational health and safety was not given, and adequate water was not available for most of the participants as compared to the water bottling factory.

Being a worker in an aluminium production factory increases the odds of developing heat-related illness nine times (AOR, CI= 95%, 9.98 (4.16-23.954)) than workers in a water bottling factory. This result was comparable to a study from South Australia that found that during heat wave periods, the odds of occupational heat-related illness were about 4–7 times higher than those during non-heat wave periods **(46)**. Another study found that working in a steel factory (exposed) increases the odds of developing HRI by six times (AOR, CI = 95%, 6.026 (0.784–59.113)) as compared to the non-exposed group **(9, 40)**.

According to OSHA (Occupational Safety and Health Administration), workers' physical activity was classified as light, moderate, and heavy **(47).** The result of this finding showed 52.9% and 29.9% of aluminium factory workers were engaged in heavy and moderate work types, respectively. The finding showed the type of work is significantly associated with heat-related illness. Workers engaged in heavy physical activity had 1.7 times (AOR, CI = 95%, 1.74 (0.806–3.738)) increased odds of developing heat-related illness than workers engaged in light physical activity. Another study also found supportive results (AOR, CI=95%, 10.279 (2.083–50.715)) **(9, 41).**

According to NIOSH (National Institute for Occupational Safety and Health), the recommended fluid intake is 5.7–9.5 liters per day. From this study, the average water intake was 2.3 and 2.6 among aluminium factory and water bottling factory workers, respectively, which is below the recommended fluid intake. The majority of respondents in the aluminium factory reported drinking less than 3 liters of water (67.2%). Another study found that participants reported drinking three liters of water daily (42.4%), and only 19.7% of the workers drink around five-liters of water daily; this was higher in the amount of water consumed as compared to this study **(21)**. Workers with a water intake of <3 liters have five times (AOR, CI = 95%, 5.08 (2.786–9.265)) higher odds of developing heat-related illness than workers who drink ≥3 liters of water. Similar results were also found in different studies **(9, 48)**. In this study, sex was not significantly associated with heat-related illness (P-value >0.05), but in other studies, being female was found to be a potential risk factor for heat-related illness. This was due to females having demonstrated more blunted thermoregulatory responses than males, resulting in higher body temperatures while performing similar work **(49)**.

Clothing affects air circulation over the skin as well as evaporative cooling and moisture regulation. Breathable clothing allows hot air to escape through the garment, minimizing the rise in skin temperature and keeping the wearer cooler. The National Institute for Occupational Safety and Health (NIOSH) recommends the clothing should be light and loosely fitted to the body to facilitate convective and evaporative heat exchange and better reflect solar radiation, whereas in this study, only 48% of participants dressed in breathable cotton among aluminium factory and water bottling factory participants. Similar results also found that nearly 50% of the workers wear thick cotton overall **(21)**. In this study, workers dressed in thick cotton overall had three times (CI = 95%, AOR = 3.75 (2.479–5.657)) higher odds of developing heat-related illnesses than workers dressed in breathable cotton. Participants dressed with clo> 1 have four times higher odds of developing HRI (CI = 95%, AOR: 4.743 (1.696–13.264)) **(9)**. A study found that weight and movement restrictions imposed by protective clothing and equipment can lead to increased muscle work and metabolic heat production **(50)**.

The majority of the participants work extra hours (more than 8 hours) in both the aluminium factory and the water bottling factory. Respondents who work extra hours have 2 times (CI = 95%, AOR = 2.128 (0.524-4.621)) higher odds of developing heat-related illness than workers who don't work extra hours. This result is consistent with a study that found participants working extra hours are at risk of experiencing HRI (CI = 95%, AOR: 4.019 (1.57–10.288)) **(9)**. In this study, age, smoking, and alcohol use were not significantly associated with the risk of HRI. Contrary to this, another study found that being old increases the risk of developing a heat-related illness **(51)**.

The result from this study found that the average TWA WBGT temperature in the aluminium factory was 31.8°C and the average TWA WBGT temperature in a water bottling factory was 22.1 °C, whereas the permissible heat exposure threshold limit values (TLVs) in wet bulb globe temperature (WBGT) TWA and ACGIH recommend that the metabolic heat for continuous light work is 30 °C, moderate work is 26.7 °C, and heavy work is 25 °C. whereas for 75% of work and 25% rest each hour, the metabolic heat for light work is 30.6°C, moderate work is 28 °C, and for heavy work is 25.9°C **(52)**. Aluminium factory workers were exposed above the threshold limit values (TLVs) of TWA WBGT, as 82.8 % of aluminium factory workers were engaged in a heavy and moderate workload at 31.8°C, but water factory workers were exposed below the threshold limit values (TLVs) of TWA WBGT at 22.1 °C. A similar result was found from a study conducted in a steel factory: the WBGT TWA was 27.49 °C in the smelting station **(53).** OSHA recommends humidity control in the range of 20%–60% **(54)**, Whereas in this study, the average humidity was 31.8% and 60.1% among aluminium factories and water bottling factories, respectively. The humidity in the water bottling factory was a little higher than recommended by OSHA.

7. Strengths and Limitations of the Study

Strengths

- The working environment's heat was measured, and environmental observational checklist methods were used in addition to the questionnaire.
- Use of an instrument to measure heat stress level
- Using a comparative study

Limitations

1. As all heat-related illness symptoms were self-reported by the participant, there might be recall bias.
2. It is difficult to generalize the results to the general population in the metal industry because the research was conducted in only two factories.
3. The measurement and data collection were done in the rainy season (Ethiopian summer); this might lower the measured value of WBGT. To know the accurate exposure of workers, it should be done in the hot season.
4. Unable to measure outdoor WBGT measurement because of the difficulty accessing the device due to having only one measuring device.
5. The two factories located in different geographic location, this may change weather level.

8. Conclusion

- The result of this study showed a higher prevalence of heat-related illness (85.3%), among aluminium factory workers than water bottling factory workers (27%), with CI of 95%. The prevalence of HRI symptoms was high in aluminium production factories. Sweating was the most commonly reported HRI symptom among workers in aluminium factories (80.9%) and water bottling factory workers (65.7%).
- Appropriate precautions and training related to heat-related illness and HRI symptoms were not provided to the workers in both factories. Group of industry, water availability, occupation, clothing, water intake, working extra hours, and ventilation have significant associations with a heat-related illness (p-value<0.05).
- The average WBGT heat stress level (31.8 ºC) of the working environment temperature in the aluminium production factory was above the recommended value (25 ºC), whereas in the water bottling factory the WBGT heat stress level was 22.1 ºC, which is below the recommended value.

9. Recommendation

Depending on the result of this study, some important recommendations are given to the Ministry of Labour and Skills, the Aluminium Factory, and the workers.

Ministry of Labor and Skill (MOLS):-

- Regular health and safety inspection and monitoring programs.
- Provide guidelines, regulations, and limitations on the work area. heat stress levels to minimize the risks of workers' exposure.
- Monitor the presence of appropriate coping mechanisms and access to medical services when needed.

Aluminium Factory:-

- Provide sufficient rest breaks in cool locations at the workplace.
- Water for drinking and showering should be accessible to every worker at the workplace.
- Provide training to create awareness about heat-related illness and HRI symptoms, and coping mechanisms among the workers.
- Minimize heavy work by replacing modern machines rather than using manual force.

Workers:-

- Drink cold water between works.
- Take a break or rest in a cool place.
- Use personal protective devices properly.

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11. ANNEX

Annex 1 - Dummy tables

Table1: General information and behavioral characteristicsofproduction workers among Secondary Aluminium production Factory and Alpha water bottling factory, 2023.

		Aluminum factory		Water bottling factory		
Variable	Categories	Frequency	Percent (%)	Frequency	Percent (%)	p-value
Sex	Male					
	Female					
Age group	20-30					
	30-40					
	40-50					
	Above 50					
Educational status	Illiterate					
	Primary					
	Secondary					
	Higher/college					
	University/above					
Work section						
Smoking	Smoker					
	Non-smoker					
	Ex-smoker					
Consuming alcohol	Yes					
	No					
	Ex- drink					
Any existing	Diabetes					

illness	Hypertension					
	Respiratory illness					
	Other__					

Table2: Self-reported prevalence of HRI symptoms among study participants in Secondary Aluminium production Factory and Alpha water bottling factory, 2023.

		Aluminum factory		Water bottling factory	
Symptoms	Categories	Frequency	Percent (%)	Frequency	Percent (%)
Sweating	Yes				
	No				
Exhaustion	Yes				
	No				
Thirst	Yes				
	No				
Muscle cramps	Yes				
	No				
Headache	Yes				
	No				
Tiredness	Yes				
	No				
Dizziness	Yes				
	No				
Nausea/Vomiting	Yes				
	No				
Increase	Yes				

heartbeat	No				
Skin, neck and cheat redness	Yes				
	No				
Fainting	Yes				
	No				
Other					

Table3. Bivariate logistic regression of HRI among study participants in Secondary Aluminium production Factory and Alpha water bottling factory, 2023.

Variable	Categories	Heat illness symptom >=4 Yes	No	COR (95%)	P- value
Factory group	Exposed group				
	Non-exposed group				
Age group	20-30				
	30-40				
	40-50				
	Above 50				
Sex	Male				
	Female				
Educational status	Illiterate				
	Primary				
	Secondary				
	college				
	University and above				
Work					

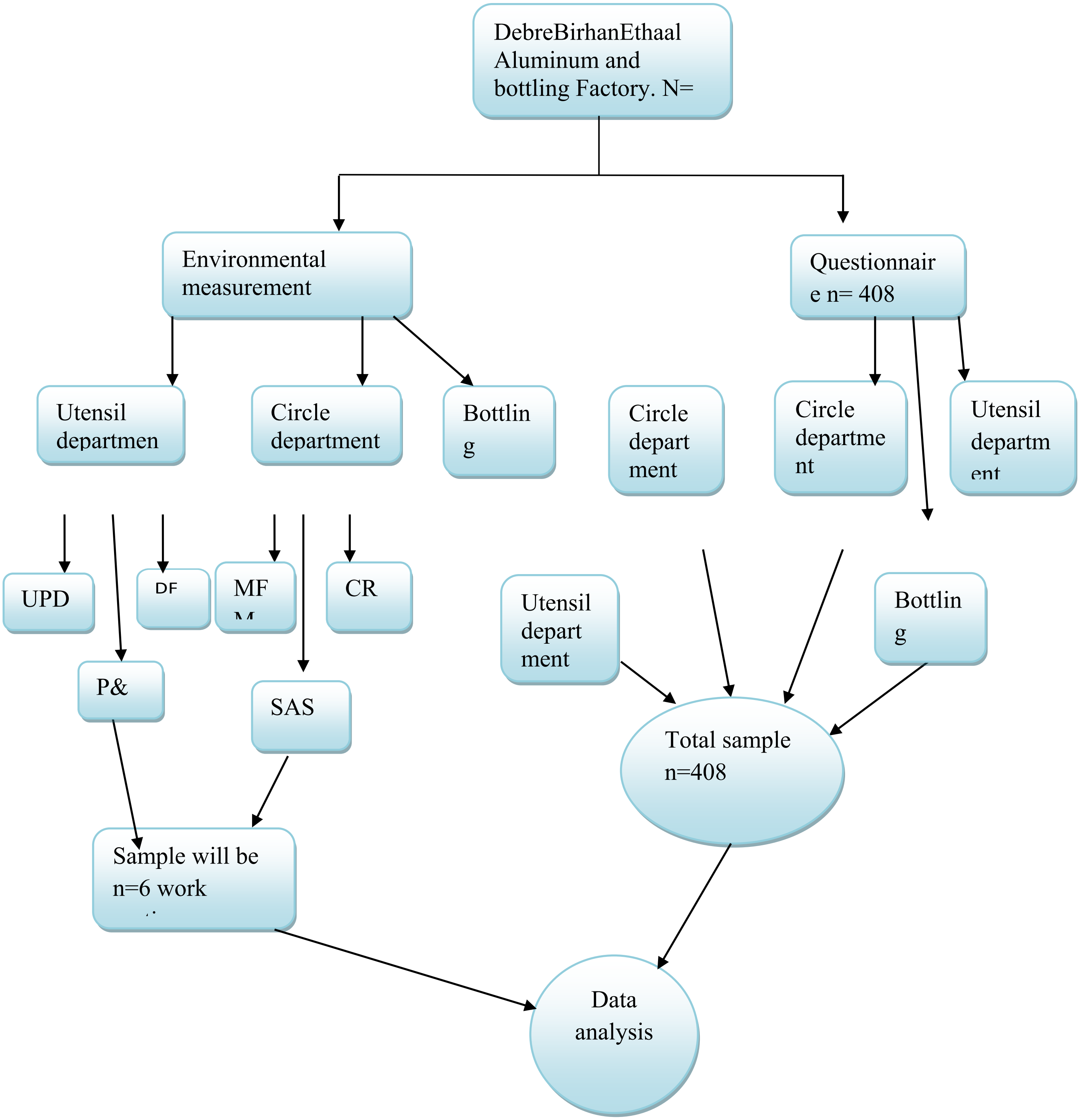
department					
Medical illness	Yes				
	No				
Alcohol	Yes				
	No				
	Ex-smoker				
Smoking	Yes				
	No				
	Ex-smoker				
Physical activity	Light				
	Moderate				
	Heavy				

Table4. Multivariate logistic regression analysis of factors associated with HRI among study participants in Secondary Aluminium production Factory and water bottling factories, 2023.

Variable	Categories	Heat illness symptom >=4		COR (95%)	AOR (CI=95%)	P- value
		Yes	No			
Factory group	Exposed group					
	Non-exposed group					
Working hour/day	< 8 hour					
	9 hour and above					
Extra working hours	Yes					
	No					
PPE	Yes					
	No					

Age group	20-30					
	30-40					
	40-50					
	Above 50					
Sex	Male					
	Female					
Educational status	Illiterate					
	Primary					
	Secondary					
	college					
	University and above					
Work department						
Medical illness	Yes					
	No					
Alcohol	Yes					
	No					
	Ex-smoker					
Smoking	Yes					
	No					
	Ex-smoker					
Physical activity	Light					
	Moderate					
	Heavy					

Annex 2. Data collection procedure



Annex 3. Stratified sample size determination, 2023.

No	Department	Work section	Total number of workers		Proportionate sampling	Sample
1	Primary department	Raw material sorting and grinding.	27			
2	Circle department	Melting furnace and moulding	68	$\frac{68}{149} \times 67= 31$	$\frac{149}{454} \times 204 = 67$	67
		Cold rolling	27	$\frac{27}{149} \times 67= 12$		
		Sizing aluminium sheet	54	$\frac{54}{149} \times 67= 24$		
3	Utensil department	Utensil polishing	33	$\frac{33}{305} \times 137= 15$	$\frac{305}{454} \times 204 = 137$	137
		Dross furnace	56	$\frac{56}{305} \times 137= 25$		
		Pressing and kittle	216	$\frac{216}{305} \times 137= 97$		
4	Finishing department	Packing	23			
5	Maintenance department	Technical and quality control and others	75			
total			579			
6	one bottling factory					204
total						408

Annex4.Information Sheet and Consent Form in English Version

Information Sheet

Assessment of Occupational Heat Stress, Heat Related Illness and Associated Factors among Workers in Secondary Aluminium production Factory in DebreBerhan City, Ethiopia

Assessment of Occupational Heat Stress, Heat-Related Illness and Associated Factors among Workers in Secondary Aluminium production Factory in DebreBerhan City, Ethiopia

Study Aims. The study aims to assess heat stress, the health impact of heat stress and associated factors. The assessment of the prevalence of heat-related illness, heat stress level and associated factors among Secondary Aluminium production Factory workers. In our country employees who are working in different industries are exposed to the negative effect of heat which is not studied very well. The study will help identify heat stress at work and any health effects of working in a heat-stress environment. Looking at how workplaces manage heat and minimize occupational exposure during hot environmental conditions.

Activities: heat stress level was measured to get an idea of the working environment to which workers are exposed. Each interview will take 15-20 minutes and is fully voluntary with participants within these workplaces. Participation, as mentioned above is completely voluntary and participants may choose to withdraw at any time. Refusal to participate will not impair any existing relationships between the participants and institutions or people involved.

Risks associated with the study: There is no risk or serious invasive procedure at the beginning as well as at the end of the study and there is no additional time required from you to stay during the study.

Benefits of the study: There will be no financial or other direct benefits to you. But the result of the study will play a role in the control program.

Use of information: The information collected from any participants will not be made available to other participants. The response from all the interviews will be de-identified and aggregated into a report. Your organization's idea on heat stress and workplace issues will be respectfully and accurately portrayed. There will also be a draft of the paper sent out to your organization for proofing before the final document is presented.

Confidentiality of your information: Confidentiality is one of the main priorities. The results of the findings will be kept confidential and could only be accessed by the researcher and the responsible physician. There wil be no personal information to be attached to your data.

Questions: If you have any queries, questions or concerns about the research please feel free to contact Genet Walle, by phone number- 251948158962, email- genetwalle22@gmail.com.

Consent form

Name of industry____________________ Name of the department ____________________

Name of the working section____

Greeting

How are you? My name is ___________________ I come from Addis Ababa Universityandam here to collect information for the study. I have a few questionnaires which will generally assess general information, heat-related and heat related illness symptoms of the participants. This will help us to improve occupational safety, health and working environment services provided to you based on your answer to our questions. Your name will not be written in this form and will never be used in connection with any information you tell us. All information given by you will be kept strictly confidential. Your participation is voluntary and you are not obliged to answer any question you do not wish to answer. As a chance you are one of the possible participants that we come across. After hearing the following general things about the study if you are willing, we will proceed with interviewing. Do I have your permission to continue?

1. If yes, continue to the next page

2. If no, skip to the next participant by writing reasons for his/ her refusal

Informed consent Certified by

Interviewer: Code_____________ Name__________________________ signature________

Date of interview____________ Time started___________ Time completed________

Result of interview: 1. Completed 2. Respondent not available 3. Refused 4. Partially completed

Checked by Supervisor: Name___________________ signature___________ Date_______

For any inconvenience or problem, you can contact the principal investigator.
Genet Walle, phone number- 251948158962, email- genetwalle22@gmail.com.

Annex5. Questionnaire in English Version
Addis Ababa University College of Health Science School 0f Public Health Department of Preventive Medicine Environmental and Occupational Health Unit.

The questionnaire is developed to assess occupational heat stress and Heat Related Illness among Workers in Secondary Aluminium production Factory and bottling factory.

Quantitative Questionnaire

1. ID No: _______________
2. Date of interview: ___________________
3. Name of the interviewer: _____________________
4. Code of the industry: _________________________

Part 1:General information about person interviewed			
Number	Question	Response	
1	Age		
2	Age group	1. 20-30 2. 30-40 3. 40-50 4. 50 and above	
3	Sex	1. Male 2. Female	

4	Educational status	1. Do not attend formal education 2. Primary 3. Secondary 4. Higher /college/ 5. University and above	
5	Designation	1. Worker 2. Supervisory 3. Manager	
6	Smoking	1. Smoker 2. Non-Smoker 3. Ex-smoker	
7	Consuming alcohol	1. Yes 2. No 3. Ex	
8	Any existing illness	1. Diabetes 2. Hypertension 3. Respiratory illness, specify __________ 4. Others, specify__________	
Part 2: Questions concerning the type of work			
1	Type of work	1. Light 2. Moderate 3. Heavy 4. Very Heavy	
2	What were your previous job and where (relating to temp)?	__________	
3	How long you are employed here?	_____________years/months (more than 6months means acclimatized)	
4	How many hours per day do you usually work excluding regular break timings?	__________	
5	When and how long are the regular breaks?	_____________________	

6	Do you work near a direct heat source(naked flame/hot air/outdoors/radiant heat)	1. Yes 2. No	
7	Is the place you work well ventilated?	1. Yes 2. No	
8	Do you have additional breaks during hot season?	1. Yes 2. No	
9	If yes for question ,8	mention no of hours/minutes________	
10	Describe the work that you do	________	
Part 3: Questions in relation to heat exposure at work			
1	Are you comfortable with the workplace temperature?	1. Yes 2. No	
2	What do you feel about temperature now?	A. Hot B. Warm C. slightly warm D. neutral E. slightly cool F. cool	
3	What would you like to be now?	A. cooler B. warmer C. no change	
4	How many months do you feel hot /uncomfortably hot in this workplace?	1. 1-3 months 2. 4-6 months 3. 7-9 months 4. 9-12 months 5. Never	
5	Is sufficient water and showers available at all times when you need it?	1. Yes 2. No	
6	During hot season how much water you drink daily	____	

7	Describe how bad the heat stress can be in the hot season.	a. Extremely bad b. Very bad c. Bad d. Manageable e. No stress at all	
Part 4: Questions concerning impacts of temperature on health			
1	What symptoms do you face when you work in the factory?	1. Sweating□ Yes □ No 2. Exhaustion□ Yes □ No 3. Thirst □ Yes □ No 4. muscle cramps □Yes □No 5.Tiredness/weakness □Yes □No 6. Dizziness□Yes□No 7. Headache□Yes□No 8.nausea or vomiting □Yes □No 9. Fainting□Yes□ No 10. increase heart beat□Yes□ No 11. skin, chest, and neck redness □Yes □ No 12. Others_______________	
2	To achieve production target or complete do you have to work extra hours?	1. Yes 2. No	
Part 5. Questions concerning impacts of heat on worker's productivity			
1	Have you ever taken sick leave/permission due to heat?	1. Yes 2. No	
2	If yes, question 1,	Approx. how many hours in a week?----------------- Month-------------	
3	Have you ever been admitted in hospital/medical centre due to heat related sickness? Yes/No	□1 Yes / □2 No	
4	If yes, question 3,	approximately how many days____	
5	Have you lost any wages due to absenteeism because of heat related illness?	□1 Yes □2 No	
6	If yes, question 5,	how much _____(in birr)	
Part 6: Questions concerning impacts of clothing on heat stress			

1	Dress material of the workers	1. Breathable cotton 2. Thick cotton overall 3. Rayon/Nylon 4. Plastic PPE 5. Others_____	
2	Do you feel hotter with uniform/ Does the Dress Material increase heat stress?	1. Sure 2. Maybe 3. Not sure 4. No, not at all	
3	Have you taken any training concerning Heat stress?	1. Yes 2. No	
4	If yes, question 3,	When? ________	
Part 7: Questions concerning coping mechanisms:			
1	How do you limit heat exposure, when needed?	a. get away for a while b. remove the clothing c. drink water d. any other method, ___	
2	If you are feeling unwell from heat exhaustion how do you cope with this?	.1. take rest 2. cool shower, or sponge bath 3. move to an air-conditioned/cooler environment 4. switch to Light weight clothing 5. drink water 6. any other method,___	
3	What do you recommend to cope with heat stress level?	1. take rest 2.cool shower, or sponge bath 3.move to an air-conditioned/cooler environment 4.switch to Light weight clothing 5.drink water 6.any other method,___	

Thank you for your participation

Annex 6. Amharic Version Information Sheet and Consent Form

አዲስአበባዩኒቨርሲቲጤናሳይንስኮሌጅ

የሕብረተሰብጤናትምህርትክፍል

በደብረብርሀንበሚገኘየአልሙኒየምፋብሪካሰራተኞችላይበሙቀትመጠንምክንያትየሚመጣህመ ምስርጭትእናየሙቀትመጠንለማወቅየሚደረግየዳሰሳጥናት

የሠራተኞችየተሳታፊነትመረጃፎርም

መግቢያ;- ጤናይስጥልኝ።ስሜ ________________________

እባላለሁየመጣሁትወ/ሪትገነትዋለየተባሉትለሁለተኛድግሪመመረቂያየሚሆንጥናታዊፅሁፍበኢታልየአልሙኒየምፋብሪካሰራተኞችላይበሙቀትመጠንምክንያትየሚመጡየጤናችግሮችእናየሙቀትመጠንለማወቅየዳሰሳጥናትመረጃለመሰብሰብነው።ይህንለመስራትደግሞበአ.አ.ዩጤናሳይንስኮሌጅየህብረተሰብት/ትክፍልፍቃድአግኝተዋል።

የጥናቱዓላማ;-

ይህጥናትበስራበታየሙቀትመጠንመጨመርበሠራተኞችጤናላይየሚያስከትለውንጉዳትለመለየትተብሎእየተሰራያለነው።በሀገሪቱውስጥባሉየፋብሪካሠራተኞችበሙቀትአማካኝነትየሚመጡየጤናእናተያያዥችግሮችላይየተደረጉጥናቶችባለመኖራቸውየተነሣይህንጥናትሊደረግአሥበዋል።በመጨረሻምጥናቱሲጠቃለልበሥራበታለይበሙቀትምክንያትየሚደርሱየጤናችግሮችንለመቀነስናለመከላከልየሚያግዙመንገዶችንያመላክታል።

የሚሠሩሥራዎች;-ይህጥናትሰራተኛተጋላጭነትንመረጃለማወቅየሥራበታየሙቀትመለኪያመሣሪያ

(WBGT)

በመጠቀምናሠራተኞችንበመጠየቅይሠበሰባልከእያንዳንዱሰራተኛየግልመረጃናአስፈላጊቃለመጠይቅለማከናወንበአማካይ 15-20ደቂቃሊወስድይችላል።

በጥናቱላይመሳተፍየሚችሉ;-

ተሳትፎመረጃመሰብሰብሙሉለሙሉበፍቃደኝነትላይየተመሰረተነው።ማንምሰውበፈለገግዜማቋረጥይችላል።በሚያቋርጥሰዓትመረጃውአይያዝምየጥናቱምአካልአይሆንም።በጥናቱላይአለመሳተፍበሰራተኛውላይምንምአይነትችግርአያመጣም።

መረጃአጠቃቀም ;-

ይህንመረጃለመሰብሰብየፋብሪካውንሀላፊያስፈቀድንሲሆንእርስዎበፍቃደኝነትለይበመተሰረየሚሠጡኝመ ረጃሚስጥራዊነቱየተጠበቀናለጥናቱብቻየሚውልነው።የግልመረጃዎችንየሚንፀባርቁይህጥናትእንዳለቀእን ደሚሰረዙሆኖነገርግንጥሬሀቆችየጥናቱንማለቅተከትለውቢያንስእስከ 5ዓመትየሚገለግሉይሆናል።ሥለዚህፍቃደኛከሆኑከ15-20 አብረንእንቆያለን።

ጥያቄካለዎት ;-

ማንኛውምሠውበመጠይቁዙሪያጥያቄካለዎአልያምተጨማሪማብራሪያቢያስፈልግዎወ/ሪትገነትዋለንበአካ ልወይምበሥልክቁጥር0948158962 ወይምበኢ-ሜልአድራሻ genetwalle22@gmail.com በማንኛውምጊዜመጠየቅይችላሉ።

የተሳታፊዎችየፍቃደኝነትመጠየቂያቅጽ

የፋብሪካውስም------------------ የዲፓርትመንቱስም---------------- ክፍል-------------------

ጤናይሥጥልኝእኔ--

እባላለሁ።የመጣሁትበአ.አ.ዩየጤናሳይንስኮሌጅለሚደረግጥናትመረጃበመሰብሰብነው።እርሰዎለዚህጥናት ተሳታፊመሆንከሚችሉሰዎችመካከልአንዱሲሆኑከእርስዎጋርየተገናኘነውአስፈላጊነዎትተብሎበተደረገምር ጫነው።የተወሰኑመጥይቆችበማህበራዊ-

በጤናችግርምልክቶችእናየሙቀትሁኔታዳሰሳዙሪያነው።ይህእርስዎየሚሠጡትመረጃበሀገራችንለሚከናወኑ ትየሥራወይምየሙያደህንነትለማሻሻልናለመከላከልከፍተኛእገዛይኖረዋል።የሚሠጡትመረጃሚሥጥራዊነ ቱየተጠበቀነው።ከዚህጥናትጋርበተያያዘበማንኛውምቦታናግዜሥምዎእንደማይፃፍናእንደማይጠቀስልንገል ፅልዎእንወዳለን።በአጠቃላይመጠይቁከ15-20

ደቂቃገደማየሚወስድሲሆንበጥናቱየሚሳተፉትየእርስዎንሙሉፍቃደኝነትስናገኝብቻነው።በመጠይቁሂደት ለመመለስየማይፈልጉትንጥያቄዎችያለመመለስመብትዎየተጠበቀነው።

በጥናቱለመሳተፍፍቃደኛነዎት?

1) አዎ …………. ወደሚቀጥለውይሻገሩ

2) አይደለሁም….. ፍቃደኛያልሆኑበትንምክንያትበመፃፍወደቀጣዩተጠያቂይሽጋገሩ።

የጠያቄመለያቁጥር--------------- ስም------------------- ፊርማ -----------------------

ቀንመጠይቁየተሞላበትቀን----------------------

የተቆጣጣሪስም --------------------------ፊርማ------------------------- ቀን -----------------

ውጤት

1. ተጠቃልሏል 3) ተጠያቂውተቃውመዋል

2. ተጠያቂውአልተገኙም 4) በከፊልተጠናቋል

ማንኛውምማሠረጃለማግኘትአጥኙውንበሚቀጥለውአድራሻማግኘትይቻላል።ገነትዋለበሥልክቁጥር0948 158962 በኢ-ሜልአድራሻ genetwalle22@gmailncom.

Annex 7: Questionaire in Amharic Version

እዝል 1 መጠየቅ፤

1. የመታወቂያቁጥር፡ --------- 2. መጠይቁንየሞላስም፡ -----

3.የተጠየቀበትቀን፡ ---------- 4.የፋብሪካዉስም/ኮድ-----

ክፍል 1 የተሳታፊዎችጥቅልመረጃበተመለከተ			
ተ.ቁ	ጥያቄ	መልስ	ወደ..ሒድ
1	እድሜ		
2	የእድሜክልል	1. ከ20-30 / 2. ከ30-40 3. ከ40-50 4. 50 እናበላይ	
3	ጾታ	1. ወንድ2. ሴት	
4	የትምህርትደረጃ:	1. ያልተማረ2. የመጀመሪያደረጃት/ት3.	

		ሁለተኛደረጃ 4. ኮሌጅ5. ዩንቨርሲቲዕናከዚያበላይ	
5	የስራመደብ:	1. ሰራተኛ 2. ተቆጣጣሪ 3. ሃላፊ	
6	የማጨስባህሪይ:	1. አጨሳለሁ 2. አላጨስም 3. ድሮአጨስነበር	
7	አልኮልየመዉሰድሁኔታ/የመጠጥባ ህሪዎ:	1. እጠጣለሁ 2. አልጠጣም 3. ድሮእጠጣነበር	
8	የጤንነትዎሁኔታ፣ምንአይነትህመ ምአለበት	1. ስኳርህመም 2. የደምግፊትህመም 3. የመተንፈሻአካልህመምግለጽ---------------------, 4. ሊላህመምካለበትይግለጹ፡----	
ክፍል 2 የስራአይነትንየሚመለከቱጥያቄዎች			
1	የስራአይነት:	1. ቀላል 2. መካከለኛ 3. ከባድ 4. በጣምከባድ	
2	የቀድሞስራዎምንነበር፤ሰራቦታስየ ሙቃትሁኔታዉስ ?	__________	
3	እዚህድርጅትከተቀጠሩምንያክልጊ ዜሆነዎት?	_____________አመት/ወር	
4	መደበኛየእረፍትጊዜዎንሳይጨምር በቀንዉስጥለምንያክሌጊዜታመር ታሆህ?	__________	
5	መቼእናለምንያክሌጊዜበመደበኛነ ትታርፋለክ	_____________________	

6	በምትሰራበትቦታቀጥታየሙቀትምንጭአለ(እሳት/ወባቅአየር/ቀጥታፀሃይወዘተ)	1. አዎ 2. የለም	
7	የምትሰራበትቦታበደንብአየርይናፈሳል?	1. አዎ 2. የለም	
8	በሙቀታማወቅትተጨማሪየእረፍትጊዜአዎት?	1. አዎ 2. የለም	
9	ለጥያቄቁ 8 መልስዎአዎከሆነ	ለምንያክሌሰዓት/ ደቂቃነዉ________	
10	የምትሰራዉንስራግልጽአድርግእስኪ	________	
ክፍል 3 ለሙቀትመጋለጥንመሰረትያደረጉጥያቄዎች			
1	በስራቦታክያለዉየአየርሁኔታለአንተአመችነዉ?	1. አዎ 2. አይደለም	
2	በአሁኑ (በዚህ) ሠዓትሙቀቱእንዴትነው?	1) በጣምሞቃት 2) ሞቃት 3) ቀለልያለሙቀት 4) ሙቀትምቅዝቃዜምየለም 5) ቀለልያለቅዝቃዜ 6) በጣምቀዝቃዜ	
3	በአሁኑ (በዚህ) ሠዓትየአካባቢውሙቀትምንእንዲሆንይፈልጋሉ?	1) ቀዝቀዝያለ (እንዲቀዘቅዝ) 2) ሞቅያለ 3) ለውጥአስፈልግም	
4	በስራቦታህበአመትዉስጥለምንያክሌጊዜምቾትሳይሰማክታሳልፋለክ?	1. ለ1-3 ወራት 2. ለ4-6 ወራት 3. ለ7-9 ወራት4. ለ9-12 ወራት 5. ምንምጊዜሙቀትአይሰማኝም	
5	አንተበምትፈልግበትጊዜበቂዉሃእናሻወርታገኛለክ?	1. አዎ2. የለም	

6	በሙቀታማወቅትምንያክልዉሃበቀንትጠጣለክ?	_____	
7	በሞቃታማወቅትየሙቀቱመጠንምንያክልየከፋይሆናልብለህታስባለህ?	a..እጅግበጣምከባድ b. በጣምከባድ c. ከባድ d. መቋቋምየሚቻል e. ምንምሙቀትየለም	
ክፍል 4 የሙቃትተጽኖበጤናላይየሚያስከትለዉችግርየተመለከቱጥያቄዎች			
1	በስራቦታበሙቀትምክንያትምንአይነትስሜት/ህመም/ምሌክት/ ይሰማዎታል?	1. ማላብአዎ /የለም 2. አቅምማነስአዎ/ የለም 3. የዉሃጥምአዎ /የለም5. የጡንቻመሸማቀቅአዎ /የለም 6. ከፍተኛድካምአዎ/ የለም 7. ራስማዞርአዎ / የለም 8. የራስምታትአዎ/የለም 9.ማቅለሽለሽ/ማስመለስአዎ/የለም10. ራስንመሳትአዎ/የለም11. የልብምትመፍጠንአዎ/የለም 12.የቆዳ፤አንገት፤ደረትሽፍታአዎ/የለም 13. ሌላካለይግለጹ_________	
2	የምርትመጠንእቅድለማሳካትአሊያምተጨማሪክፍያለማግኘትተጨማሪሰዓትይሰራሉ?	1. አዎ2. የለም	
ክፍል5 የሙቀትችግርበምርታማነትላይየሚያመጣውንተጽእኖአስመሌክቶየሚጠየቁጥያቄዎች			
1	በሙቀትምክንያትፈቃድጠይቀው /የህመምመውጫጽፈውያውቃሉ	1. አዎ2. የለም	
2	ለጥያቄቁ 1 መሌሰአዎከሆነ	በአማካኝስንትሰአትይሆናልበሰምንት-------በወር----------	
3	በሙቀትምክንያትታመውየህክምናማእከልተኝተውታክመውያውቃሉ	1. አዎ 2. የለም	
4	ለጥያቄቁ 3 መሌሰአዎከሆነ	በአማካኝለስንትያክልቀናትይሆናል_____	

5	ከሙቀትጋርበተያያዘታመውከስራቀርተው በዚህምክንያትደመወዝዎተቆርጦያ ውቃል?	1. አዎ 2. የለም	
6	ለጥያቄቁ 5 መሌሰአዎከሆነ	ምንያክል _____(በብር)	
ክፍል 6 የስራልብስተጽኖእናየሙቀትችግርንአስመልክተዉየሚጠየቁጥያቄዎች			
1	የሰራተኞችየስራልብስምንአይነትነዉ	1. ስስየጥጥልብስ 2. ሙሉወፍራምልብስ 3. የናይለንጨርቅ /ሀርመሰይሌብስ 4. ፒሊስቲክመከሊከያ 5.ሌላአይነትከሆነግለጽ______	
2	የስራጋወንበመጠቀማችሁበስራቦታ ሙቀትይጨምርባችዋል/ የስራጋወንመልበስእንዲሞቃችሁያደ ርጋል	1. በትክክል 2. ሊሆንይችላል 3. እርግጠኛአይደለሁም 4. አያደርግም	
3	የሙቃትተጽኖበጤናላይየሚያስከት ለዉችግርአስተመልክቶስሌጠና/የግ ንዛቤማስጨበጫወስደዉያዉቃሉ	1. አዎ2. የሆም	
4	አወከሆነ	መችነዉየወሰደ_________	
ክፍል 7 ሙቀትንለመከላከልየምንጠቀምበትሂደቶችጋርበተያያዘያሉጥያቄዎች			
1	የሙቀትችግርንለመቋቋምምንቢደረግይመ ከራለ?	a. ለተወሰነሰአትወደውጭበመውጣት b. ልብስበማውለቅ c. ውሃመጠጣት d. ሌላካለይጥቀሱ_______, ___	
2	በሙቀትምክንያትደህንነትየማይሰማዎትከ ሆነአሌያምየሙቀትጭንቅስያጋጥምሙቀ ትንለመቀነስምንይደረጋል	a) በር /መስኮትበመክፈት b)አርቲፊሻልቬንትሌሽንመጠቀም c) ውሃመጠጣት d) ስስልብስበመልበስe) .በቀዝቃዛውሃገላንመታጠብ f)ሌላካለይጠቀስ___	
3	በስራቦታዎያለውንሙቀትለመቀነስ ምንቢደረግይሻላልይላሉ?	a) በር /መስኮትበመክፈት b) አርቲፊሻልቬንትሌሽንመጠቀምc.ውሃመጠጣትdስ	

		ስልብስመልበስe) ሌላካለይጠቀስ_______	

ክፍል 8 ሰዋዊልኪታወች

የሰውነትሙቀት---------(ዲግሪሲልሽየስ)

የልብምት ----------(ምት/ድቂቃ)

ስለተሳተፉከልብአናመሰግናለን::

Annex 8. Observational checklist
Factors to be considered in heat stress assessment in the **factory workers**

1. Department፡--------------- 2. Name of the observer፡-------------
3. Date: --------------------------- 4. Code of the industry፡-------------------------

Activities	**yes**	**No**
Heat-generating Machinery		
Furnaces		
Heat-generating machines		
Welding		
Working at ventilated		
Is the place you work well ventilated?		
Are open doors used to increased air flow		
Are blowers or fans used to increase air flow in poorly ventilated areas?		
Performing heavy manual work		
Are mechanical aids provided or powered lifting machinery used, as appropriate, to minimize physical exertion?		
Is the work reorganized to minimize intensity and pace of bodily movement of workers so far as reasonably practicable		

Are suitable rest breaks		
Provision of drinking water on site		
Is sufficient potable drinking water provided on site?		
Is the drinking water provided at locations within close proximity to all workers?		
Sufficient rest/brake cool room		
Are sufficient showers available at all times when you need it		
Clothing		
Do the workers wear thin and air permeable cloth		
Does your job require the use of heat protective clothing		
do you use personal protective equipment during working?		
Gauntlet gloves		
Face shield		
Google		
Are there necessary precautions		
(e.g. providing cooling vests) adopted at workplaces with a higher risk of heat stroke (e.g. in poorly ventilated places with hot machinery in use Posters		