Impact of Occupational Heat on the Comfort of Factory Workers: A Case Study of Kambaa, Ikumbi and Mungania Tea Factories

Nderitu David Muchemi

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DECLARATION

This thesis is my original work and has not been presented for a degree in any University.

Signature.. Date..

Muchemi David Nderitu

This thesis has been submitted for examination with our approval as University supervisors.

Signature.. Date..

Dr. Ciira Kiiyukia

JKUAT, Kenya

Signature.. Date..

Mr. Charles Mburu

JKUAT, Kenya

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LIST OF ACRONYMS AND ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienist
BMI	Body Mass Index
C	Convection
^{o}C	Degree Celsius
CBT	Core Body Temperature
CET	Corrected Effective Temperature
CDC	Centre for Disease Control
CFU	Continuous Fermentation Unit
CTC	Cutting, Tearing and Curling
DOHSS	Directorate of Occupational Health and Safety Services
ETCR	Effective Temperature Corrected for Radiation
ETI	Effective Temperature Index
FDS	Factory Door Sales
GDP	Gross Domestic Product
HSE	Health and Safety Executive
HSI	Heat Stress Index
ILO	International Labour Office
KG	Kilograms
KTDA	Kenya Tea Development Agency Ltd.
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration

PPE	Personal Protective Equipment
P4SR	Predicted 4-Hour Sweat Rate
R	Radiation
SCDA	Special Crops Development Authority
TLV	Threshold Limit Value
VO_2 Max	Maximum Oxygen Uptake
WBGTI	Wet Bulb Globe Temperature Index
WHO	World Health Organization
IK	Ikumbi
KA	Kambaa
MU	Mungania

ABSTRACT

The study was conducted to establish the impact of workplace heat on workers' comfort in tea factories and was a case study of small scale tea producers in Kenya. The objectives of the study were to assess Wet Bulb Globe Temperature Index (WBGTI) at the work environment which is the most widely used index to measure indoor temperatures. Personal factors that influenced the behavior of employees within the indoor environment were also established. These factors were employees' clothing and physical demand of work that influence their behavior at work. This was achieved by determining four variables that influenced the degree of indoor temperature. The variables were air temperature, radiant temperature, relative humidity and air flow. The two thermal factors measured were used to obtain Wet Bulb Globe Temperature Index which indicated the level of indoor thermal comfort. The WBGT value was then compared to the reference value provided in the international standard. Questionnaires were administered to selected target population in the factories in order to compare and support the study variables with the outcome of the actual measurements. The result for the three factories under study indicated that the WBGTI in three departments exceeded the permissible heat exposure threshold level as provided by the American Conference of Governmental Industrial Hygienist (ACGIH) and Occupational Safety and Health Administration (OSHA) standards for the hot indoor environments. The research concluded that employees working in the boiler, drying, packing/sorting sections in the tea factories were exposed to heat discomfort.

CHAPTER ONE

LITERATURE REVIEW

1.1 Introduction

As industry developed, through industrial revolution to our present highly technological society on- the-job, potential for injury and illness from acute exposure to heat has increased far beyond that known earlier to home-centred craftsmen (Levy *et al.,* 2005). Among the more dangerous original industrial vacations were those using molted materials, such as glass and metal. In these first “hot industry”, the hazards resulting from burns, explosions and spills of molten materials were well known and accepted as were potential illness and death from very hard physical work in excessively hot environments. The traditional hot work industries (such as foundries, smelting, fire fighting, military, mining, construction, utilities, glass working, tyre, rubber, and textile industry worker) are being augmented by industries at even greater risk. Knowledge of the process involved in the exchange of heat between the worker and the environment and the effects of heat can reduce the potential adverse effects of heat exposure (Health Sci. Eng, 2008).

There are an estimated 5 to 10 million workers in industries where heat stress is a potential safety and health hazard. Statistics indicates that from 1992-2002, exposure to environmental heat killed 291workers in the United States and contact with hot objects killed an additional 141 workers. On average approximately 4000, people die each year in United States from exposure to excessive heat in work, home and community settings (Krake, 2006). Heat related occupational illness, injuries and strain occur in any situation where total heat load (environmental heat plus heat generated by the body's metabolism) exceeds the capacity of the body to maintain normal bodily functions. Situations that have increased potential for causing heat strain include high ambient air temperatures, radiant heat sources (such as the sun, oven, driers, boilers, foundry, furnaces) direct physical contact with hot objects, high humidity and strenuous physical activity. A hot humid environment, which impedes evaporative cooling combined with heavy work activity, pose the highest risk for workers because the metabolic load placed on the body generates even more heat (Work Safe Albert, 2006).

1.2 Occupational Heat Exposure

1.2.1 Effects of occupational high-heat exposure

The climate of tea growing areas is often cold and wet, therefore temperatures at the work environment are relatively cool. However, with the changes on global temperatures, most of these areas are becoming hotter. During the warm season of the year the temperatures in these areas are usually high, ranging between 21^{o}C and 27^{o}C. Despite the temperatures being low at the workplace, two main processes of drying and steam generation do contribute to hot indoor conditions. The nature and effectiveness of the ventilation system within the factory does contribute to retention of warm air, thus raising the indoor temperatures to 27^{o}C-32 ^{o}C. Ventilation by displacement makes it possible to introduce warmer air into the given space than would be required by a system of ventilation by dilution. This is because the warm air that is extracted is at a temperature several degrees higher than the temperature in the occupied zone of the working space (Piombino, 2005).

Contact with hot water, steam lines and process equipment result in serious injury from burns. Most burns occur on the hands, arms and face. Heat sealers and glue operations on packaging lines especially for the Factory Door Sale (FDS) tea also cause burns (Piombino, 2005). Guarding and lagging of exposed hot points on equipment is important for both heat retention and safety of employees. The proper evaluation of the hazards, selection and use of Personal Protective Equipment (PPE), help reduce or eliminate worker exposure to high temperatures and burns. Use of pipeline breaking and lockout procedures protect workers from the unexpected release of hot liquids and steam. Employees' awareness, protective appliance, engineering control measures or safe system of work would reduce most of these accidents and the resulting poor health of employees.

1.2.2 Sources of heat exposures in tea factories

KTDA is the largest private tea management company in Kenya (KTDA Ltd). It currently manages 57 operational factories in the small-scale tea sub-sector in Kenya. It has a goal and objective of meeting and exceeding customer's expectations in providing quality products and associated services. Its mandate is to purchase materials for seedlings propagation on behalf of the growers. Through the technical staff, KTDA ensures tea cultivation and harvesting is well supervised. Other functions include purchase of green leaf from the farmers, processing of green leaf at the factory, and marketing of black tea. On financial consent, KTDA collects revenue, pays the farmers and manages the financial resources. Tea plucked from the fields around the factory is delivered to the factory for processing. The raw material for production of black tea is the young shoot, the terminal bud and the two adjacent leaves plucked from the tea plant. The tea is processed in four distinct stages; these are withering, rolling, fermentation and drying. Each stage involves characteristic changes in the physical and biochemical composition of the leaves and the cumulative effective of these changes are ultimately reflected in the quality of the finished product, black tea. After the drying is over, the leaves are sorted into different grades, ready for the market. The processes within the tea factories, all of which contribute to heat exposure to workers are discussed below:-

Withering

It is an operation of running fans onto warm air in order to achieve even withers of the desired moisture content throughout the processing duration in the most cost effective method. Withering is a procedure which brings about physical and chemical changes in the shoots to produce quality, apart from conditioning the leaf for rolling by reducing weight and volume. Temperature is controlled by adding hot air volume at about 100^{o}C maximum. The fan inlet temperature is between 35^{o}C and 38^{o}C.

Processing, Cutting, Tearing and Curling

When a satisfactory withering has been obtained, the leaf is ready for rolling. This processes twists the leaf, breaks it up and expresses the juices. The Cutting, Tearing and Curling (CTC) process of rolling are comparatively rigorous activities which force the leaf through a machine having two steel cylinders. The cylinders move in inverse direction at a speed of 70 and 700 revolution per minute respectively with marginal clearance between them. As the leaf passes consecutively through a bank of three to four such machines, it gets much reduced in size and its cell is recaptured for accelerated as well as intensive fermentation. The whole process leaves the leaf granulated. Rolling ruptures the cell wall thereby enabling the release of pectase and polyphenol oxidase enzymes. The enzymes facilitate oxidation of the ruptured leaf. It is during this process that tea leaf changes from green, through light brown, to a deep enzymatic brown. This happens at about 26^{o}C for 30 minutes while rolling in between a giant roller.

Fermentation

The purpose of fermentation is to obtain bright, even ferments for brisk and high quality liquoring characteristics under hygienic conditions. Fermentation process involves oxidation of matter, which is rolled out of ruptured tea leaves. This is facilitated by the presence of polyphenol oxidase enzyme. The mechanical aspect involves blowing of heated air into the tea leaves macerated by rolling placed in fermentation trolley or the Continuous Fermentation Unit (CFU) for a specified period that depends on the quality of leaves. The optimum temperature for this process is between 24^{o}C and 29^{o}C.

Mid ball - breaker

The process involves dispersing tea particles clustering together to enhance even product fermentation and reduce ball formation. Disperse tea particle is then taken through the drying process.

Drying

Drying process is achieved by controlled running of the driers to achieve desired dried tea during the manufacturing process. This is done to reduce moisture content of the fermented product. This process reduces the moisture content of rolled and fermented leaves from 45-50% level to a 3% level in dried black tea. The drying process also arrest further fermentation and stops any microbial activity. It also facilitates further processes like sorting, grading and packing. Drying is physically achieved by blowing hot air of between 135-145^{o} C through ferments as they are conveyed into the drier. Along the drying process, the temperatures are varied based on the different chambers and the desired product. The drying process usually lasts about 20 minutes before black tea is obtained.

Sorting (Grading)

Sorting is the operation in which tea particles of the bulk are separated into various grades of different sizes and forms conforming to the trade requirements. While the tea is still relatively warm, it is first passed through the minimum of four slow speed electrostatic fibre extractors to clean the floating fibre. Large pellets and flat pieces of caked tea are removed at the same time and kept aside for grinding and reconditioning. After this process the tea is then stored in the storage bins.

Packing

After sorting, the graded tea is packed aseptically in laminated paper-sacks at a gross weight of between 62.6 -78.6 kg or poly bags and stored ready for market.

1.2.3 Heat exposure due to accidents in factories

Various power driven machines are used in the factories. Even in such a case, substantial work is done manually. Employees are therefore likely to be exposed to various health hazards ranging from organic dust, high noise levels and heat. Incidents of injury are also reported within the tea processing factories (Piombino, 2005). On average each factory reports 10 accidents annually. Among the injuries reported are minor cuts from processing machine parts or sharp objects, electrocution, heat exposure and burns from hot parts of equipment. Machines and equipment also cause entanglement and crush injuries within the manufacturing process. Tea processing involves use of equipment and machinery where workers are exposed to chains, sprockets, belts, pullies, rotating shafts and high-speed conveyor lines containing a number of dangerous pinch points. Most injuries are as the result of lacerations and bruises to the fingers, hands or arms. The various machines, plant and equipment that poses hazards include:- withering fans, rotor vane / CTC humidifier, driers, sorting racks / pre sorter, vibro-screen, packers, boilers, generators, lathe, drills, grinders and circular saw.

1.3 Statement of the problem

Although human beings possess considerable ability to compensate for naturally occurring heat impact, many occupational environments and / or physical activities exposes employees to heat loads which are so excessive as to affect or put pressure on health and productivity (Nunneley, 2005). High environmental temperature, high humidity, exhausting exercise or impaired heat dissipation may cause heat disorders. They include heat syncope, heat oedema, heat cramps, heat exhaustion and heat stroke as systematic disorders and skin lesions as local disorder. (Ogawa, 2005). However, despite this heat related problems, little has been done to analyze the impact of work room temperature in the tea processing factories. This is an omission particularly when put into consideration that there are various plants that directly generate heat and steam into the workroom. The process elevates the workroom temperature and increases relative humidity, which may be a direct contributor to temperature discomfort. For example, a steam-generating boiler and tea driers both do release steam into the workroom. The boilers consume firewood to produce steam, which in turn is transmitted through the lagged pipes into the driers where it is utilized to dry the tea. The moisture released from fermented tea is then dissipated into the workroom raising the relative humidity. The nature and effectiveness of the ventilation systems have a direct impact on the workroom temperature and relative humidity is one of the factors that determine the level of employees' comfort (Diberardinis, 2006). In the long run, various techniques can be explored in order to minimize the possible incident of heat disorders or discomfort and reduce the severity of cases when they do occur.

1.4 Objectives

1.4.1 General objective

To assess the impact of occupational heat on employees' comfort in tea manufacturing factories.

1.4.2 Specific Objectives

i. To determine occupational temperature by measurement of Wet Bulb Globe Temperature index (WBGTI) and environmental factors at the work environment within the sampled factories.

ii. To determine occupational heat comfort factors within indoor workplace environment.

iii. To identify gaps of engineering and administrative controls and make suggestions of measures to be taken by the management to reduce the occupational heat related discomfort for employees at the factories.

1.5 Hypothesis

H_1 There is a significant relationship between the magnitude of high occupational heat and worker's comfort.

1.6 Research Questions

The researcher sought to answer the following questions:-

i) Does occupational heat within the working environment exceed the permissible heat exposure threshold values while putting into consideration of the workload as guided by

Occupational Safety & Health Administration (OSHA standard) and American Conference of Governmental Industrial Hygienist (ACGIH)?

ii) Does occupation heat comfort factors exist within the indoor working environment?

iii) Are there any gaps identified and steps or measures to be taken to reduce the impact of occupational heat in the factories?

1.7 Rationale and Justification

The success of a controlling program for temperature impact at the workplace begins with hazard assessment *(*Fanger, 1973). A process or operation where heat stress is of concern needs to be reviewed prior to installation of control measures (HSE, 2006). For existing operations, field assessment using the heat stress determining index and personal factors should be performed to determine if additional engineering and administrative controls are needed (Iran J. Environ. Health. Sci. Eng., bulletin, 2008). It is important to realize that heat stress can be an insidious occupational hazard when not well understood by employees and management (ILO, 2006).

1.8 Conceptual Framework

Employees' workroom temperature comfort is a condition of the mind, which expresses satisfaction with the thermal environment. The recommended heat comfort limits are: temperature between 23-26^{o}C dry bulb, air velocity between 0.25-0.5m/s and relative humidity 50 ± 10% that is 40% to 60% (ISO /DIS 7730, 1984). Under ideal temperature conditions, individuals are unaware of being too hot or cold - they feel "thermally comfortable”. An employee feeling “thermally uncomfortable” will feel too hot but will not suffer harm as a direct result. However, being too hot may make the employee feel stressed. The employee may also be less productive and may make more mistakes that could result to an accident.

Workers should be made as comfortable as possible under hot conditions. At many workplaces, some degree of temperature comfort may be unavoidable. Although the temperature conditions for a working employee cannot be controlled, clothing, physical activities and the timing of the work can (Workplace Health and Safety bulletin, 2008). If the workers experience discomfort for only a few days a year, it may not be reasonable to spend resources to control the thermal environment. Administrative controls may be appropriate.

Only a small section of the fermentation process has so far been automated. Nevertheless, heavy work still prevails, particularly in other sections such as tea packing, leaf sorting, feeding boiler with fire wood and cutting wood into small pieces. It is important to estimate the rate at which work is done, that is the workload. These factors are nutritional state, the nature and quality of food consumed the frequency of meals, oxygen uptake, cardiac output and oxygen extraction (Khogali, 1992). Heat produced by the body and environmental heat, together determine the total heat-load. Therefore if work is to be performed under hot environmental conditions, the work-load category of each job should be established, and the heat-exposure limit pertinent to the work-load evaluated (ACGIH, 1991). Tremendous amount of investigations and research has been conducted to determine the effect of thermal stress on work efficiency, performance and productivity, whether indoor or outdoor (Khogali, 1992). There is evidence that the decline in heat tolerance affects on all types and categories of performance, whether it is a matter of dexterity (Weiner and Hutchinson, 1992), reaction time (Meese, 1988), mental work (Hancock 1981), or strenuous physical work (Smith *et al.*, 1988). In general, a heat stressed person processes information poorly, disregards, danger warnings, and makes irrational decisions. Irrespective of the type of job or task there is a significant decline in the performance of workers in conditions of thermal stress.

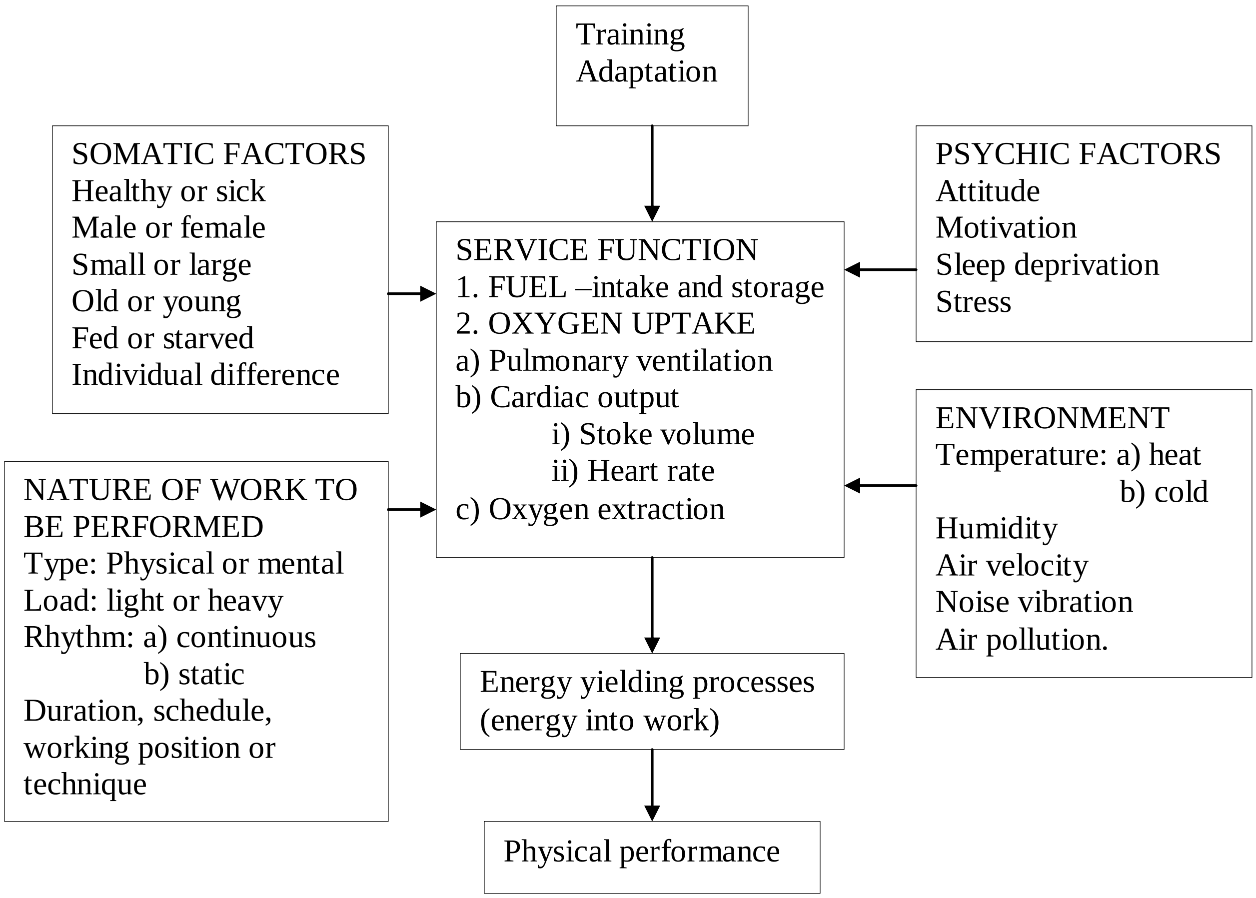

Figure1. Factors affecting physical performance (Rodahl, 2003)

CHAPTER TWO

THEORY ON HEAT STRESS IN INDUSTRY

2.1 Occupational Heat Stress and Strain on the Body

The human body works at its best within a narrow temperature range. Man must keep the temperature of his vital organs such as the brain, heart, liver etc within this narrow limit. If man is to survive exposure to unbalanced environments, 2^{o} C or more above or below the body's normal temperature of 37^{o} C problems can start to happen. is The core body temperature of the brain, heart and other organs is 37^{o} C (Work safe Alberta, 2009). Skin temperature may differ from core body temperature by a few degrees. As heat impinges upon man, his first response is a sensation of discomfort (Bell, 1974). As the heat discomfort increases, thermoregulatory adjustments are made to counteract thermal stresses on the body. The body controls its core temperature in a few ways. Sweating lowers the temperature; shivering raises it. Increasing blood flow to the skin helps remove heat; reducing the flow of blood help conserves heat. Inefficiency in the performance of work or tasks, an increased susceptibility to minor accidents and change in the emotional tone of employees are found associated with the changes in sensation and body temperature (Mottair, 2004).

Permissible heat-exposure threshold limits values as given by (OSHA, 1998; ACGIH, 2002*)* (given in ^{o} C WBGT) must be set for the thermal severity of workplaces if employees are performing hard work. Employees must also maintain their thermal balance throughout a working day or over the duration required for completion of a specific task. If the combination of workload and environmental heat is so great that the thermal balance cannot be maintained, employees will become susceptible to heat collapse. Variation between workers, between workloads, and between environmental thermal characteristics must be taken into consideration when recommendations are made on the durations of exposure over which employee will be protected from heat collapse (Bell, 1974). The level of occupational temperature related comfort depended on physical activity employees performed and various environmental factors. International Labour Office has standards which are considered as proposed norms for comfort environmental factors as showed on Table 1.

Table 1: Proposed norms for environmental factors

Environmental factors	Proposed norm
Air temperature	21^{o} C
Average radiant temperature	$\geq 21^{o}$ C
Relative humidity	30-70%
Speed of the air flow	0.05-0.1m/s

Source ILO, 1993

For workplaces with extremely high environmental temperatures above permissible heat-exposure threshold limit values, the exposed skin surfaces and respiratory organs of employees may be subjected to extreme discomfort, pain or tissue damage (Rodahl 2003). Limits must be placed on the duration of exposure or on the environment to be accessed by unprotected employees. The value of heat stress is a function of the difference between skin and air temperature and the rate of air movement over the skin. Skin temperature is normally assumed to be 35^{o} C. Therefore, for a worker wearing a single layer of clothing (long- sleeved work shirt and trouser), an ambient air temperature of greater than 35^{o} C will cause the body to gain heat from the air, whereas an ambient air temperature of less than 35^{o} C will cause the body to lose heat into the air (Work safe Alberta, 2009). Wearing cloth made of fabric that wick the sweat away from the skin would allow sweat evaporation and thus improving the comfort (Lotens, 2005). When vapour-impermeable protective clothing is worn, the humidity inside the garment increases as the wearer sweats because the sweat cannot evaporate. If the employee was wearing this type of protective clothing the humidity within the microclimate of the garment may be high.

Working in cooler, less strenuous environments can also pose a risk depending on individual's heat-tolerance capabilities (Krake, 2006). Total heat stress is defined by the National Institute for Occupation Safety and Health (NIOSH, 1998) as the sum of the heat generated by the body (metabolic), plus the heat gained from the environment (primarily through evaporation). Heat strain is defined as the body's response to the heat stress it experiences. Bodily responses to heat stress are desirable and beneficial because they help regulate internal temperature and in situation of appropriate repeated exposure help the body adopt (acclimate) to the work environment. However at some individually determined stages of heat stress, the body's compensatory measures cannot maintain internal body temperature of the level required for normal functioning. These results in the risk of heat-induced illnesses, disorders and accidents substantially increase.

For the body to continue with its normal function, deep core body temperatures must be maintained within the acceptable range of about 37^{o} C ± 1^{o} C. Achieving this equilibrium requires a constant exchange of heat between the body and the environment (Jeyaratnam, 1992). The amount of heat to be exchanged is a function of the total heat produced by the body (metabolic heat) and the heat gained from the work environment. The rate of heat exchanged with both hot and cold environments is a function of air temperature, humidity, skin temperature, air velocity, evaporation of sweat, radiant temperature, and type, amount and characteristics of clothing. The mode of heat exchange between workers and their environment are convection, radiation and evaporation. Convection refers to the rate of heat exchange between the individual's skin and the air immediately around the skin, assuming the air is moving. Its value is a function of the difference between the skin and air temperatures and the rate of air movement over the skin (Krake, 2006).

There are several concepts that must be considered when performing hazard assessments for heat stress. These concepts are the basis of education and training programs (Health and Safety Executive, 2008). Conduction, which is the transfer of heat to the skin from direct contact with hot equipment or floor or from hot liquids, plays a minor role in heat stress other than for brief periods of time the body would be contact with such objects. Radiation heat exchange also refers to heat that is transferred between the skin and solid surfaces or objects, cold or hot, but without direct skin contact. Working in direct sunlight is one example of thermal heat exposure. Evaporation of water from the surface of the skin (sweating) is the body's primary method of regulating internal body temperature. Evaporative cooling also occurs from the lungs but with the exception of handwork in very dry environment, its contribution to overall heat reduction is minor. The evaporative capacity of the body is a function of ambient air velocity and the water vapour pressure difference between the ambient air and the wetted skin at skin temperature, which is assumed to be 35^{o} C.

The human body, being warm blooded, maintains a fairly constant internal temperature, even through it is being exposed to varying environmental temperatures. To keep internal body temperatures within safe limits, the body must get rid of its excess heat, primarily through varying the rate and amount of blood circulation throughout the skin and the release of fluid onto the skin by the sweat glands (NIOSH/CDC, 1998). When at 36.3^{o} C human bodies are kept in balance and controlled by the brain (NIOSH, 1986). In this process of lowering internal body temperature, the heart begins to pump more blood, blood vessel expand to accommodate the increased flow, and the microscopic blood vessels (capillaries) which thread through the upper layers of the skin begin to fill with blood. The blood circulates closer to the surface of the skin, and excess heat is lost to the cooler environment (ACGIH, 1991). If the heat loss from increased blood circulation through the skin is not adequate, the brain continues to sense overheating and signals the sweat glands in the skin to shed large quantities of sweat onto the skin surface. Evaporation of sweat cools the skin, eliminating large quantities of heat from the body.

As environmental temperatures approach normal skin temperature, cooling of the body becomes more difficult. If air temperature is as warm as or warmer than the skin, blood brought to the body surface cannot lose the heat. In such conditions, the heart continues to pump blood to the body surface, the sweat glands pour liquids containing electrolytes onto the surface of the skin and the evaporation of the sweat becomes the principal effective means of maintaining a constant body temperature. Sweating does not cool the body unless the moisture is removed from the skin surface through evaporation. Under conditions of high humidity, the evaporation of sweat from the skin is decreased and the body’s efforts to maintain an acceptable body temperature may be significantly impaired. These conditions adversely affect an individual’s ability to work in the hot environment. With so much blood going to the external surface of the body, relatively less goes to the active muscles, the brain, and other organs; strength declines; and fatigue occurs sooner than it would otherwise. Alertness and mental capacity also may be affected. Workers who must perform delicate or detailed work may find their accuracy suffering, and others may find their comprehension and retention of information lowered (NIOSH/CDC, 1998).

2.2 Response to work in Heat

Work in the hot places brings about great strain on the thermoregulation system, especially in the acclimatized person. The ease or difficulty of the physiological response or adaptation to thermal stress is a function of a number of modifying factors. The maximum oxygen uptake (VO_2 max) varies greatly from one person to another. The physical workload may be assessed by measuring VO_2 during the actual operation. In manual labour, the energy expenditure during the performance of similar type of work may vary greatly, depending on the technique used in accomplishing the work (Strand and Rodahl, 1992). Muscular work is associated with an increase in metabolic rate. Since the mechanical efficiency (the ratio of external work to the extra energy used) may vary from 0 to 25% depending on the kind of work, at least 75% of energy is converted into heat (Astrand and Rodahl, 1992)

The greater the intensity, the greater the total amount of heat produced. The excess heat has to be dissipated in order to prevent hyperthermia. At higher metabolic rate there is a curvilinear relationship between VO_2 max and core body temperature (Davies *et al*., 1976). Individuals with high VO_2 max. appear to have an advantage in terms of exceptional heat tolerance. Heat – tolerance is reduced in the older individuals. When exposed to heat, they start to sweat later than do young persons, and their body temperature takes longer to return to a normal level. The elderly, with their reduced efficiency of circulation and reduced VO_2 max., are more susceptible to heat disorders and heat related illnesses (Khogali, 1992). Earlier studies reported that women exhibit a higher skin temperature and a poorer sweat-response than men. According to (Shapiro *et al.,* 1979) their thermoregulatory set point is higher than men. But recently evidence suggests that, when they are aged-matched for VO_2 max. , sex difference in heat-tolerance disappears (Avellini *et al.,* 1992).

Obese people are less adaptable to heat. Obesity can alter the blood flow between the skin and the working muscle (Vroman *et al.,* 1983). They are also disadvantaged because of their low VO_2 max. and low surface-area to body- mass ratio. They are less capable of working efficiently in conditions of heat stress. The daily water loss is 2600 ml from the gastro- intestinal track, 200ml from the respiratory track, 400ml from the skin, and 1500ml from the kidneys. Therefore on average for a normal healthy person, 4.7 litres of water is lost per day when working in hot environment. Regular intake of fluids assists to balance high sweat-rate and generally the loss of body fluids. In this case employees who consumed enough fluids would tolerate heavy physical work in relatively hot environment. The loss is balanced by regular intake of fluids. Prolonged exposure to heat and / or physical work can lead to high sweat-rate, loss of body fluids, and a dehydrated person does not tolerate heavy physical work (Vroman *et al.,* 1983). The behavior of frequent water consumption has direct bearing on replacement of the body water loss while working. Drinking to satisfy thirst is not enough to keep a person well hydrated. Most people do not become aware of thirst until they have lost 1 to 2 litres of body water, and persons highly motivated to perform hard work may incur losses of 3 to 4 litres before clamorous thirst forces them to stop work and drink water (Nunneley, 2005).

Acclimatization is a physiological change occurring within the lifetime of an organism and reduces the strain caused by stressful changes in the natural climate (Bligh and Johnson, 1978). Repeated or continuous exposure to heat causes a gradual adjustment or acclimatization, resulting in better tolerance of the temperature stress in question. Many studies conclude that acclimatization is a result of working in high temperatures, but not an inevitable outcome of fitness. Acclimatization is always relative and specific. Any increase in this load or in thermal burden may lead to health damage. To achieve good acclimatization for heavy work under hot conditions, it is better to subject the individual to very heavy work under moderate warm conditions than to subject him to light work under hot internal environment conditions. Un-acclimatized worker should work at least 50 percent of the required work for the first day and increase production at a rate of 10 percent each day thereafter until full acclimatization is achieved. Once the sweating rate is achieved the cooling of the skin is also achieved leading to a low core body temperature and heart rate during work (Nielsen, 2005). It is established that absence from work for three weeks usually exposes a person to virtual loss of acclimatization unless that worker is very athletic and good physical condition (Nunneley, 2005). This signified increase in the level of temperature related discomfort for employees.

2.3 Health Effects of Exposure to Hot Environment

The level of heat stress at which excessive heat strain will result is highly individual and depends on heat tolerance capabilities of each individual, age, weight, degree of physical fitness, degree of acclimatization, metabolism, use of alcohol or drugs and variety of medical conditions e.g. hypertension and diabetes. All these conditions affect a person's sensitivity to heat (Krake, 2006). A core body temperature increase of only 0.66 ^{o} C above normal encroaches on the brain's ability to function. Heat disorder and health effects of individuals exposed to hot working environments include irritability, lack of judgment and loss of critical thinking skills, skin disorders (e.g. rushes and hives), heat syncope (fainting), heat cramps, heat exhaustion, heat stroke and even death. Fainting results from blood flow being directed to the skin for cooling, leading to decreased supply to the brain.

Heat cramps and syncope often accompany heat exhaustion, or weakness, fatigue, confusion, nausea and other symptom that generally prevent a return to work for at least 24 hours. Dehydration, sodium loss and elevated Core Body Temperature (CBT) above 36.99^{o} C of heat exhaustion are usually due to individuals performing strenuous work in hot conditions with inadequate water and electrolyte intake (Krake, 2006). Heat stroke occurs when hard work, hot environment and dehydration overload the body's capacity to cool itself. Thermal regulatory failure is a life threatening emergency requiring immediate medical attention. Signs and symptoms include irritability, confusion, nausea, convulsions or unconsciousness, hot dry skin and a (Core Body Temperature) CBT above 39.1^{o} C. Death can result from damage to the brain, heart, liver or kidney.

Prolonged increase in CBT and chronic exposures to high levels of heat stress are associated with disorder such as temporary infertility (male & female), elevated heart rate, sleep disturbance, fatigue and irritability during the first trimester of pregnancy. A sustained CBT great than 37.65^{o} C may endanger the fetus (Krake, 2006). In addition, one or more occurrences of heat-induced illness predispose a person to subsequent injuries and can result in temporary or permanent loss of ability to tolerate heat stress.

2.4 Evaluating and Assessing Heat Stress

There are several index that can be used for assessing industrial heat stress in the working environment. These includes, Effective Temperature Index; Equivalent Effective Temperature Corrected for Radiation index, a modification of effective temperature that helps to determine the contribution made by radiant heat; Predicted 4-Hour Sweat Rate; Heat Stress Index; Wet Bulb Globe Temperature index.

Effective Temperature Index is an index that combines dry-bulb temperature, wet-bulb temperature, and air velocity to estimate a thermal sensation to that given temperature of still air, saturated air. A nomogram is used where dry-bulb thermometer temperature is connected to the wet-bulb temperature with a straight line. Corrective Effective

Temperature can be read where this line intersects the measured corresponding air velocity. Effective Temperature Index began to be used in 1923 as compared to Wet Bulb Globe Temperature that was first used in the late 1950s. The use of a black-globe temperature in place of a dry-bulb temperature will allow a correction for the contribution by surrounding radiation sources. This is known as the equivalent ETCR. The nomogram is also used to determine ETCR just as ET. The Predicted 4-Hour Sweat Rate is an index on observation of sweat rate under various environmental conditions. The index is expressed in litres and is representation of the amount of sweat generated by a fit well-acclimatized worker. Most workers will be unable to tolerate 4 hours of exposure as P4SR raised above 4.5litres. Another metabolic rate method to measure heat stress is Heat Stress Index. The HSI is determined by combining the heat exchange of Radiation (R) and Convection (C) components with metabolic heat (M) in terms of the required sweat evaporation $E_{reg.}$ The HSI is determined by 100 times the ratio of (E_{reg}) to the maximum evaporation capacity of the environment ($E_{max)}$. Body heating occurs when the HSI is less than 100 (Venetta and Collipi, 1999).

Assessing heat in employees using Wet Bulb Globe Temperature (WBGT) index involves measuring environmental temperatures at the work locations and assessing personal factors involved in each task (Krake, 2003). The wet- bulb globe temperature index is used to assess the environmental contribution to heat stress, accounts for the combined effects of air movement, temperature, humidity, and radiative heat. The WBGT index gives an indication as to how the employees feels or perceives the work environment. This is a function of dry-bulb (ambient air) temperature, natural wet-bulb temperature (simulates the effects of evaporating cooling), and a black-globe temperature, which estimates radiant (infrared) heat load. The individual task metabolic rates can be estimated using permissible heat exposure threshold limit values table (shown in Table 2), "Estimated metabolic heat production rates by task analysis," or by using the work rate categories of the ACGIH. The WBGT index has proved successful in monitoring heat stress and heat casualties in the United States and has been widely adopted. It has been adopted as a principal index for the threshold limit value for heat stress established by the ACGIH (Venetta and Collipi, 1999). The WBGT index is an algebraic approximation of the effective temperature concept.

It is important to note that WBGT index values assumes an employee is physically fit, in good health, "normally clothed" with adequate salt and water intake. If conditions stay within limits, employees are able to work efficiently without exceeding the body core temperature of 38^{o} C. Inside buildings and outside buildings without experiencing the effects of radiation from the sun (solar load), the value of WBGTI is given by ISO equation (OSHA Technical Manual, 1989):-

$$WBGT = 0.7\,(t_w) + 0.3\,(t_g) \quad \ldots\ldots\ldots\ldots \quad [1]$$

Outside buildings with solar load, or where a radiant heat source is present indoors, it is given by the equation:-

$$WBGT = 0.7 (t_w) + 0.2 (t_g) + 0.1 (t_a) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. [2]$$

Where:

WBGT= Wet Bulb Globe Temperature Index
t_w = Natural Wet-Bulb Temperature
t_g = Globe Thermometer Temperature
t_a= Dry-Bulb (air) Temperature

2.5 Management of Worker's Heat Exposure

Development of education and training program is an important aspect in mitigating the effects of stress on employees. The training program may include all workers and have to be conducted prior to assigning jobs where heat exposure is a concern. Training must also explain the need for employees to take frequent breaks. In workplaces workers have a tendency of accumulating breaks with an intention of leaving work early at the end of the day. Under medical surveillance a health monitoring program should include a pre-employment physical examination and history, with concentration on cardiovascular, metabolic, renal, skin and pulmonary systems. Previous intolerance of hot environments or pregnancy are reasons for special consideration.

Clothing can have profound effects on the heat exchange process. When hot, clothing interferes with heat loss and can be harmful. The insulation value of most materials is a direct linear function of its thickness. When workers wear impermeable clothing for protective purpose it is imperative that these workers are closely monitored and a strict work rest regimen should be planned and enforced to prevent heat stress problem. Different personal protective equipment should be used to fit the nature of heat hazards as a worker is exposed to. A PPE such as water-cooled garment, air-cooled suits and metallized reflecting fabrics can provide protection to a worker. Workers need to be trained on the limitation of protective clothing. Workers tend to don wetted cotton, which is cooler and more comfortable to wear than manmade fabric. Shortening the duration of exposure and / or increasing the frequency and length of rest periods, allows workers to self-limit exposure. Workers should rest before becoming fatigued until heart rate drops. Low- humidity rest areas speeds the rate and degree of recovery.

The most fundamental approach to engineering control of heat in the workplace is elimination of heat at point of generation. Heat is controlled most effectively if it is regulated at the source. The options for controls of heat at source are isolation, reductions in emissivity, insulation, radiation shielding and local exhaust ventilation (Stranks, 2006). Isolation prevents the escape of sensible and radiant heat into the work environment. Workers who operate high- temperature furnaces or boilers throughout the day may face significant radiant heat exposure. The control strategy is to use heat-reflective curtain between the furnace and the worker.

The rate at which an employee works and the activities being performed will have a directed effect on his/her potential to experience heat stress. This work rate must be taken into consideration when establishing safe work practices for employees working in hot environment. The threshold limit values are based on the assumption that nearly all workers are acclimatized fully, clothed with adequate water and salt intake and are able to function effectively under given working conditions without exceeding a deep body temperature of 38^{o}C. They are also based on the assumption that the Wet Bulb Globe Temperature Index of the resting place is same or very close to that of the workplace. A guide on the work-rest regimen for work in hot environment is shown on Table 2.

Table 2: Permissible heat-exposure threshold limit values (OHSA technical manual of 16th September 2008)

Work-rest regimen	**Work load**		
	Light	**Moderate**	**Heavy**
Continuous work	30.0^{o} C	26.7^{o} C	25.0^{o} C
75% work, 25% rest , each hour	30.6^{o} C	28.0^{o} C	25.9^{o} C
50% work, 50% rest , each hour	31.4^{o} C	29.4^{o} C	27.9^{o} C
25% work, 75% rest , each hour	32.2^{o} C	31.1^{o} C	30.0^{o} C

Values are in ^{o} C, WBGT

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study areas

There are nine different regions within the tea growing areas in Kenya. These areas are Kisii, Kericho, Nandi, Kiambu, Muranga, Nyeri, Kirinyaga, Embu and Meru. Although all these regions were potential study areas, Ikumbi, Kambaa and Mungania tea factories, which are among the 57 factories managed by KTDA, were selected. Ikumbi, Kambaa and Mungania tea factories are located in Murang'a South, Kiambu and Embu districts, respectively. Ikumbi and Kambaa tea factories are situated at the slopes of Aberdare ranges while Mungania tea factory is situated at the slope of Mount Kenya. The three study areas were selected because of their geographical (latitude and altitude) and climatic (humidity and temperature) similarities. The selection criteria resulted in the minimization of the influence of these two attributes to the findings of the three areas. Each factory also employs one hundred employees and produces on average three million kilograms of tea. The sampling strategy lead to an in-depth analysis related to the fundamental issues. Visiting the sampled factories from Nairobi was found to be cost effective since the researcher was based at the head office (KTDA).

The three factories were sampled out on the criteria of having similar construction and design. Each factory had two firewood boilers, three driers, similar network of steam transmission pipes and similar layout of the physical building. The steam pipes had leaking joints and loose control valves which had not been repaired. Lagging and cladding of steam pipes were not enhanced causing heat dispersion into the working area. Stocking of firewood in the boiler sections was performed manually at the three factories. Employees performing firewood stocking were not provided with means to secure themselves from direct heat. Moreover no face shields were issued to protect them from heat. The boilers and driers at the three factories had their surface treatment peeled off causing heat dispersion into the workroom. Each of the three factories had malfunctioning mechanically driven exhaust system and the roof designs were not fitted with natural ventilation facilities such as cyclone fans. From the review of the occupational safety and health training records both employees and management within the three factories were not trained on heat related risks and the means of managing them. Occupational accidents records were also reviewed on which it was noted that minor burns experienced by workers at the boiler sections were not recorded and mitigation measures taken.

3.2 Instrumentation

To measure the variables, the following equipment were used: -

a) Dry-bulb thermometer (Made in England) with shielded mercury-in-glass, 0^oC to 50^o C, with $0.5\,^oC$ graduation was used to measure air temperature.

b) Psychometric wet-bulb thermometer, 0^oC to 50^o C, with $0.5\ ^o$ C graduation for measurement of humidity.

c) Non-Contact Infrared thermometer (HI 99550) for measurement of radiant temperature, (Made in Hungary), Range -10 to 300^oC. Kestrel air flow meter, with maximum flow 1000 ft/min, manufactured by Richard P. Russell Ltd, USA, for air flow measurement.

d) Kestrel air flow meter, with maximum flow 1000 ft/min, manufactured by Richard P. Russell Ltd, USA, for air flow measurement.

3.3 Methodology and data collection tools

3.3.1 Preliminary data collection method and determination of wet bulb-globe temperature index

Factory visits were made to Ikumbi, Kambaa and Mungania Tea factories to carry out the research. The parameters measured during the study period were air temperature, air relative humidity, radiant temperature and air flow. Humidity was obtained by taking the difference between the two readings of wet-bulb and dry-bulb thermometers. These figures of the readings were compared to the ones in the provided relative humidity chart upon which relative humidity was determined (Caltech and NASA/ Jet propulsion laboratory, 2006). Wet-bulb and dry-bulb thermometers were suspend on a pillar at the midpoint of the working room on estimated worker's waist level. The radiant temperature was obtained by directing the sensor of the non-contact infrared thermometer to the sources of heat. The distance of the measuring instrument was kept 9 meters away the heat emitting objects. Air temperature was obtained by placing dry-bulb thermometer on top of a table at the midpoint of the working room upon which readings were taken. The location of the dry-bulb thermometer was also about 9 metres from the heat sources. The air flow meter was also placed on a table at the centre of the room. This meter sensed air flow from all directions. Measurement commenced at the start of the day shift at 8.30am and continued at an interval of one hour until the end of the shift at 4.30pm.

In order to provide the best result of employees' exposure, instruments were placed in the zones where employees spend most of their time during working hours. These areas were also considered because they had no rapid fluctuations of the parameters being determined. The determination of WBGT index was done by collecting three major measurements that reflected the contribution of environmental factors to heat stress. The measurements included the dry-bulb temperature, natural wet-bulb temperature and globe temperature. The dry-bulb temperature measured the ambient temperature. The natural wet-bulb temperature recorded the ambient temperature, but reflected the influence of humidity and air movement. High humidity and low air movement resulted in an elevated wet-bulb temperature. The globe temperature reflected the contribution of radiant heat. The integration of all the three measurement yielded the WBGT index. The WBGT value was compared to the reference values provided (permissible heat - exposure threshold limit values (given in WBGT).

3.3.2 Employees personal behavior data collection method

At the end of the preliminary data collection period, structured interview was employed to determine the employees' personal behavior within the indoor working environment. The aim of the approach was to ensure that each interview was presented with exactly same questions in the same order. Questionnaires contained twenty (20) structured questions that were related to heat comfort factors of the workers as indicated on appendix. The interview was conducted with informed consent of the workers. All respondents selected for the study possessed some knowledge about their working environment and were active participants in the organization operations. Results of the interview were tabulated and presented on bar graphs.

3.3.3 Sample size for employees' personal behavior data

The research focused on indoor areas suspected to have thermal comfort challenges and was based on case study design. Purposive sampling was used to identify workers to be interviewed in order to ensure reliability of the data (Kombo and Tromp, 2006). This design allowed for the in-depth investigation of the impact of occupational heat on the workers comfort. The structured interview focused on both permanent and seasonal contract employees. These categories of workers were engaged consistently at the factories and therefore factors such as acclimatization could be easily identified. Daily casuals were not reliable since they were either placed in departments in which thermal comfort was not a challenge or they were not consistently engaged in employment.

Kambaa, Ikumbi and Mungania tea factories employ a total of 300 persons. However, the number fluctuates depending on the season and the amount of crop available. A total of 100 employees were serving in the three factories, during the day shift. A list of employees was prepared for each department and a systematic random sampling was performed as indicated on the table 3 below. Every 1^{st}, 3^{rd}, 5^{th}…. person from the list was selected therefore bias was minimized (Kombo and Tromp, 2006).

Table 3: Sampled population

Departments (in the 3 factories)	**Population size**	**Total sample size**	**Sample size per factory**
Packing /sorting	35	18	6
Drying	12	6	2
Withering	30	15	5
Boiler	23	12	4
	100	**51**	**17**

3.3.4 Evaluation of questionnaire data

Even when physical measurements were made in the workplaces, questionnaires were essential since they developed an adequate exposure picture by systematically collecting personal and other characteristics data. Information captured by the questionnaire targeted various data that were not available from other sources. Duration of work in a normal working day was to establish a period of exposure to hot conditions within a day. Data on age were important since they signified the heat tolerance ability on individuals within different age groups. Work rest regimen data were meant to indicate the ratio of work intensity performed per hour and the rest period. Data on general sensation of environmental condition of the workplace were obtained from respondents. Such data were the feel of air condition, fluctuation of temperature during the working hours, presence of high humidity, presence of steam and identifying sources of heat at the workplace. This information was aimed to support the measurements previously performed. The status of the ventilation system was also assessed by the feeling of employees on flow of air from out door-environment. Data on how employees behaved during hot working periods while wearing personal protective clothing or equipment was also assessed.

Employees habit on frequency and amount fluids or water consumed per day was assessed throughout the sampled population. Acclimatization was observed by looking at responses involving breaks away from work. Body mass index was determined from sampled population to show physiological response to hot environment. Due to its ease of measurement and calculation, it was used as a diagnostic tool to identify weight problems within the sampled population (WHO, 2006). This assisted in establishing whether individuals were underweight, overweight or obese. All data in the completed questionnaires were compiled and statistical analysis carried out using statistical package Microsoft excel and result present in chapter four.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The data collected through questionnaires represented individual employee information in three factories. Results were presented separately for each factory and departments. The assumption made was that employees' opinion remained the same despite relocation from one location to the other. Preliminary measurements were recorded and presented separately for the three factories and departments. These measurements were determined based on specific sites.

4.2 Determination/analysis of WBGT index value

Figure 2 shows the WBGT index of the various departments in each of the three factories.

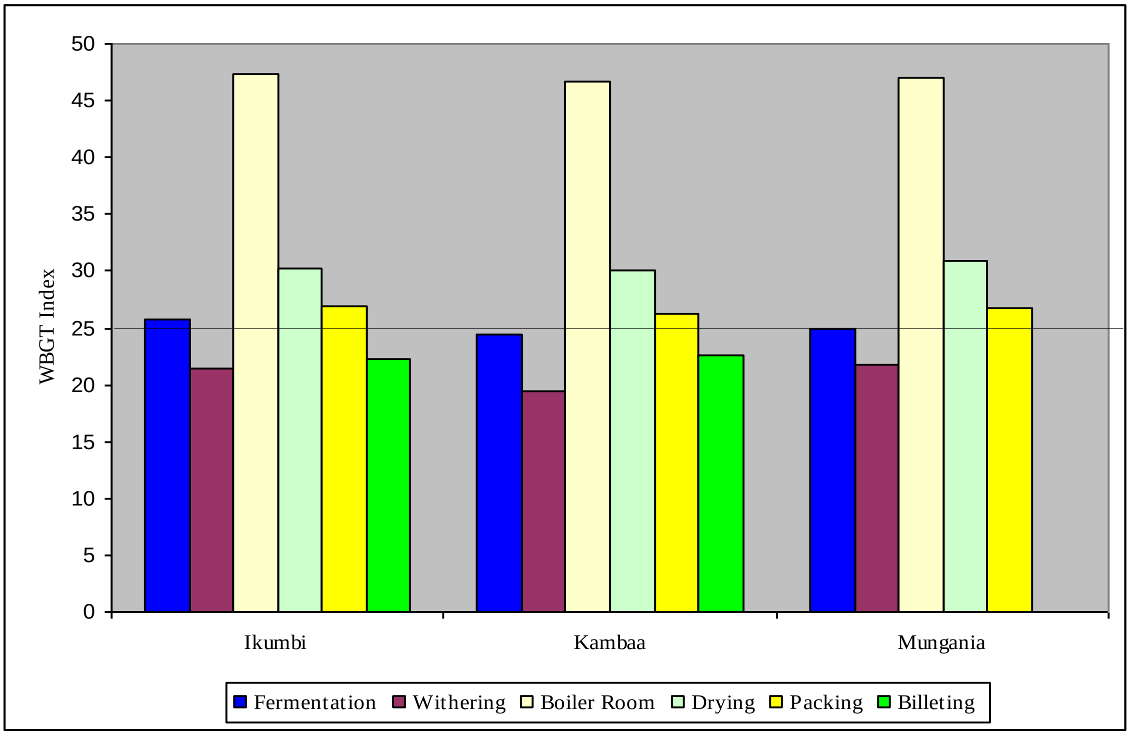

Figure 2: WBGT index (in degrees Celsius) for the fermentation, withering, boiler, drying and packing rooms for Ikumbi, Kambaa and Mungania factories

The boiler, drying and packing/sorting sections exceeded the screening criteria for heat stress as provided by ACGIH and OSHA standards for hot environment as indicated on Table 2. The boiler, drying and packing/sorting sections had WBGT index above 25.9^{o}C. Therefore workers were exposed to strenuous conditions. The set of index of the duration of work and rest periods for all the workload categories in the three factories ranged between moderate and heavy workload as shown in Table 4. Employees supplying fire wood manually to the boiler were further exposed to direct radiant heat and flames.

Table 4: Metabolic work-load of activities

Light work-load activities (<230 watts)	**Moderate work-load activities (230-400 watts)**	**Heavy work-load activities (>400 watts)**
Sitting: • Light arm work • Driving a car • Working with machines e.g. cutting **Standing:** • Light hand work • Printing • Casual work	**Sitting:** • Heavy arm work • Tractor ploughing **Standing:** • Heavy arm work • Hoeing • Cement mixing	**Standing:** • Trench digging • Trunk work • Work with axe • Tree felling

4.3 Analysis of measured environmental factors

The level of occupational temperature-related comfort depended on physical activity employees performed, the amount of air that circulated, the ambient temperature and humidity. Figures 3(a), 3(b), 3(c) and 3(d) illustrated the outcome of various environmental factors upon which the comfort consideration was based on the ILO standards for environmental factors as indicated on Table 1.

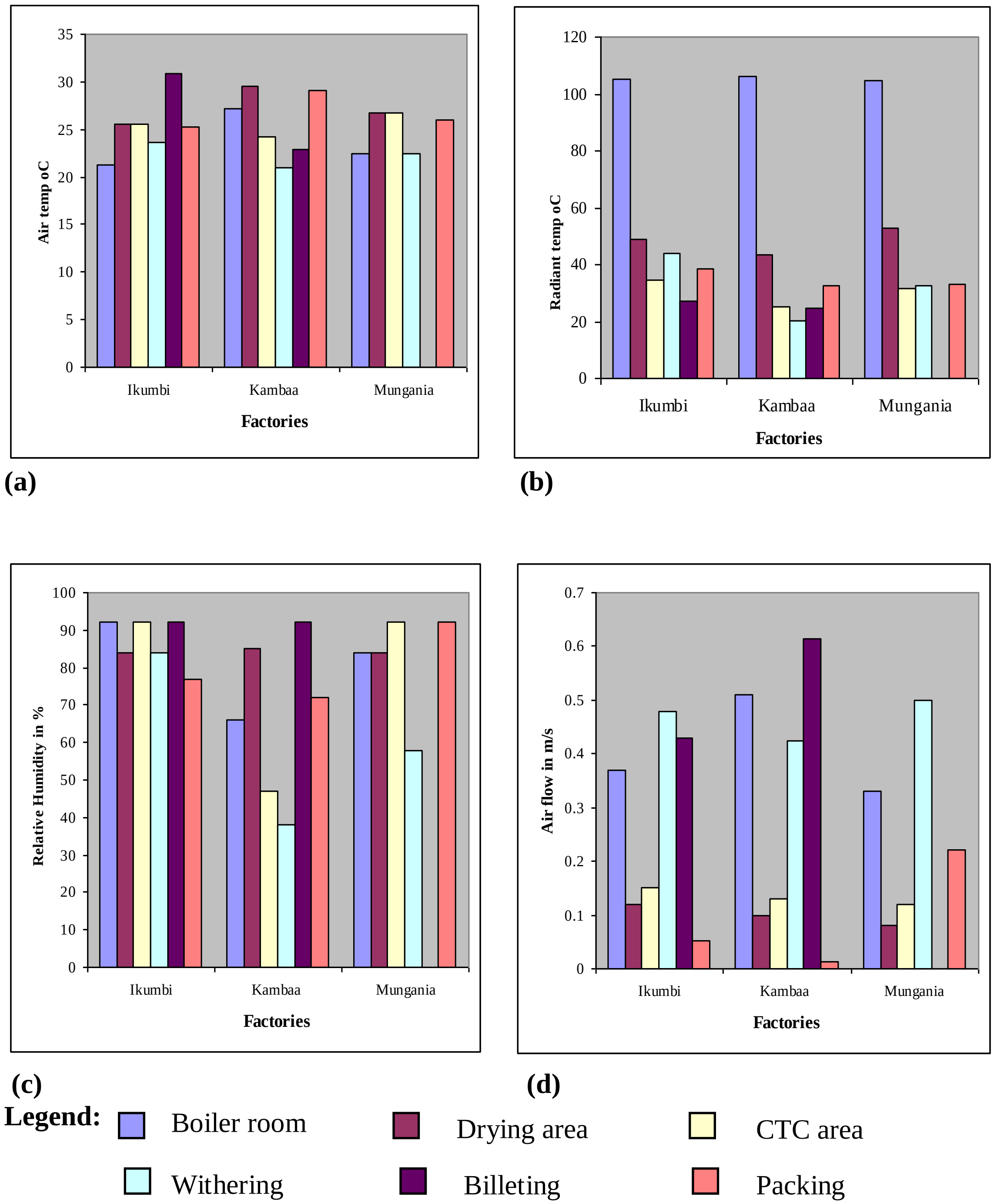

Figure 3: Bar graphs of heat stress factors for Ikumbi, Kambaa and Mungania Tea Factories showing: (a) air temperature, (b) radiant temperature, (c) relative humidity and (d) air flow

Figure 3(a) shows that air temperature was beyond 21^{o}C in all the departments of the three factories with exception of withering department at Kambaa tea factory. This was beyond the proposed norm of environmental factors as stipulated in Table 1. The departments that registered very high air temperature within Ikumbi tea factory were billeting, CTC, drying and packing. In Kambaa tea factory, boiler, drying, and packing areas had elevated air temperature affecting workers comfort. Mungania tea factory had high temperature at drying, and CTC areas. It is evident from Table 3(b) that for each of the three factories, boiler and drying areas had radiant temperature above 21^{o}C of the proposed norm of radiant temperature. It is observed from the Figure 3(c) that Ikumbi tea factory had relative humidity above upper limit of the 30-70% comfort range in all the departments. Relative humidity went above upper limit of the 30-70% comfort range in the drying, billeting and packing departments at Kambaa tea factory. Similar humidity conditions were observed for the boiler, drying, CTC and packing departments at Mungania tea factory. Air speed was within the comfort range of 0.05-0.1m/s in all departments at the three factories. There was an exception in Kambaa tea factory were packing department had air speed below the range. As evident from Figures 3(a) and 3(c) the higher the humidity level the higher the air temperature was recorded. The lower the air speed the higher humidity and air temperature. This was evident from departments such as packing and drying which had lower air speed therefore raising both air temperature and humidity levels.

The billeting department at Mungania tea factory was not included for the research because of restriction of access. The factory was undergoing expansion during the period of the research therefore restricting access.

4.4 Analysis of questionnaires on personal factors.

Figures 4-22 and Tables 5-23 indicate the outcome of various personal factors analyzed from the questionnaires. These factors were as a result of exposure of heat to the workers at the sampled factories. They were analyzed and presented on tables and graphs upon which interpretations and conclusions were derived. The total percentages for each factory discussed in part 4.4 were obtained by tallying successive percentages appearing at each department (packing/sorting, drying, withering and boiler).

Table 5: Total working years for the workers in different areas of the three factories

	% of response											
No. of year worked	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
2-5 yrs	0.0	0.0	0.0	5.9	0.0	0.0	0.0	23.5	5.9	5.9	0.0	11.8
6-10 yrs	35.3	35.3	35.3	5.9	11.8	11.8	29.4	5.9	23.5	17.6	23.5	11.8

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

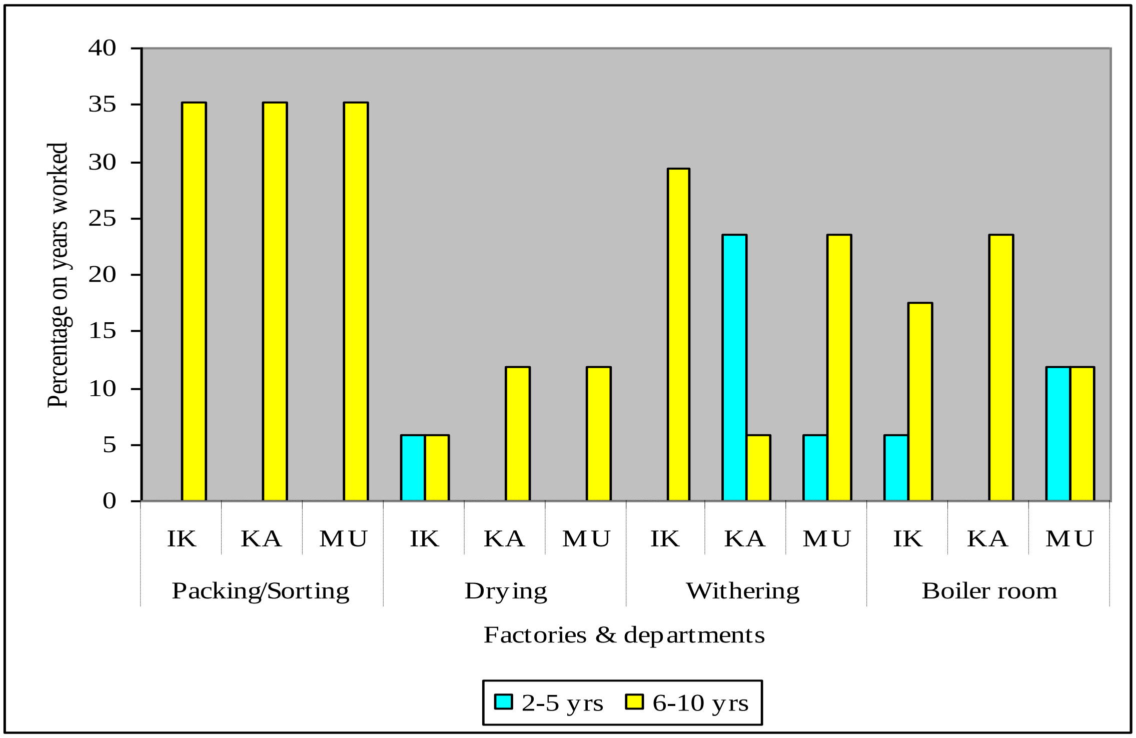

Figure 4: The working years for workers in different areas of the three factories

It is noted from Figure 4 that 88.2%, 76.5% and 82.4% of the employees at Ikumbi, Kambaa and Mungania tea factories respectively, had worked for 6 years and above. This indicated a fairly good degree of acclimatization.

Table 6: Total working hours for the workers in different areas of the three factories

	% of response											
Working hours	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
8 hours	11.8	5.9	11.8	0.0	5.9	0.0	5.9	0.0	17.6	0.0	5.9	5.9
More than 8 hrs	23.5	29.4	23.5	11.8	5.9	11.8	23.5	29.4	11.8	23.5	18	18

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

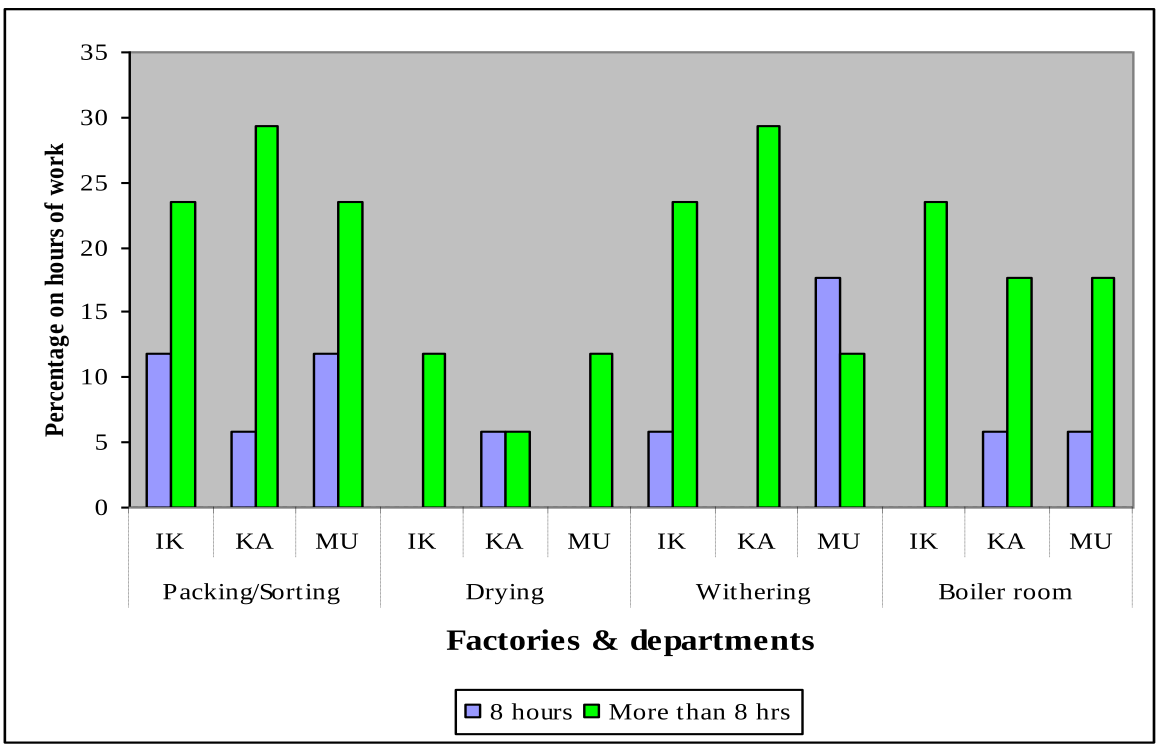

Figure 5: Daily working hours for the workers in different areas of the three factories

It is evident from Figure 5 that 82.3 %, 64.7% and 64.7% of employees at Ikumbi, Kambaa and Mungania tea factories, respectively, were working for over 8 hours, including overtime a day. While 17% of the employees at Ikumbi factory and a similar percentage at Kambaa tea factory were engaged for eight hours, Mungania tea factory had 35.3% of its employees who worked for the same period. Employees working in the boiler room, drying and packing/sorting sections worked for an average of 8 or more hours in a day, indicting continuous exposure to high temperature strenuous conditions within a working day.

Table 7: Employees' age brackets for the workers in different areas of the three factories

	% of response											
Age bracket	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
40yrs and below	29.4	23.5	17.6	11.8	5.9	11.8	23.5	29.4	23.5	17.6	17.6	23.5
40-65yrs	5.9	11.8	17.6	0.0	5.9	0.0	5.9	0.0	5.9	5.9	5.9	0.0

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

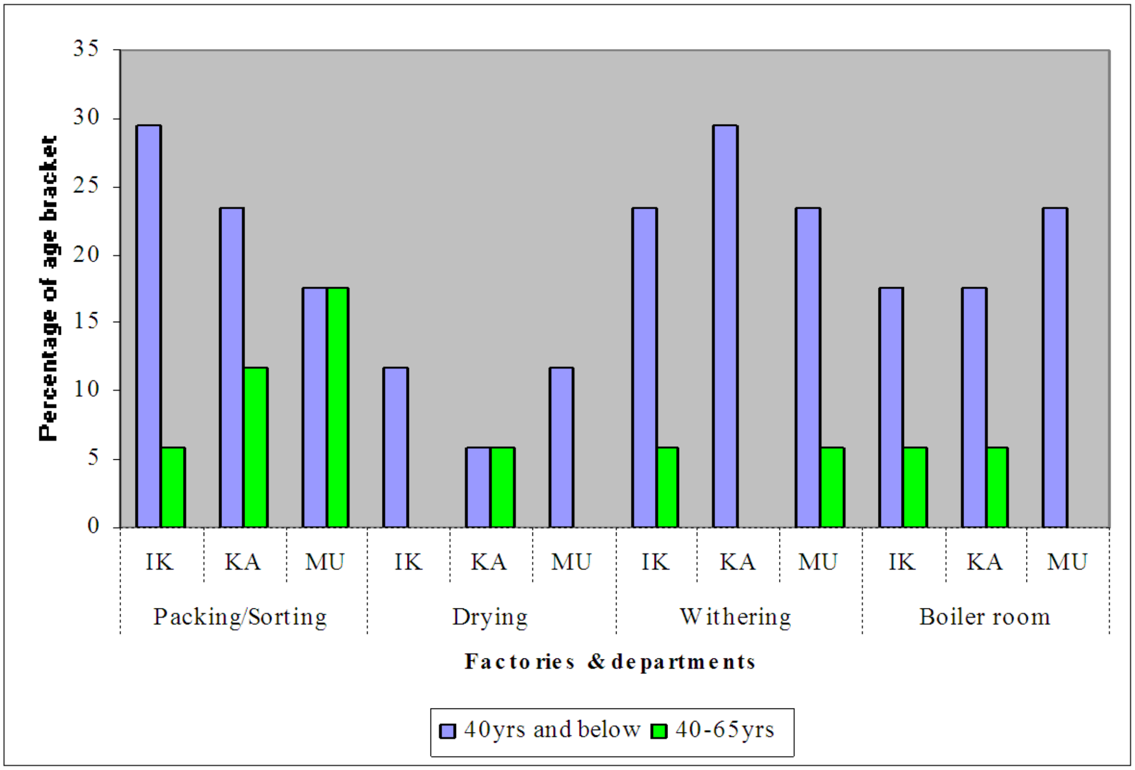

Figure 6: Employees' age brackets for workers in different areas of the three factories

The result of the study as indicated in Figure 6 showes that 76.4% of the respondents at Kambaa factory and a similar percentage at Mungania tea factory were in the age bracket of 40 years and below, indicating that this category of workers had heat tolerance capabilities. Similarly, 64.7% of the respondents in Ikumbi tea factory were below 40 years of age. Persons below forty years of age have high degree of heat tolerance capabilities than individuals of age between forty and sixty fives year age bracket who have a poorer adaptive characteristic (Nielsen, 2005). Despite the indoor environmental conditions, these categories of employees were less exposed. Another 23.6% of the employees for each; Kambaa and Mungania tea factories were above 40years age bracket which showed possibility of reduced heat tolerance.

Table 8: Work-rest regimen ratio in percentage of each hour for the workers in different areas of the three factories

	% of response											
Work-rest cycle ratio	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
75 Work 25 Rest, each hour	35.3	35.3	35.3	11.8	11.8	11.8	29.4	29.4	29.4	23.5	23.5	23.5

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

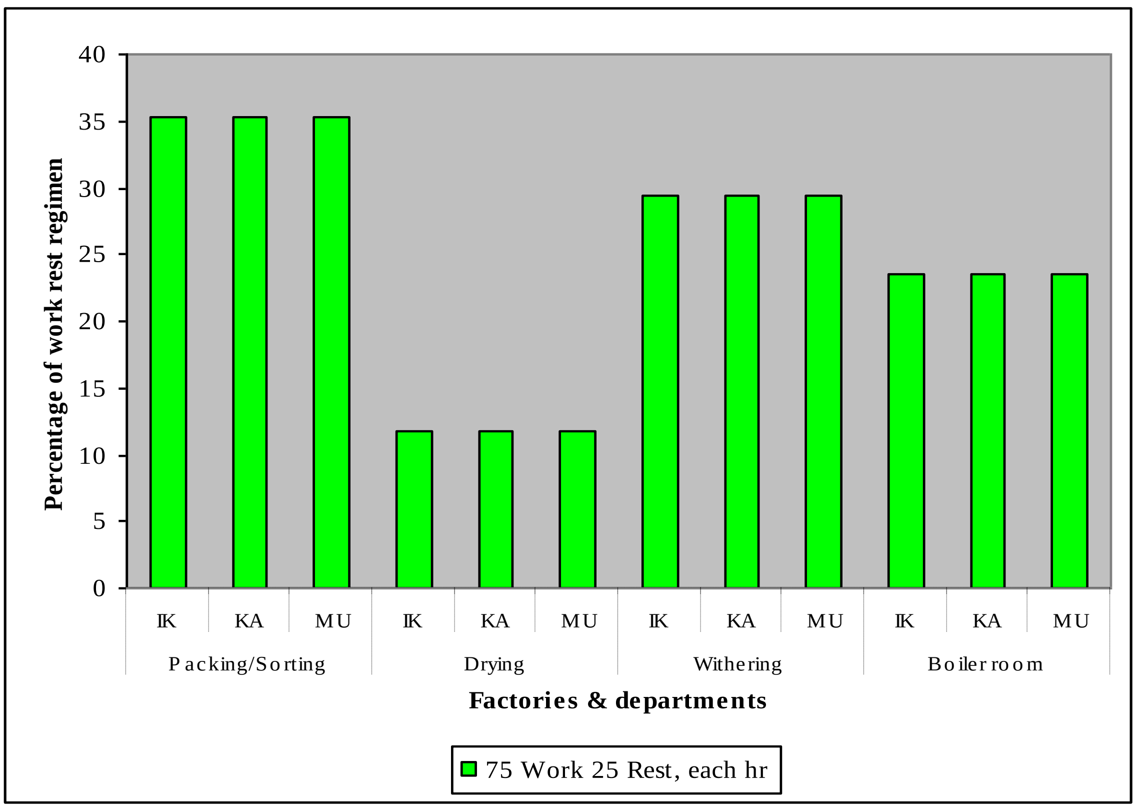

Figure 7: Work-rest regimen ratio in percentage of each hour for workers in different areas of the three factories

From Figure 7 above, results indicated that 100% of the respondents at each factory had a working and resting regimen of 75:25 ratio of each hour signifying workers interviewed had about 15 minutes of each hour to rest and 45 minutes of work in the indoor hot work environment. The pattern of work-rest regimen stated above was the trend of work practice in the facilities. All the respondents felt work-rest regimen of 75% work and 25% rest indicated a heavy workload in high temperature environment. There were no respondents in the working and resting regimen of 75:25 and 25:75 ratios despite being considered during the interview.

Table 9: Employees opinion on whether the indoor air was hot in different areas of the three factories

	% of response											
Feel on the indoor environment	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
Felt hot	11.8	25.5	11.8	5.9	11.8	5.9	0.0	0.0	0.0	23.5	24	24
Did not feel hot	23.5	11.8	23.5	5.9	0.0	5.9	29.4	29.4	29.4	0.0	0.0	0.0

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

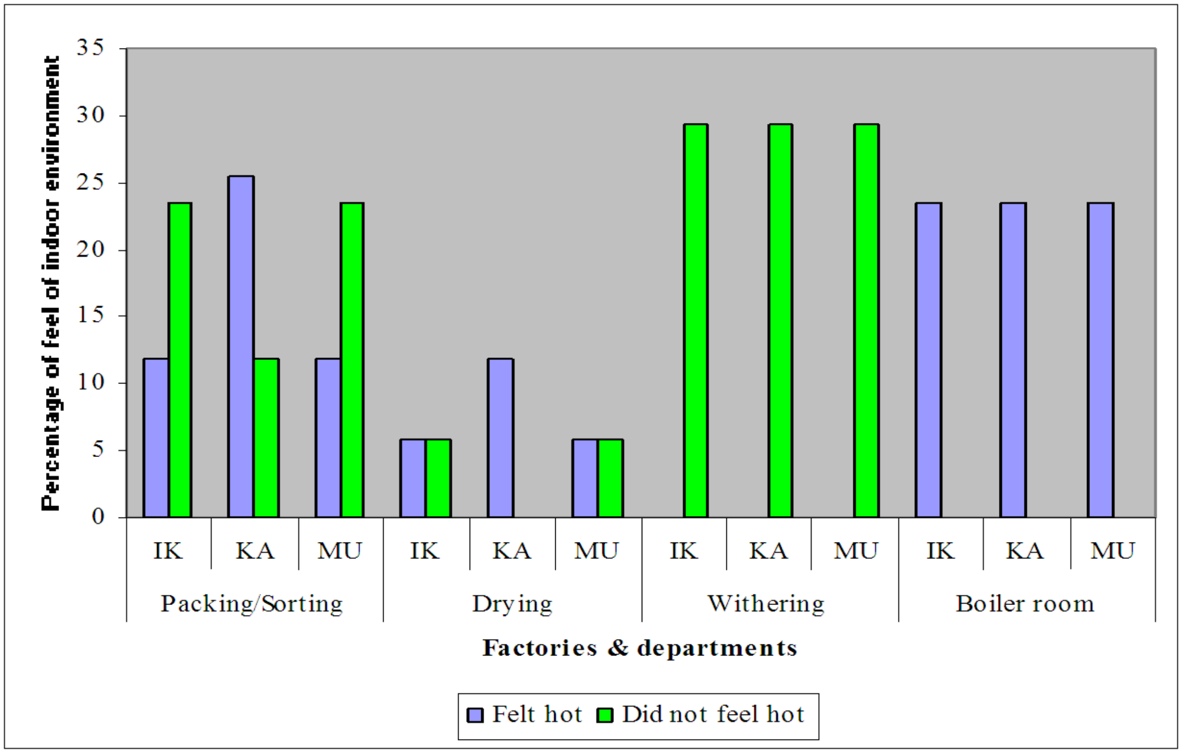

Figure 8: The employees' opinion whether the indoor air was hot or cold shown as a percentage of workers in different areas of the three factories.

Figure 8 shows that 41.2% of respondents in Ikumbi, 58.8% in Kambaa and 41.2% in Mungania had a feeling that work environment was hot during the daily performance of their tasks, showing existence of high temperature related discomfort during work process. All respondents in the boiler area in all the factories had a feeling that the work environment was hot. In all the three factories, withering section was noted to be the most comfortable to workers.

Table 10: Employees' sense of temperature fluctuation during the working day for workers in different areas of the three factories

	% of response											
Sense of temperature fluctuation	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
Fluctuated	29.4	29.4	23.5	5.9	0.0	0.0	17.6	11.8	17.6	23.5	12	18
Did not fluctuate	5.9	5.9	11.8	5.9	11.8	11.8	11.8	17.6	11.6	0.0	12	5.9

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

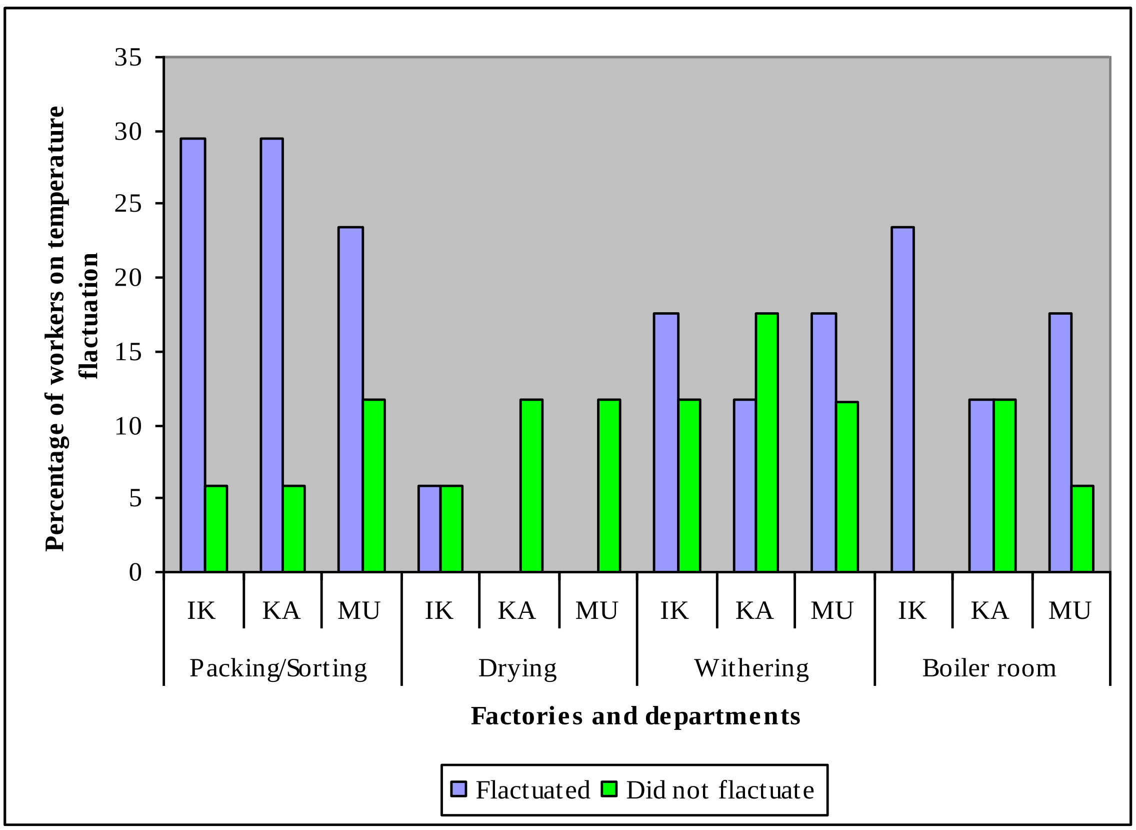

Figure 9: The employees' sense of temperature fluctuation during the working day for workers in different areas of the three factories

Figure 9 indicates that 76.4%, of the respondents at Ikumbi, 53% in Kambaa and 58.7% in Mungania tea factories acknowledged that temperature fluctuated during the normal working day, interfering with the process of acclimatization of the operatives in the exposed departments such as packing/sorting section. Failure to acclimatize the individual employees work output is compromised (Bligh and Johnson, 1978). The findings also indicted that 23%, 47.3% and 41.1% of the employees at Ikumbi, Kambaa and Mungania tea factories respectively felt that temperature did not fluctuate.

Table 11: Employees' opinion as whether there existed defects on plants that emitted excessive heat into work environment

	% of response											
	Packing/Sorting			**Drying**			**Withering**			**Boiler room**		
Plants with defects	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
Boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.5	24	24
Drier	5.9	5.9	5.9	11.8	11.8	11.8	0.0	0.0	0.0	0.0	0.0	0.0
Steam pipes	5.6	0.0	5.9	0.0	0.0	0.0	5.9	11.8	5.9	0.0	0.0	0.0
None	0.0	5.9	0.0	0.0	0.0	0.0	23.8	17.6	23.5	0.0	0.0	0.0

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

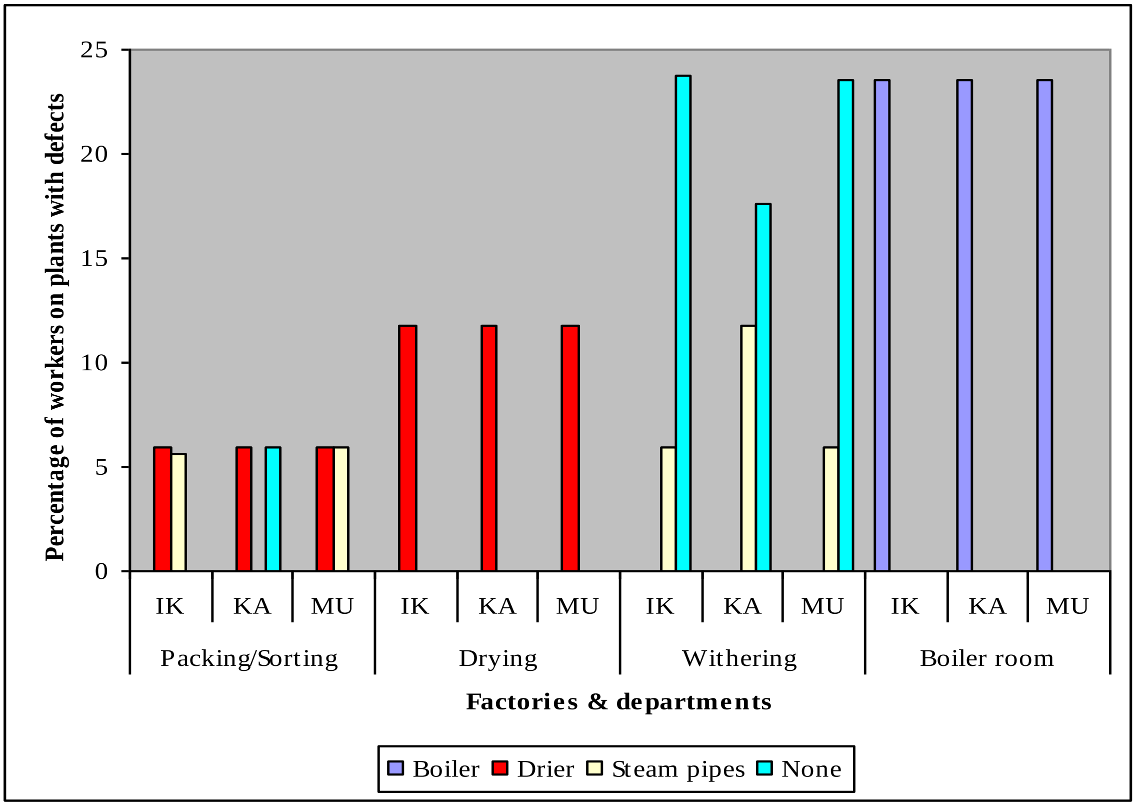

Figure 10: The employees' opinion as whether there existed defects on plants emitting excessive heat at their departments within the three factories

Figure 10 shows that 23.5% of the respondents in each of Ikumbi factory, Kambaa and a similar percentage at Mungania tea factory confirmed that the boiler plants had defects that contributed to excessive heat loss into the working environment. Similarly, 17.7% of the respondents in each of the three factories confirmed that driers had defects that caused excessive heat while 11.8% established that defects on steam pipes were contributing to excess heat to their working area. Further, 23.5% of the respondents in each of the three factories felt that there were no defects on heat emitting system within their internal work environment.

Table: 12 Employees who had knowledge of defects on systems that caused leakage of steam into working area influencing humidity levels.

	% of response											
	Packing/Sorting			**Drying**			**Withering**			**Boiler room**		
Defects on steam system that raised humidity	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
Defects	23.5	17.9	29.4	11.8	5.9	11.8	5.9	0.0	5.9	23.5	17.6	23.5
No defects	11.8	17.3	5.9	0.0	5.9	0	23.5	29.4	23.9	0.0	0.0	0.0

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

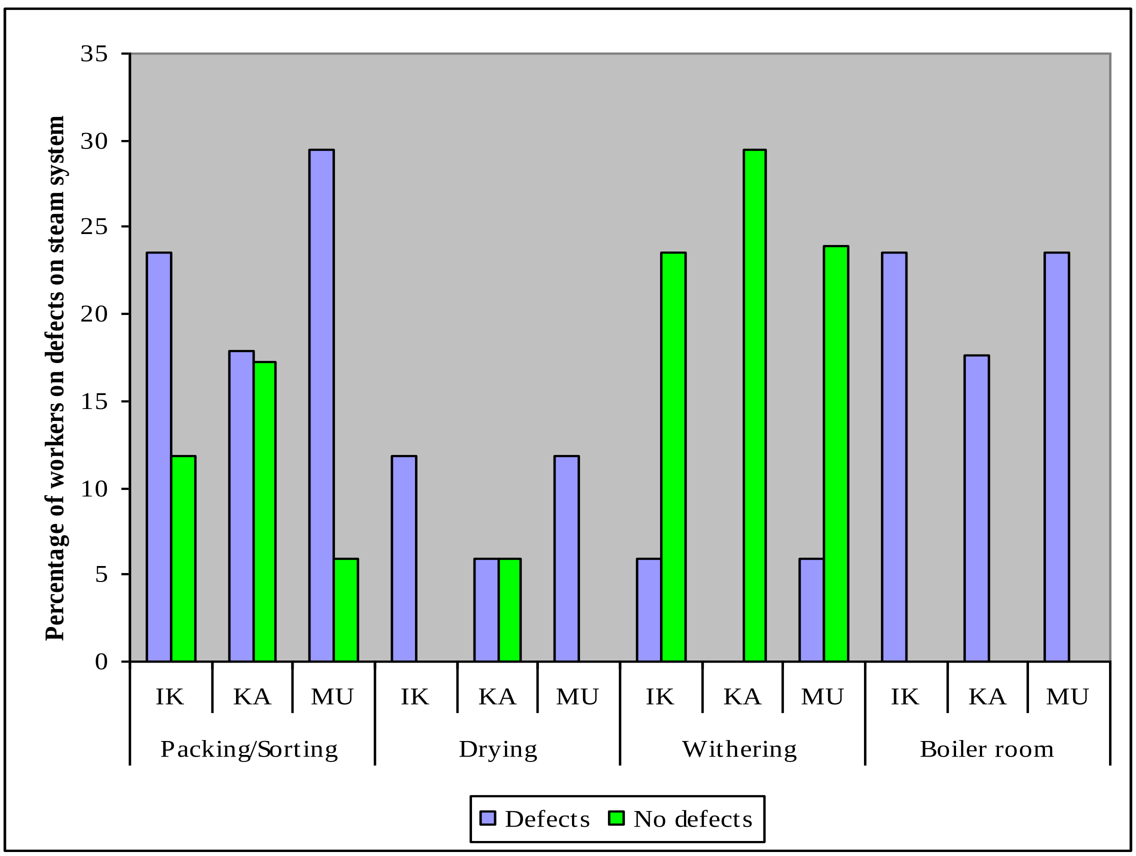

Figure 11: Knowledge of defects on plant systems that caused steam leakage into the working area that influenced humidity levels

On the knowledge regarding presence of defects on plant system that caused steam leakages 64.7% of employees at Ikumbi tea factory, 47.1% at Kambaa and 70.6% at Mungania tea factories were aware that there were equipment with defects. These equipment caused steam leakage into the indoor work environment and attributed to high relative humidity. The rest of the 35.3% of the respondents at Ikumbi, 53.0% at Kambaa and 29.8% at Mungania tea factories said that there were no any defects on plant steam system that attributed to increase of relative humidity at the workstation. Increase in relative humidity may have elevated further the indoor temperatures.

Table 13: Employees who wore vapour impermeable personal protective clothing

	% of response											
Wear-ing of vapour imper-meable protect-ion	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
Do not wear	35.3	35.3	35.3	11.8	11.8	11.8	29.4	29.4	29.4	23.5	23.5	23.5

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

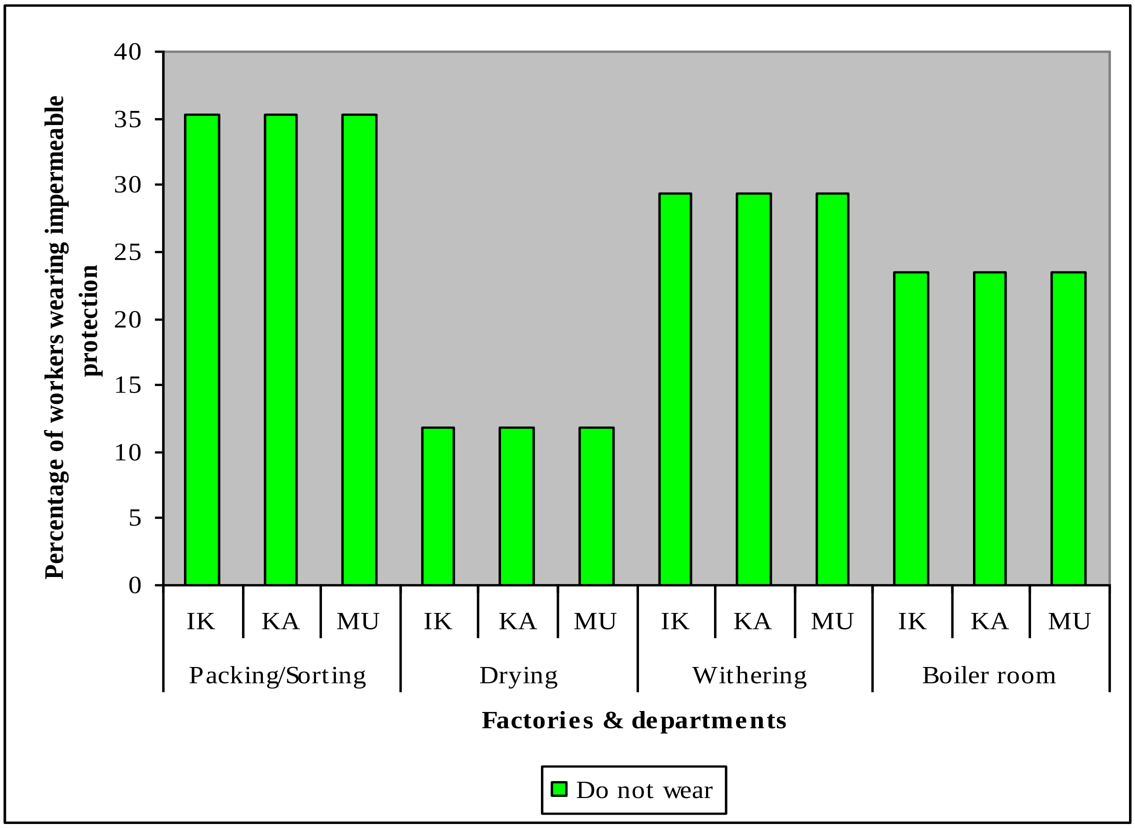

Figure 12: The percentage of employees that wore personal protective clothing that was vapour impermeable

The research further established that 100% of the respondents in each of Ikumbi, Kambaa and Mungania tea factories did not wear any impermeable personal or protective clothing during working hours. If employees had worn impermeable clothing then the level of discomfort would have arose from reason that body sweat would have been hampered from evaporating from the skin surface. All respondents wore vapour permeable protective clothing since that aspect was considered during the interviews.

Table 14: Employees sense of high or low humidity

	% of response											
Employee sense of humidity	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
High humidity	11.8	0	5.9	11.8	11.8	11.8	5.9	5.9	0	17.6	11.8	17.6
Low humidity	23.5	35.3	29.4	0.0	0.0	0.0	23.5	23.5	29.4	5.9	11.8	5.9

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

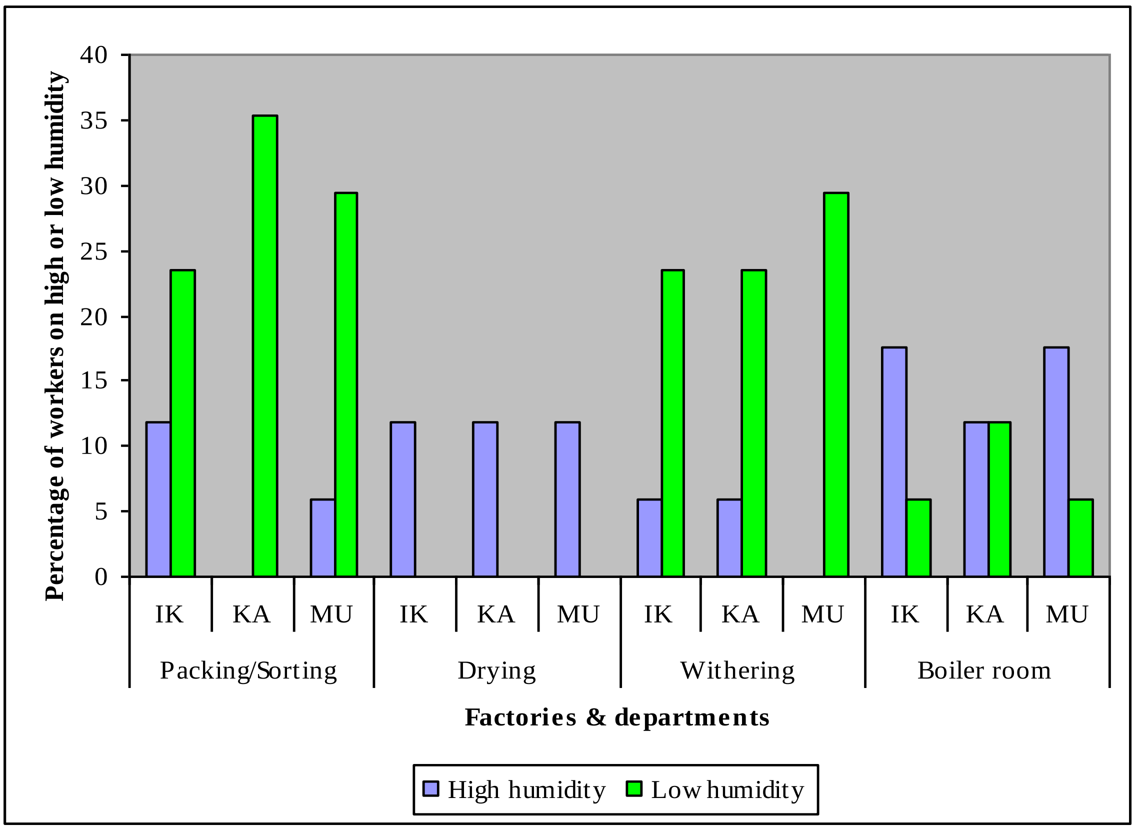

Figure 13: Employee that sensed working area to be having high or low humidity levels

From Figure 13 above the results indicated that 47.1% of the respondents at Ikumbi tea factory, 29.5% at Kambaa and 36.0% at Mungania tea factories felt that the indoor air had relatively high humidity in the working area leading to low evaporation cooling from their skin surface and thus increasing temperature related discomfort. High humidity was aggravated by steam that escaped from leaks on steam transmission pipes and surface moisture evaporation from fermenting tea. The most affected departments were boiler and drying areas. It was also noted also that 52.9%, 70.5% and 64.0% of the employees at Ikumbi, Kambaa and Mungania tea factories respectively felt that the humidity was low.

Table 15: Employees' feeling of their work in hot conditions

	% of response											
	Packing/Sorting			**Drying**			**Withering**			**Boiler room**		
Employees' workload	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
Moderate	11.8	5.9	11.8	5.9	5.9	11.8	17.6	29.4	29.4	5.9	5.9	5.9
Heavy	23.5	29.4	29.4	5.9	5.9	0	11.8	0	0	17.6	12	12
Very heavy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	5.9

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

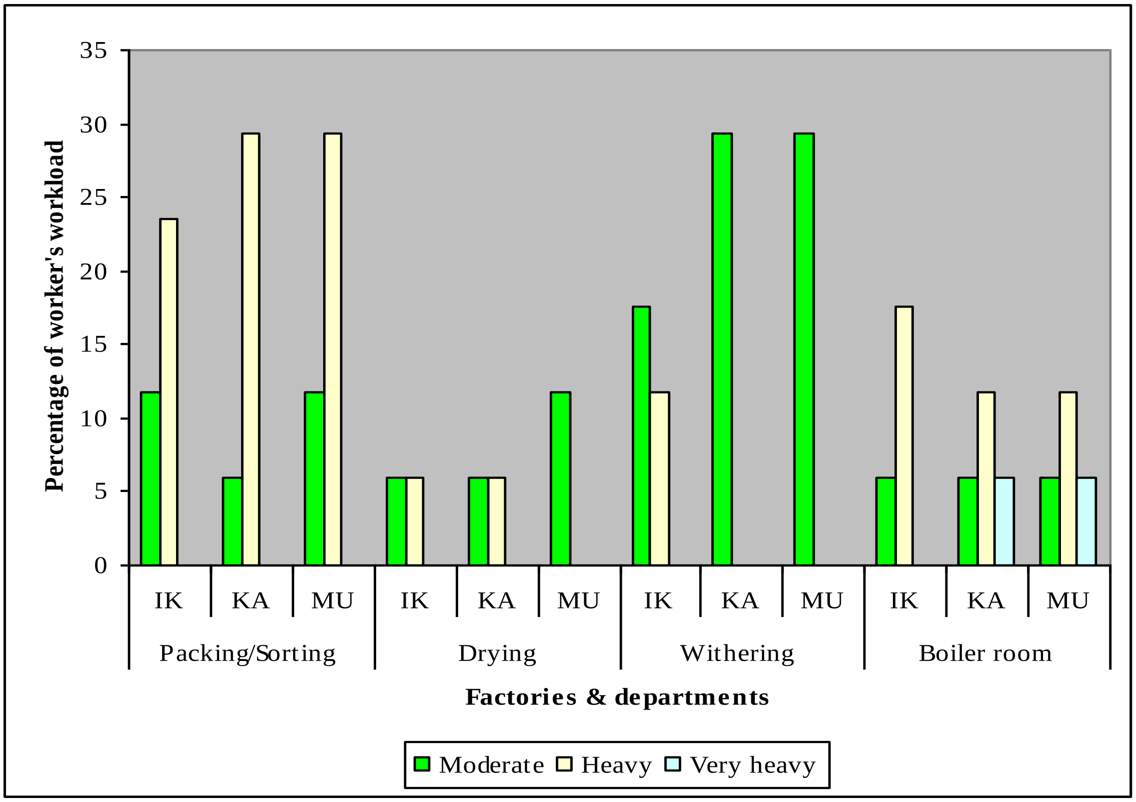

Figure 14: Expression of the employees feeling of their work in hot conditions

As indicted in figure 14, 41.2% of the respondents at Ikumbi tea factory, 47.1% at Kambaa and 41.2% at Mungania tea factories felt that their daily tasks were heavy while working in the factories' hot conditions. This reflected high metabolism rate and more heat generated from the body that could have led to uncomfortable work condition. Muscular work was associated with an increased in metabolism rate and thus rises in body temperature (Krake, 2006). A further 41.2% of the respondents at Ikimbi, 47.1% at Kambaa and 58.9% at Mungania tea factories had a less work intensity making them feel more comfortable at work. Only 5.9% of the respondents at Ikumbi factory and a similar percentage at Kambaa tea factories felt that their work was of extreme workload.

Table 16: Employees allowed to remove protective clothing

Removal of PPE	% of response											
	Packing/Sorting			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
Allowed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	5.9	11.8
Not allowed	35.3	35.3	35.3	11.8	11.8	11.8	29.4	29.4	29.4	17.6	17.6	11.8

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

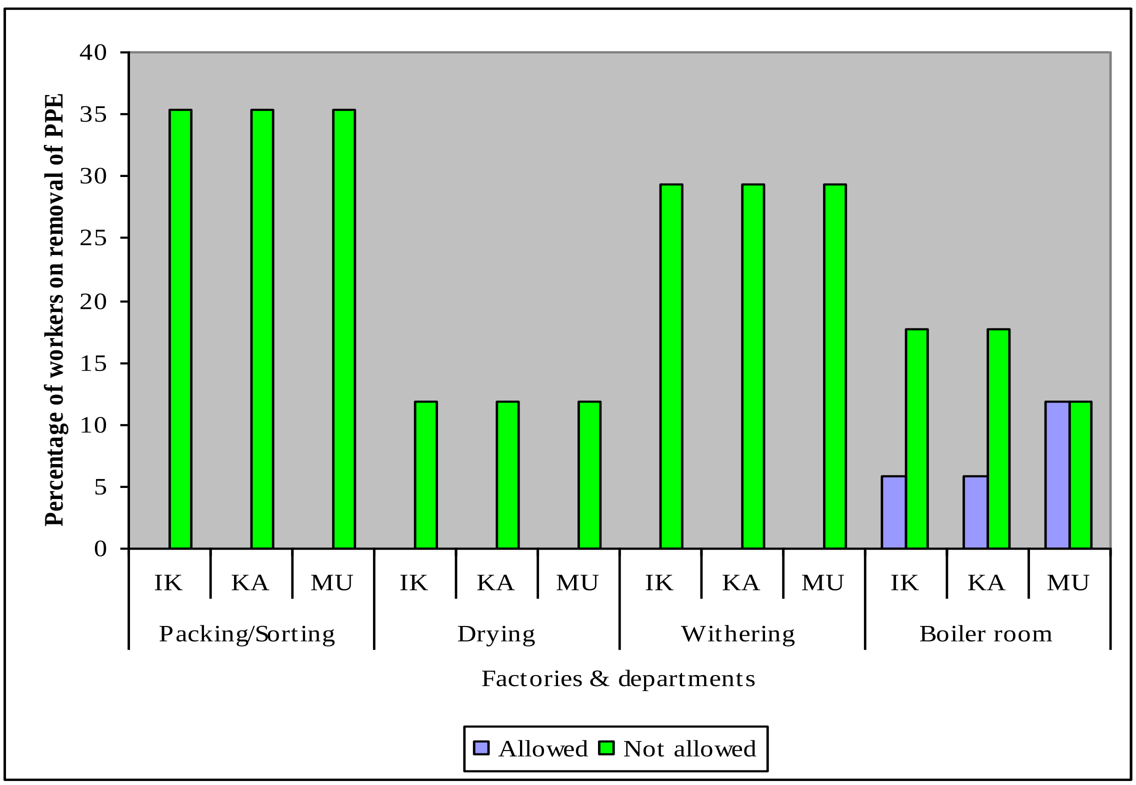

Figure 15: The employees allowed removing protective clothing during working hours.

The results on Figure 15 shows that 94.1% of the respondents at Ikumbi tea factory, 94.1% at Kambaa and 88.3% at Mungania tea factories confirmed that they were not allowed to remove their personal protective clothing to respond to indoor temperature changes at the working area, therefore feeling uncomfortable while working. The use of full personal protective clothing during working hours was mandatory as a company policy. However, 11.8% of the respondents at Mungania, 5.9% at Kambaa and another 5.9% at Ikumbi tea factories could remove protective clothing to respond to temperature changes though against the company policy. This affected the boiler section only.

Table 17: Employees using respiratory protection during work

Type of respiratory protection	**% of response**											
	Packing/Sorting			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
Dust mask	35.3	35.3	35.3	11.8	11.8	11.8	0.0	0.0	0.0	0.0	0.0	0.0
None	0.0	0.0	0.0	0.0	0.0	0.0	29.4	29.4	29.4	23.5	23.5	23.5

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

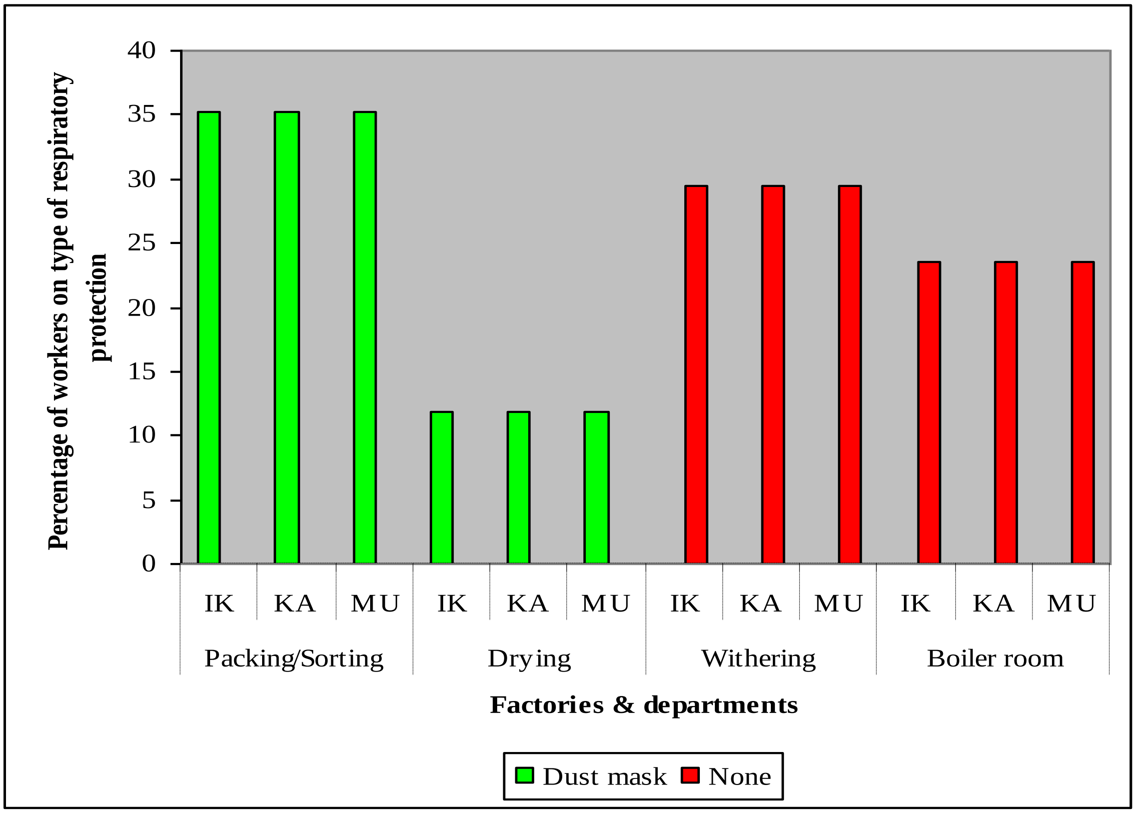

Figure 16: The employees using any type of respiratory protection during work

On the use of respiratory protection 47.1% of the respondents at each Ikumbi, Kambaa and Mungania tea factories, confirmed that they wore dust masks as protection of the respiratory system against tea dust at their work station, while the rest 52.9% also for each of the three factories, did not wear any type of respiratory protection. Those wearing masks limited the heat loss through respiratory track system therefore it made work in hot environment uncomfortable (Vroman et al., 1983*)*.

Table 18: Employees' feeling on workplace comfort.

	% of response											
Feeling on temperature comfort	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
Not comfortable	23.5	29.4	29.4	5.9	5.9	11.8	5.9	0.0	5.9	17.6	11.8	17.3
Comfortable	11.8	5.9	5.9	5.9	5.9	0.0	23.5	29.4	23.5	5.9	11.8	5.9

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

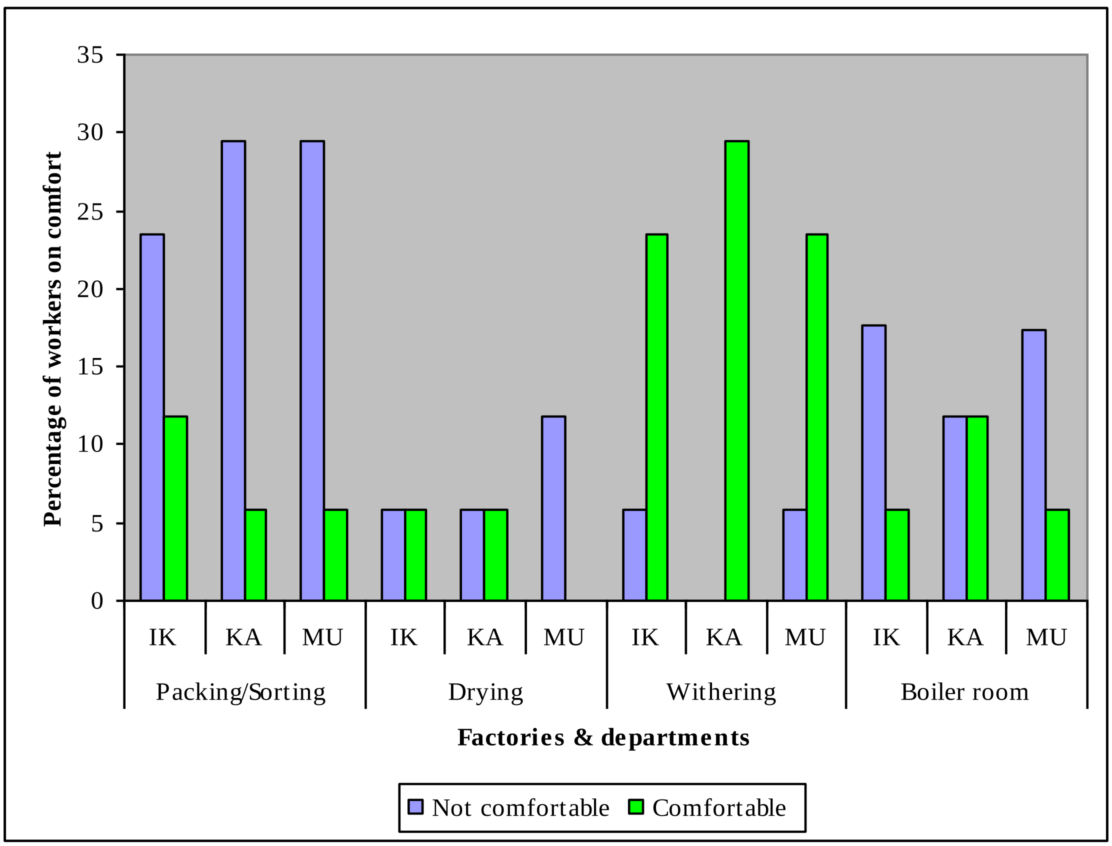

Figure 17: The feeling of employees' on workplace comfort.

It is noted from Figure 17 that 52.9% of the respondents at Ikumbi tea factory, 47.1% at Kambaa and 64.4% at Mungania tea factories felt that there were temperature related comfort challenges. This possibly led to fatigue during and after work. Also another response of 47.1% at Ikumbi, 52.9% at Kambaa and 35.3% at Mungania felt that, their sections were comfortable while working.

Table 19: Employees' frequency of drinking water.

	% of response											
Frequency of drinking water	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
Once	5.9	11.8	5.9	6.1	0	0	5.8	5.9	5.9	5.9	0	5.9
Twice	17.6	11.8	11.8	5.9	5.9	5.8	17.6	11.4	23.5	5.9	5.9	17.9
Thrice and more	5.9	17.9	11.8	5.9	11.8	5.8	5.9	0	0	11.8	17.6	5.9

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

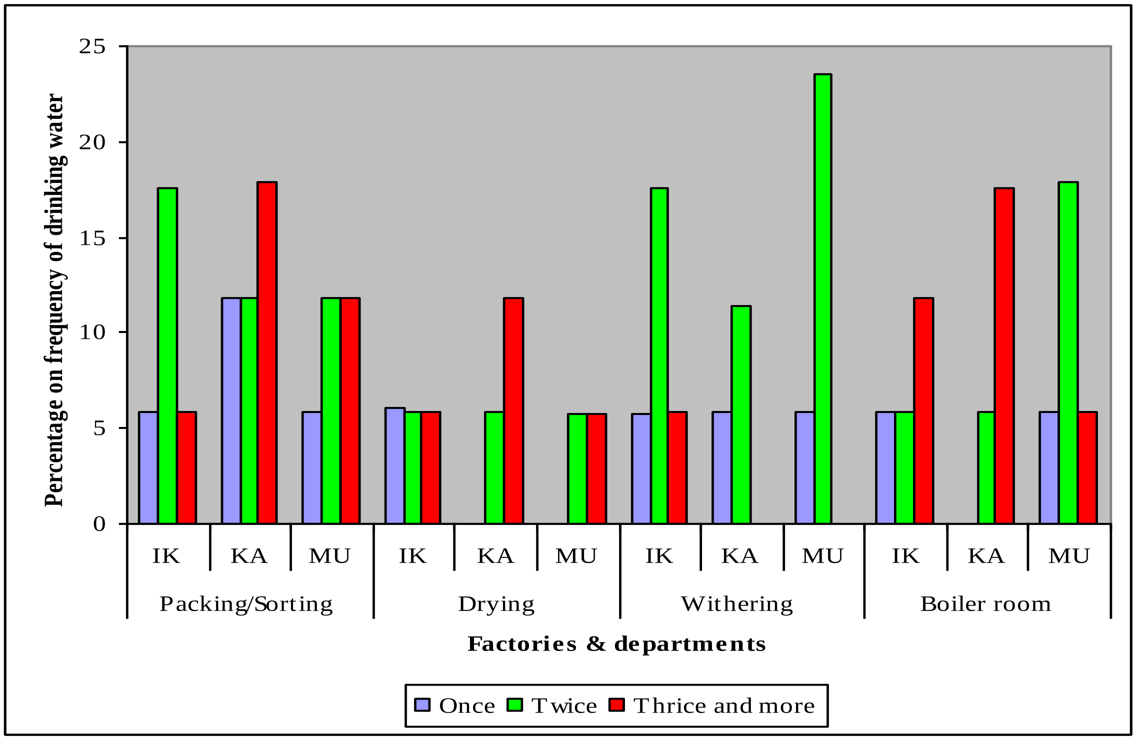

Figure 18: The employees' frequency of drinking water

It is noted from Figure 18 that 29.5%, 47.3% and 23.5% of employees at Ikumbi, Kambaa and Mungania tea factories respectively drank water thrice and more times in a working a day. The results also indicated that 47.0% at Ikumbi, 35.1% at Kambaa and 58.9% at Mungania tea factories consumed water twice in a day. Moreover 17.7% of the respondents in each of Kambaa and Mungania tea factories drank water once in a day while 23.5% of the respondents at Ikumbi tea factory also consumed water once.

Table 20: Estimated litres of water consumed per day

Litres of water consumed	% of response											
	Packing/Sorting			Drying			Withering			Boiler room		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
4.7lts & above	5.9	0	0	0	0	0	0	0	0	17.6	5.9	5.9
Between 4.7-2.4 lts	17.6	23.5	11.8	5.9	11.8	5.9	5.9	5.9	0	5.9	17.6	11.6
Below 2.4 lts	11.7	11.8	23.5	5.9	0	5.9	23.5	23.5	29.4	0	0	5.9

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

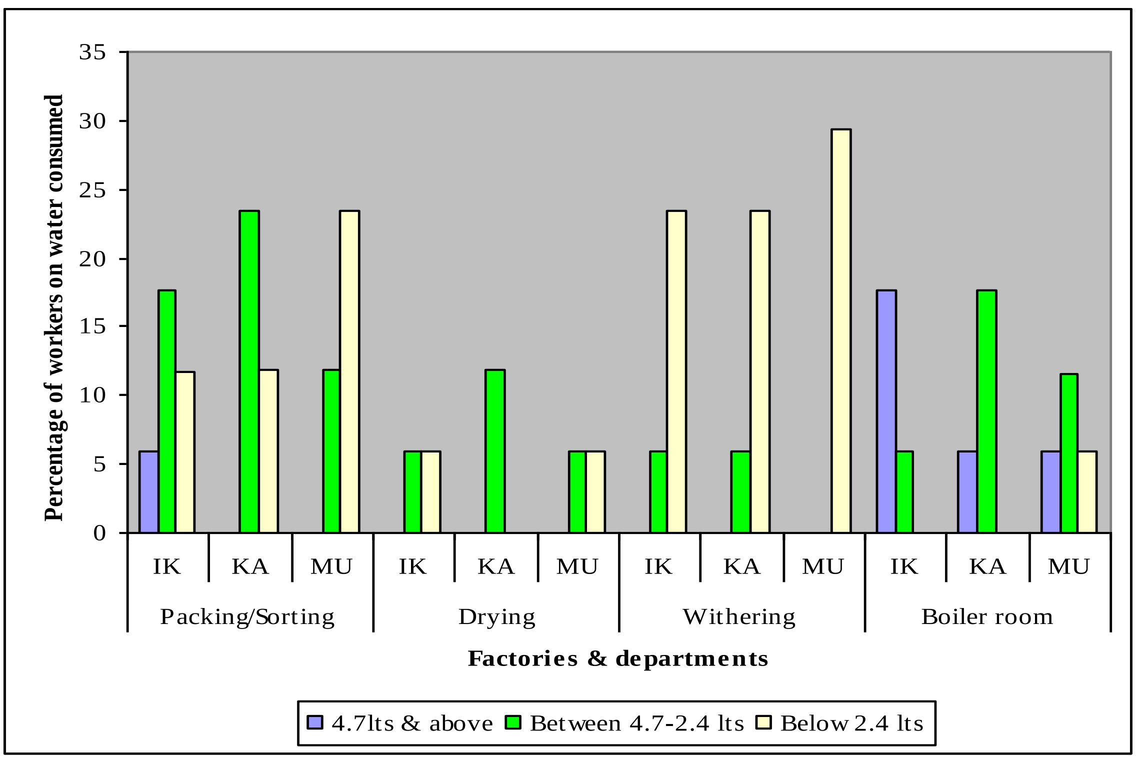

Figure 19: Estimated litres of water consumed per day by an employee.

Figure 19 shows that, 23.5% of the respondents at Ikumbi, 5.9% at Kambaa and another 5.9% at Mungania tea factories consumed water of about 4.7 litres and above per day. Another 35.3% of respondents at Ikumbi, 58.8% at Kambaa and 29.3% at Mungania tea factories consumed individually between 2.4 to 4.7 liters of water per day. A further 41.1% of the employees at Ikumbi, 35.3% at Kambaa and 64.7% at Mungania tea factories drank less than 2.4 litres of water in a day. Employees working in hot areas such as boiler, packing/sorting and drying sections had a tendency of consuming more water in response to the surrounding conditions.

Table 21: Percentage of work-load expected to be performed on the first day of work

	% of response											
Workload on first day of work	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
50% work, 50% rest	5.9	11.8	5.9	5.9	0.0	5.9	0.0	5.9	5.9	5.9	5.9	5.9
More than 50% work	29.4	23.5	29.4	5.9	11.8	5.9	29.4	23.5	23.5	17.6	17.6	17.6

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

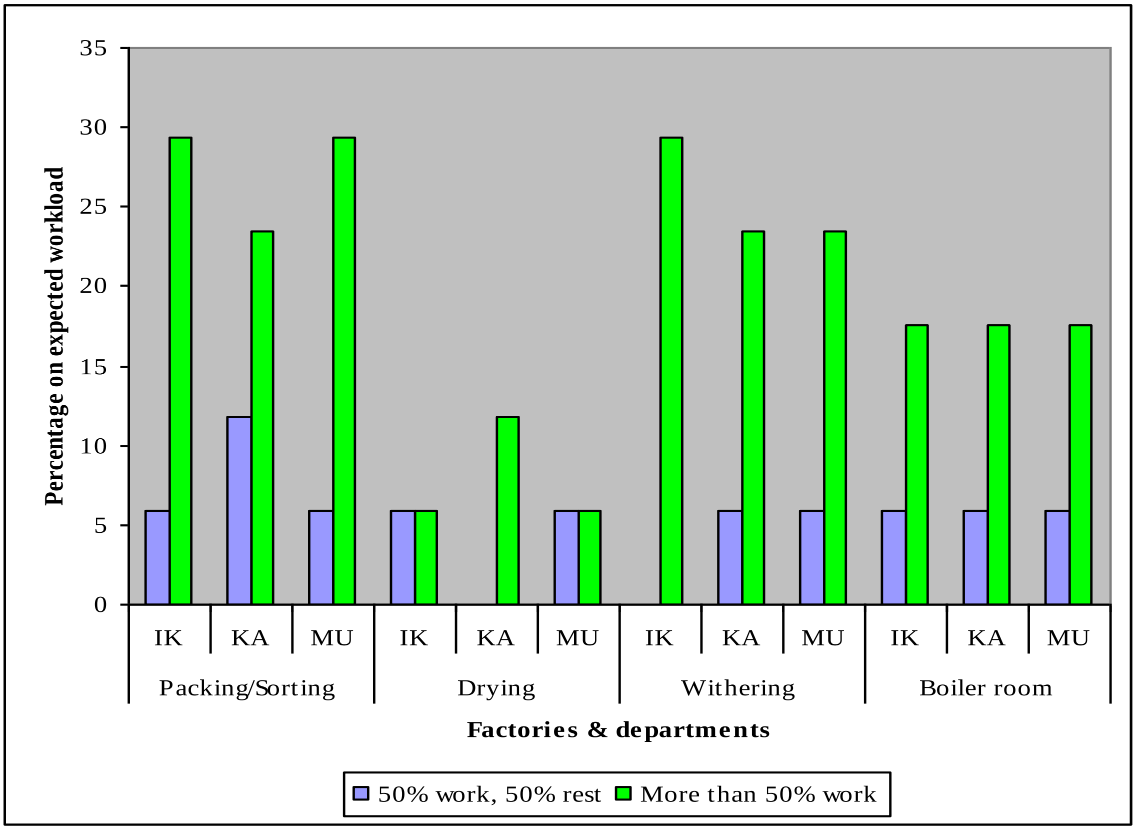

Figure 20: Percentage of work-load expected to be performed on the first day of work

Figure 20 shows that 76.4% of the respondents for each of Kambaa and Mungania tea factories were assigned work-load above 50 percent during the first day of work. Similarity, 82.3% of the respondents at Ikumbi tea factory were assigned similar work-load upon return from break. Kambaa and Mungania tea factories had each 23.6% of their respondent assigned work-load of 50 percent after return from a break. Furthermore Ikumbi tea factory had 17.7% of its employee also assigned 50 percent work-load.

Table 22: Duration of the recent break from work.

	% of response											
Recent work break	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
One week	11.8	17.6	5.9	0.0	0.0	0.0	5.9	11.8	11.8	5.9	0.0	0.0
Three weeks	23.5	17.6	29.4	11.8	11.8	11.8	23.5	17.6	17.6	17.6	23.5	23.5

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

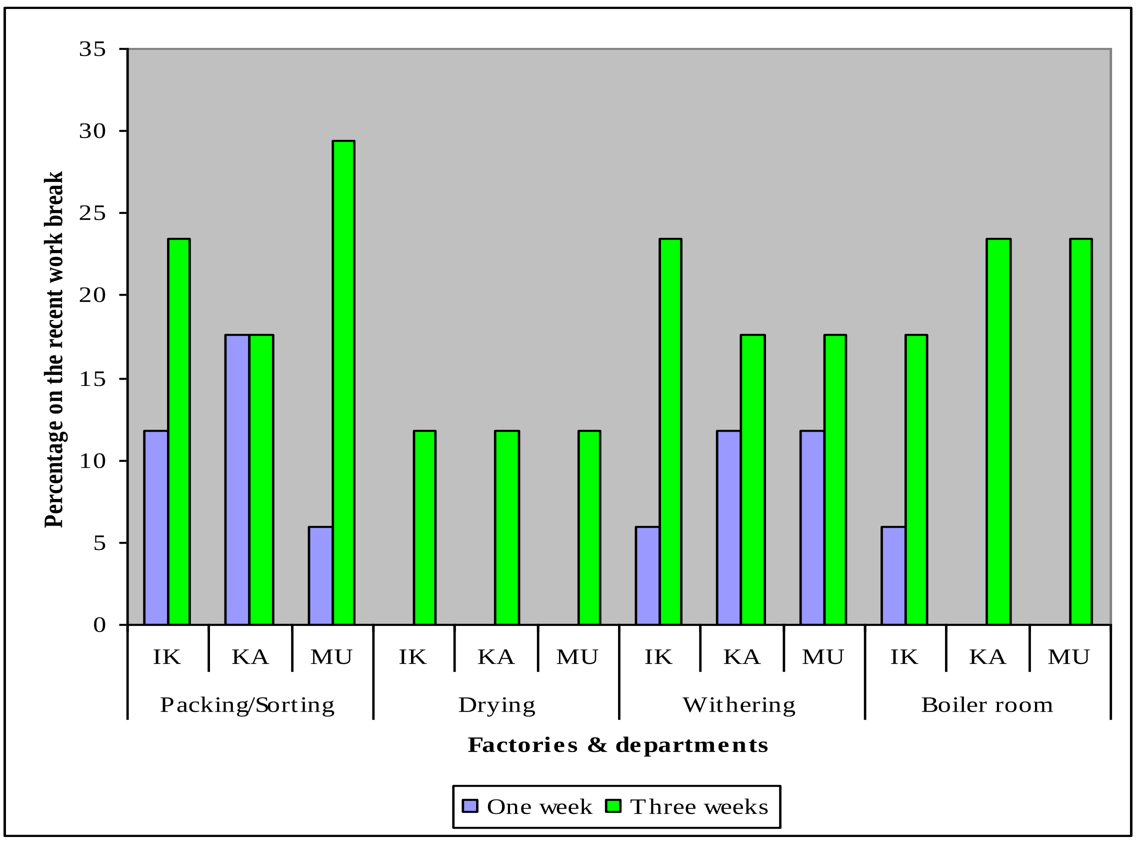

Figure 21: Duration of the recent break from work for employees.

With view to the most recent work break, 76.4% of the respondents at Ikumbi, 70.5% at Kambaa and 82.3% at Mungania tea factories acknowledged that their recent break from work exceeded three weeks therefore could have possibly virtually lost acclimatization. A further, 23.6%, 29.4% and 17.7% of the employees at Ikumbi, Kambaa and Mungania tea factories respectively had recent work break of one week.

Table 23: Employees' Body Mass Index.

	% of response											
Employees BMI	**Packing/Sorting**			**Drying**			**Withering**			**Boiler room**		
	IK	KA	MU	IK	KA	MU	IK	KA	MU	IK	KA	MU
Under weight	5.9	0.0	0.0	0.0	0.0	0.0	5.9	0.0	5.9	5.9	12	0.0
Acceptable	17.6	35.3	35.3	11.8	5.9	11.8	23.5	29.4	23.5	17.6	12	18
Over weight	11.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
Obese	0.0	0.0	0.0	0.0	5.9	0	0.0	0.0	0.0	0.0	0.0	0.0

Key: IK- Ikumbi, KA- Kambaa and MU- Mungania

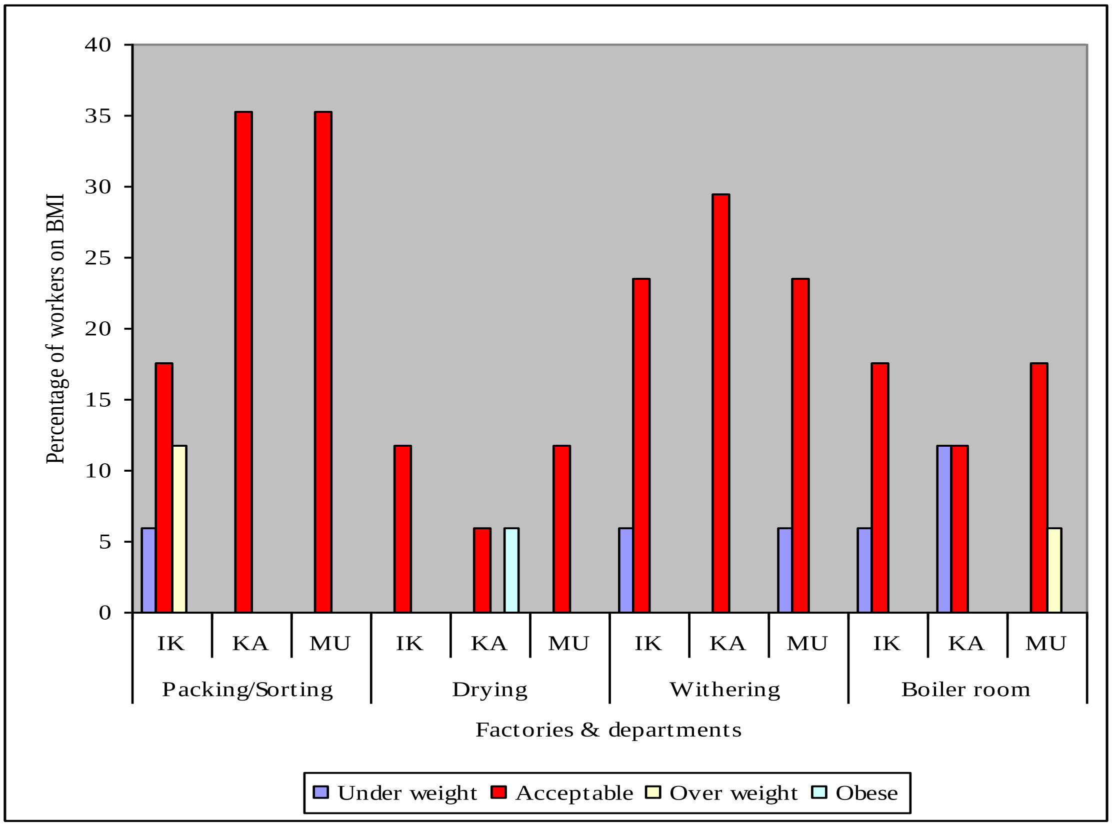

Figure 22: Employees' Body Mass Index

From the Body Mass Index calculated from the collected employees' body weight and height data the results in Figure 22 shows that 70.5% of the respondents at Ikumbi, 82.4% at Kambaa and 87.7% at Mungania tea factories had Body Mass Index (BMI) within the optimal weight range therefore they could adapt easily to hot working conditions. These categories of employees had a normal maximum oxygen uptake and high surface-area to body- mass ratio therefore can adopt easily to work in hot environment (Vroman *et al.*, 1983). This was an advantage to the worker with regard to the indoor high temperature conditions. Another, 11.8% at Ikumbi tea factory were over weight, 5.9% at Kambaa were obese and similarly 5.9% at Mungania tea factory were over weight. Employees who were overweight or obese as per the ratings were disadvantaged when working in hot conditions.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

One of main reason for doing the research was to determine occupational heat and environmental factors that affected employees' comfort at work. It is clear that employees working at the boiler, drying and packing/sorting areas at Ikumbi, Kambaa and Mungania tea factories were exposed to WBGT index of above 25.9^{o} C. Therefore these employees were exposed to high occupational heat causing discomfort, according to permissible exposure threshold limit values for work in hot environment as shown in tables 2 and metabolic work-load of activities in table 4.

For the three factories packing and drying sections had the highest air temperature recorded causing discomfort to employees working there. This was determined based on 21^{o} C provided by the proposed norms for environmental factors as shown in Table 1. Departments such as boiler, CTC and billeting also exceed the proposed air temperature but not across all factories. The radiant temperature determined at the three factories indicated the boiler, drying and packing departments exceeded 21^{o} C causing workers' discomfort. Relative humidity went above the upper limit of the 30-70% comfort range for the drying and packing departments across all the factories. Sections such as boiler, CTC, withering and billeting also exceed the proposed comfort range but not across factories. High relative humidity was attributed to driers, steam pipes and boilers. All departments within the three factories with an exception of Kambaa tea factory had air speed within the comfort range of 0.05-0.1m/s.

Occupational heat personal factors showed that employees had varying circumstances in relation to those factors. It was clearly noted that over 70% of employees in the three factories had worked for more than six years and were therefore acclimatized. Furthermore over 60% of the respondents had a daily exposure of eight or more hours making them consistently exposed to heat. Employees that were below the age of 40 years were over 60% at all the three factories therefore able to tolerate hot conditions. For the three factories all employees had work-rest regimen of 75% work and 25% rest showing a heavy workload in high temperature environment making it uncomfortable to work. It was concluded that over 50% of the employees were uncomfortable because of they felt hot while working and also experienced temperature fluctuations. Over 10% of the respondents in the three factories identified boiler, drier or steam pipes to be defective causing humidity and air temperature to raise henceforth discomfort. The results of the three factories also indicated that over 90% of the employees were restricted to take off protective clothing in response to hot environment raising employees' discomfort. For each of the three factories 47.1% of the employees wore respiratory protection raising discomfort. Since none of the employees wore impermeable protective clothing, this resulted in an increase of comfort. Over 20% of each of the three factories consumed water more than thrice a day therefore raising comfort because of fluid replacement in the body system. It was concluded that over

70% of the employees in all factories were assigned work-load above 50 percent during the first day of work and had a recent break from work exceeding three weeks resulting to discomfort since they had lost acclimatization. Finally, over 70% of the employees in the three factories had Body Mass Index (BMI) within the optimal weight range therefore they could adapt easily to hot working conditions resulting in an increase in comfort.

The research was able to identify significant factors that contributed to occupation heat discomfort to employees at the boiler room, drying and packing /sorting areas. Some of the gaps identified were:-

i. Employees engaged on manual stocking and supplying firewood boilers with wood fuel;
ii. Employees supplying boilers with firewood were not provided with face shield and body suits specifically designed to protect them against the heat intensity while factoring workers comfort;
iii. The employees in all the affected areas (boiler, drying and packing/sorting) have not been trained on how to react to the existing condition;
iv. There existed leaking steam pipes that had not been repaired to fully seal the system. Lagging of steam pipes was also not enhanced to prevent heat loss;
v. Boilers' and driers' surface had not been re-treated on the surface to prevent emissivity and

vi. Packing/sorting and drying areas had limited ventilation affected air flow within the factories.

Measures to be taken by the management to reduce the impact of occupational heat discomfort are discussed in section 5.2 under recommendations.

5.2 Recommendations

At the three factories studied, some degree or level of high occupational heat discomfort could be tolerated; nevertheless control measures could be put in place whenever applicable. There are two approaches that could be used to mitigate the negative impacts. These include both engineering and administrative controls as discussed below:-

i) Engineering controls

- Heat generated by the two boilers and 3 driers in each factory could be effectively regulated by reducing emissivity by treating the surface with aluminium paint;
- Effectively lagging and cladding the steam pipes running from the boilers to the driers;
- When not attending to the boiler the workers could stand behind the heat reflective barrier;
- At the sorting/packing area in the three factories heat removal could be achieved by exhaust opening (natural draft or mechanically operated) and

- For the boilers room operations firewood stocking and supply could be mechanized by use of a conveyor system.

ii) Administrative controls

- Education & training for exposed employees on early signs and symptoms of heat fatigue, heat exhaustion and discomfort;
- Workers at the boiler section in the three factories should be provided special heat resistant body suit and a face shield that does not hinder sweating;
- The management to ensure that employees are trained on accidents or illnesses reporting.

REFERENCES

1. **American Conference of Governmental Industrial Hygienist**, 1991. Threshold limits values. Heat stress. ACGIH, Cincinnati.
2. **American Conference of Governmental Industrial Hygienist**. 2002. Heat Stress and Heat Strain, Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. ACGIH, pg 170-178.
3. **Astrand, P. O.** and **Rodahl, K**. 1992. Textbook of work physiology. McGraw-Hill, New York.
4. **Avellini, B. A., Shapiro, Y.** and **Pandolf, K. B.** 1992. Physiological responses of men and women to prolonged dry heat exposure. Aviat. Space. Environ. Med., 51, 1081-5.
5. **Bligh, J.** and **Johnson, K. G**. 1978. Glossary of terms of thermal physiology. J Appl. Physiol., **35**, 941-61.
6. **Davies, C. T. M., Brotherhood, Collins, K. J., Dore, C., Imms, F.** and **Musgrove, J.** 1976. Energy expenditure and physiology performance of Sudanese cane cutters. Br. J. Ind. Med., 33, 181-6.
7. **Diberardinis, L. J.** 2006. Hand book of Occupational Safety and Health. New York, US. Wiley-Interscience Publication.
8. **Fanger, P. O.** 1973. Thermal Control, MC Graw Hill Book company London.
9. **Hancock, P. A.** 1981. Heat stress impairment of mental performance: A revision of tolerance limits. Aviat. Space. Environ. Med., 53, 177-80.

10. **Health Safety Executive,** 2006. Heat Stress, [internet]. Available at http: // www.hse.gov.uk / temperature/ information / heat stress / wet bulb. htm/ [Accessed 13/06/2009].

11. **ILO.** 2006 Occupational Hazards and Controls**,** [Internet]. Available at: http// www. Ilo.org/safework_bookshelf/english?contend & nd. [Accessed 14/01/2010].

12. **Iran. J. Environ. Health Sci. Eng**. 2008. Heat Exposure Assessment in the Working Environment of a glass manufacturing unit, Vol.5, No. 2, pp. 141-147. [Internet]. Available at: http://diglib.tum5.ac.ir/pub/magmng/pdf/6116.pdf. [Accessed 5/5/2010].

13. **Jeyanatnam, J.** 1992. Occupational Health in developing countries. Industrial hygiene- developing countries. Walton Street, UK, Oxford University Press. pg 156-167.

14. **KTDA Limited.** 2008. Company Highlights. [Internet]. Available at: http// www.ktdateas.com [Accessed 25/01/2010].

15. **Khogali, M.** 1992. Heat. Walton Street, UK, Oxford University Press.

16. **Kombo, D. K.** and **Tromp, D. L. A.** 2006. Proposal and thesis writing: An Introduction. Nairobi: Paulines publications Africa.

17. **Krake, A. M.** 2006. Extremes of Temperature. 530 Walnut Street Philadelphia, US.

18. **Levy, B. S., Wegman, D. H., Baron, L. S** and **Sokas, R. K. ed.** 2005. Occupational and environmental health, recognising and preventing disease and injury.5th ed. Philadelphia, USA. Lippincott Williams & Wilkins.

19. **Lotens, A. W.** 2005. Heat exchange through clothing. Geneva. International Labour Organization, 42,
20. **Meese, G.B**. 1988. The effects of moderate thermal stress on comfort and productivity. In Occupational medicine, (ed. C. Zenz), pg. 363-82. Year Book Medical Publishers, Chicago.
21. **Mottair, Z.,** 2004. Feasibility Study on Estimation of Cost of Workplace Accident, Work-related ill health and non-injury. [Internet]. Available at: http://www.osha.gov/SLTC/etools/safetyhealth/mod1_costs.html[accessed 22/10/2008].
22. **NASA Jet Propulsion laboratory,** 2006, [Internet]. Available at: http// www. iso. org. catalogue_detail. htm? Csnumber=13895 [Accessed 13/05/2010].
23. **Nielsen, B.** 2005. Effect of heat stress and work in the heat. Geneva. International Labour Organization.
24. **NIOSH,** 1986. Occupational respiratory disease, Cincinnati, OH: U.S. Department of Health and Human Services. [Internet]. Available at: http://www.osha.gov>technical links [Accessed 2/25/2009].
25. **NIOSH/CDC,** 1998. Working in Hot Environment, NIOSH Publication No 86-112, [Internet]. Available at: http://www.cdc.gov/niosh/hotenvt.html [Accessed 2/25/2009].
26. **Nunneley, S. A.** 2005. Prevention of heat stress. In Encyclopaedia of occupational health and safety, (5^{th} edn), 42, International Labour Organization, Geneva.
27. **Ogawa, T**. 2005. Heat Disorder. Geneva, International Labour Organization.

28. **OSHA Technical Manual,** 1998. Heat Stress. [Internet]. Available at: http: // www.osha.gov/dts.htm/. [Accessed 16/09/2009].

29. **Piombino, L.** 2005. Tea industry. Encyclopedia of occupational health and safety, (5th edn).International Labour Organization, Geneva.

30. **Rodahl K.,** 2002, Occupational Health Conditions in extreme Environment,[Internet]. Available at: http// www. Annhyg. Oxfordjournals.org/content/4713/241.full (factors affecting physical performance). [Accessed 14/06/2010].

31. **Shapiro, Y., Magazanik, A., Udassin, R., Ben-Baruch, G., Shvartz, E.,** and **Shoenfeld, Y.** 1979. Heat tolerance in former heatstroke patients. Ann Intern Med., 90, 913-916.

32. **Smith et al. (1988)**. Investigation into the performance of strenuous work at high environmental temperatures – The relationship between heart rate and a fixed work/rest ratio. International Journal of Industrial Ergonomics Vol 2. pg 131-141.

33. **Stranks, J.** 2006. Health and Safety pocket book. The compact first point of reference for Occupational Safety and Health. Amsterdam, UK. Butterworth - Heinmann.

34. **Venetta, M. A.** and **Collipi, R. Jr**. 1999. Heat Stress. North Andover, MA.

35. **Vroman, N. B., Buskirk, E. R.,** and **Hodgson, J. L.** 1983 Cardiac output and skin blood flow in lean and obese individuals during exercise in the heat. J. Appl. Physiol., 55.

36. **Weiner, J. S.** and **Hutchinson, J. C. D**. dry-bulb (1992). Hot humid environment: its effect on the performance of a motor coordination test. Br. J. Ind. Med., 2, 154-7.

37. **W.H.O.,** 2006**.** Body Mass Index [Internet]. Available at: http// www.who.int/bmi/index.jsp. [Accessed 14/07/2010].

38. **Workplace Health and Safety Bulletin**, Worksafe Alberta, [Internet]. Available at: http// www.worksafely.org [Accessed 13/06/2008].

39. **Work Safe Alberta,** 2006**.** Preventing Heat Stress at Work. [Internet]. Available at: http://www. Worksafebc.com/../heat_stress.pdf [Accessed on 6/13/09].

QUESTIONNAIRE

IMPACT OF WORKPLACE TEMPERATURE IN TEA PROCESSING FACTORIES: CASE STUDY OF SMALL SCALE TEA PRODUCERS

This study is aimed at establishing the impact of workplace temperature in the factories. The finding of this research will be used in designing appropriate policies and mitigation measures with view to solving the problems related to thermal environment.

Instructions

Please circle the appropriate answer to each question.

1. For how long have you been working in the factory?

    a) Less than 2 years
    b) Between 2 to 5 years
    c) Between 6 to 10 years
    d) More than 10 years

2. How long do you work inside the factory in a normal working day?

    a) 4 hours
    b) 6 hours
    c) 8 hours
    d) More than 8 hours

3. Consider your age, which age bracket do you fall into?

    a) 40 years and below
    b) 40 – 65 years

4. While working in the factory, what is your work- rest cycle % ratio of each hour?

a) 75: 25

b) 50: 50

c) 25: 75

5. During a normal working day does the air feel hot during work performance?

a) Yes

b) No

6. Does the temperature fluctuate in the workplace during your normal working hours?

a) Yes

b) No

7. Do you experience any gaps on the heat emitting sources that cause excessive heat into your working environment? If yes state the source?

a) Boiler

b) Drier

c) Steam piping

d) None

8. Among the equipment installed in the factory is there equipment that defects and hence caused leakage of steam into work environment?

a) Yes

b) No

9. Consider the PPE you wear in your section, do you feel that the PPE is vapour impermeable?

a) Yes

b) No

10. Do you complain that the air is humid?

a) Yes

b) No

11. While performing work do you think your work rate is light, moderate, heavy or very heavy in warm or hot conditions?

a) Light work – two arms, hand and arm

b) Moderate – hand, arm work, arm, leg work

c) Heavy – body work

d) Very heavy – body work

12. While performing your duty in the factory are you permitted to alternate your PPE or personal clothing in response to thermal conditions?

a) Yes

b) No

13. Do you wear respiratory protection during work?

a) Respirator

b) Dust mask

c) None

14. Do you think that there is a thermal comfort problem while performing your work?

a) Yes

b) No

15. How frequent do you drink water within a normal working day?

a) Once

b) Twice

c) Three times and above

16. By estimate, how many litres of water do you consume per day?

a) Above 4.7 litres

b) Between 2.4 - 4.7 litres

c) Below 2.4 litres

17. As a new employee (if applicable), what percentage of work-load are you expected to perform on the first day of employment?

a) 50% workload and 50% exposure time

b) More than 50% workload and more 50% exposure time

18. Consider your most recent break from work indicate how long was the break?

a) One week (quarter – two thirds loss of acclimatization)

b) Three weeks (virtually loss of acclimatization)

19. What is your average height? ....

20. What is your body weight? ....