Heat stress is the net (overall) heat burden on the body from the combination of the body heat generated while doing any activity, environmental sources (air temperature, humidity, air movement, radiation from the sun or hot surfaces/sources) and clothing requirements (ACGIH 2010). The negative impacts of increased temperature may progressively increase in developing countries especially in tropical countries like India. Increase in level of heat pose significant risk to individuals especially to the elderly, the very young and the chronically ill (Joon et al 2012). Heat-related illnesses include heat rash, heat exhaustion, heat cramps and heat stroke. Symptoms can range from profuse sweating to dizziness, cessation of sweating and collapse (Parson 2003).

1. PHYSIOLOGY OF THERMOREGULATION:

The internal temperature (core) of healthy human body should be maintained around 37°C for the various metabolic processes to function at optimum range inside the human body (Parson 2003). Variations, usually of less than 1°C occur with the time of the day, level of physical activity or emotional state (Kelly GS 2007). A change of body temperature exceeding 1°C occurs only during illness or when environmental conditions surpass the body's ability to cope with extreme temperatures. As the environment warms-up, the body tends to warm-up as well (Mackowiak et al 1992). The body's internal thermostat maintains a constant inner body temperature by pumping
more blood to the skin and by increasing sweat production. In this way, the body increases the rate of heat loss to balance the heat burden created by the environment (Longo et al 2011). In a very hot environment, the rate of heat gain exceeds the rate of heat loss and the body temperature begins to rise. There are number of physiological heat control mechanisms playing a vital role in maintaining the core body temperature even when the external air temperature is greater than 37°C (R.S Bridger 2003). The pre-optic area in the anterior hypothalamus of the brain along with posterior hypothalamus, medulla, pons and spinal cord maintain core body temperature within normal range. The thermal sensors maintain a constant core body temperature by increasing blood flow to the skin (Vasodilatation) and by increasing sweat production (Kelly GS 2007). To balance the heat burden created by the environment, the body increases the rate of heat loss. A rise in the body temperature results in heat related illnesses (Xiang et al 2014, Brode et al 2009).

The main source of heat gain in a human body is production of its own internal heat called metabolic heat. It is generated within the body by the biochemical processes that keep us alive and by the energy we use during physical activity (Levander M et al 2002). The body exchanges heat with its surroundings mainly through radiation, convection, and evaporation of sweat (NIOSH 2016). Radiation is the process by which the body gains heat from surrounding hot objects, such as hot metal, furnaces or steam pipes and lose heat to objects such as chilled metallic surfaces without contact with them (Parson 2003, Ph.D Thesis Entitled "Assessment of Heat Stress and its Impacts on Health of Workers from Different Occupational Sectors")
NIOSH 2016). No radiant heat gain or loss occurs when the temperature of surrounding objects is the same as the skin temperature (about 35°C). Convection is the process by which the body exchanges heat with the surrounding air. The body gains heat from hot air and loses heat to cold air which comes in contact with the skin. Convective heat exchange increases with increasing air speed and increased differences between air and skin temperature (Parson 2003). Evaporation of sweat from the skin cools the body. Evaporation proceeds more quickly and the cooling effect is more pronounced with high wind speeds and low relative humidity. In hot and dry workplaces, the cooling due to sweat evaporation is limited by the amount of sweat produced by the body (NIOSH 2016).

The body also exchanges small amounts of heat by conduction and breathing (Figure 1). By conduction the body gain or lose heat when it comes into direct contact with hot or cold objects. Breathing exchanges heat because the respiratory system warms the inhaled air. When exhaled, this warmed air carries away some of the body's heat. However, the amount of heat exchanged through conduction and breathing is normally small enough to be ignored in assessing the heat load on the body (Mackowiak et al 1993).
2. OCCUPATIONAL HEAT STRESS:

It is the net load to which a worker is exposed from the combined contributions of metabolic heat, environmental factors, and clothing worn which results in an increase in heat storage in the body (ACGIH 2010). Heat stress results in heat related illness and also it may account for an increase in workplace accidents, and a decrease in worker productivity (Kjellstrom et al 2009, Lucas et al 2014). Heat stroke can lead to death and needs emergency treatment, while heat exhaustion is less severe. Worker injuries attributable to heat include
those caused by sweaty palms, fogged-up safety glasses, and dizziness. Burns may also occur as a result of accidental contact with hot surfaces or steam (NIOSH 2016, Rosenthal et al 2012). In India occupational heat stress is becoming more significant as the average temperatures increase but remains overlooked (Dash et al 2011, Joon et al 2012, Lundgren et al 2013, Nag et al 2011). Workers at risk of heat stress include outdoor workers and workers in hot environments such as firefighters, bakery workers, farmers, construction workers, miners, boiler room workers, factory workers (Naley 2012, Nag et al 2001, Venugopal et al 2016). There are only few studies and regulations regarding occupational heat exposures among workers and its health impacts.

2.1 Role of climate change on occupational heat stress

The global and local climate is getting altered due to climate change that is taking place in earth because of various reasons (IPCC 2007). In the past fifteen years most of the densely populated cities having an average temperature of around 35 to 36°C have recorded an additional increase in average temperature by 1 to 2°C. Over the past 100 years average global surface temperatures have increased by about 0.74°C, with most of this increase having occurred in the past 50 years (UNFCCC 2011). It is considered very likely that this global warming has been responsible for an increased frequency of hot days and nights, and of heat waves, observed over the past 50 years (Smith et al 2008). It is of particular concern that even if the greenhouse gas emissions is kept at current levels, global warming would continue for some time
into the future due to persistence of accumulated greenhouse gases in the atmosphere (Drew et al 2006, Kjellstrom et al 2010). It has been predicted that hot extremes and heat waves will become more frequent in the future, with average temperatures predicted to rise about 2.5°C by 2030, and by up to 3.4°C by 2070 (IPCC 2007). Increased average global temperatures are predicted to be accompanied by increased temperature variability. Climate models for certain areas of America predicts that the heat waves will become more intense and longer lasting (Peng et al 2011). Strategies must be developed to promote adaptation to the consequences of climate change in order to minimize its potential negative health impacts.

The urban places are getting warmer than rural due to rapid development and deforestations to build tall buildings and roads leading to “urban heat Island effect” (Bornstein 1968). Scientists who are working in this context have concluded that global warming is occurring undoubtedly. It is predicted that in future, extremes of temperature may lead to frequent heat waves which are more frequent, more intense and longer lasting (IPCC 2007). There is substantial evidence of relationship between global warming and human health either directly or indirectly (Kjellstrom et al 2014).

2.2. Heat stress indicators

The various indices that are used to assess the heat stress in occupational sectors includes Wet bulb Globe Thermometer (WBGT), Universal Thermal Climate Index, Humidex, etc. WBGT is the gold
standard internationally accepted indices for measuring heat stress in occupational sectors (Webber et al. 2003).

The environmental temperature depends on various factors like air temperature, humidity, dew point etc. Among these factors, human comfort depends on ambient temperature and relative humidity which ranges from 20°C and 27°C and 35 to 60% respectively (Parson 2003). Human beings feel uncomfortable when these two factors increase. The commonly used heat stress index is WBGT (Wet bulb globe temperature). The Wet Bulb Globe Temperature index (WBGT), evaluated by Yaglou and Minard (1957) is a well established and widely used heat stress index that is associated with human physiological reactions to heat and the limits these reactions create for work intensity and workplace heat exposure levels. Special equipment is needed to measure WBGT according to standards (Parson 2006). Such equipment has three thermometers measuring natural wet bulb temperature (Tw), black globe temperature (Tg), and common air temperature (Ta). Tw is measured inside a water wetted small cloth sock, which simulates the heat exchange effect of evaporation from sweat covered skin. Tg is measured inside a black globe, which simulates the uptake of heat on the skin from heat radiation (e.g. solar radiation). The equations used for calculating WBGT are as follows (Yaglou et al, 1957, Webber et al 2003).

\[
\text{WBGT indoor} = 0.7 \times \text{Tw} + 0.3 \times \text{Tg} \\
\text{WBGT outdoor} = 0.7 \times \text{Tw} + 0.2 \times \text{Tg} + 0.1 \times \text{Ta}
\]
Estimates of WBGT measurements can be calculated from the data provided by the instrument by using an approximation based on the work of (T.E. Bernard et al 1999) which is accurate to about 97%.

2.3. Health hazards due to heat stress exposure

When the air temperature or humidity rises above the optimal ranges for comfort, problems can arise (Parson 2003). The first effects are subjective in nature, they relate to how you feel. Exposure to more heat stress can cause physical problems which impair workers' efficiency and may cause adverse health effects (Rodahl 2003). The heart rate increases to pump more blood through skin so that excess heat can be lost to the environment through sweating (Kjellstrom et al 2011). These changes impose additional demands on the body. Changes in blood flow and excessive sweating reduce a person's ability to do physical and mental work (Hancock et al 2003). Manual work produces additional metabolic heat and adds to the body heat burden. When the environmental temperature rises above 30°C, it may interfere with the performance of mental tasks (Parson 2003).


**Heat edema** is swelling which generally occurs among people who are not acclimatized to working in hot conditions. Swelling is often most noticeable in the ankles. Recovery occurs after a day or two in a cool environment.
**Heat rashes** are tiny red spots on the skin which cause a prickling sensation during heat exposure. The spots are the result of inflammation caused when the ducts of sweat glands become plugged.

**Heat cramps** are sharp pains in the muscles that may occur alone or be combined with one of the other heat stress disorders. The cause is salt imbalance resulting from the failure to replace salt lost due to sweating. Cramps most often occur when people drink large amounts of water without sufficient salt (electrolyte) replacement.

**Heat exhaustion** is caused by loss of body water and salt through excessive sweating. Signs and symptoms of heat exhaustion include heavy sweating, weakness, dizziness, visual disturbances, intense thirst, nausea, headache, vomiting, diarrhea, muscle cramps, breathlessness, palpitations, tingling and numbness of the hands and feet. Recovery occurs after resting in a cool area and consuming cool salted drinks.

**Heat syncope** is heat-induced giddiness and fainting because of insufficient flow of blood to the brain while a person is standing. It occurs mostly among unacclimatized people. It is caused by the loss of body fluids through sweating and by lowered blood pressure due to pooling of blood in the legs. Recovery is rapid after rest in a cool area.

**Heat stroke** (elevated body temperature) is the most serious types of heat illnesses. Signs of heat stroke include body temperature often greater than 41°C and complete or partial loss of consciousness.
The signs of heat hyperpyrexia are similar except that the skin remains moist. Sweating is not a good symptom of heat stress as there are two types of heat stroke – “classical” where there is little or no sweating (usually occurs in children, persons who are chronically ill and the elderly) and “exertional” where body temperature rises because of strenuous exercise or work and sweating is usually present.

Heat stroke requires immediate first aid and medical attention. Delayed treatment may result in damage to the brain, kidneys and heart. Treatment may involve removal of the victim's clothing and spraying the body with cold water. Immersing the victim in cold water more efficiently cools the body but it can result in harmful overcooling which can interfere with vital brain functions so it must only be done under close medical supervision. Certain type of kidney, liver, heart, digestive system, central nervous system and skin illnesses were explained by some researchers which is caused due to long-term heat exposure.

The lens of the eye is particularly vulnerable to radiation produced by red-hot metallic objects (infrared radiation) because it has no heat sensors and lacks blood vessels to carry heat away. Glass blowers and furnace-men have developed cataracts after many years of exposure to radiation from hot objects. Foundry workers, blacksmiths and oven operators are also exposed to possibly eye-damaging infrared radiation (NIOSH 2016).
A possible link between occupational heat exposure and reproductive problems has been suggested (Jensen et al 2006). Data from laboratory experiments on animals have shown that heat stress may adversely affect the reproductive function of males and females. When animals are simultaneously exposed to heat and toxic chemicals, the influence of heat exposure seems to accelerate the chemical reactivity (Slimen et al 2015). Exposure of males resulted in reduced rate of conception. Exposure of females caused disruption of the reproductive cycle until they became acclimatized to heat (Sharpe 2010).

Increase in testicular temperature more than 3 to 5°C decreases sperm counts (Sheynkin et al 2004). There is no conclusive evidence of reduced fertility among heat-exposed women. There are no adequate data from which conclusions can be drawn regarding the reproductive effects of occupational heat exposure at currently accepted exposure limits. Laboratory study of warm-blooded animals has shown that exposure of the pregnant females to hyperthermia may result in a high incidence of embryo deaths and malformations of the head and the central nervous system (Slimen et al 2015). There is no conclusive evidence of teratogenic effects of hyperthermia in humans. The NIOSH 2016 recommends that a pregnant worker's body temperature should not exceed 39-39.5°C during the first trimester of pregnancy.

In foundries, steel mills, bakeries, smelters, glass factories, and furnaces, extremely hot or molten material is the main source of heat
(NIOSH 2016). In outdoor occupations, such as construction, road repair, open-pit mining and agriculture, summer sunshine is the main source of heat (Uwerevu et al 2014). In laundries, restaurant kitchens, and canneries, high humidity adds to the heat burden. In all instances, the cause of heat stress is a working environment which can potentially overwhelm the body's ability to deal with heat (NIOSH 2016).

The major reason that working people belong to vulnerable group is because of internal heat produced when muscles are used during work (Parsons 2003). Some people tend to keep working beyond the safe limit for heat exposure because of their need to complete work tasks during a particular period or their need to maintain work output to get paid (Kjellstrom et al 2016). The risk of heat-related illness varies from person to person. A person’s general health also influences how well the person adapts to heat and cold. Those with extra weight often have trouble in hot situations as the body has difficulty maintaining a good heat balance. Age (particularly for people about 45 years and older), poor general health, and a low level of fitness will make people more susceptible to feeling the extremes of heat (Kelly 2007). Occupational heat exposure can lead to accidents resulting from the slipperiness of sweaty palms and to accidental contact with hot surfaces (NIOSH 2016). During prolonged work periods in the heat, the high sweat rates leads to progressive dehydration. It has been well documented that losses of fluids through sweating can lead to dehydration which has a detrimental effect on productivity (Cheuvront SN et al 2005). Strategies to minimize the effects of dehydration have
also been well studied (Bates et al 2008). Fluid and electrolyte losses pose a serious risk to health, the intake of fluid during the working period to replace sweat losses is therefore extremely important, to prevent imbalance in body fluids, however guidelines for this replacement are often conflicting (Pethick 2007). Fluid replacement guidelines state that fluid intake after exercise should exceed fluid deficit by up to 150% (Parson 2003). It is difficult to replace fluid loss adequately if the amount of loss is unknown. The calculation of sweat rate quantifies the amount of fluids lost, providing more tangible guidelines for fluid replacement (Pethick 2007). An ideal fluid replacement beverage for industrial use should have significant sodium content with minimum carbohydrate and it should be easily available and affordable (Convertino VA et al 1996).

The threats to health, well-being and the economic/ productivity loss warrant the need for (Kjellstrom et al 2009)

(a) Preventive policies and interventions (adaptation) through design of urban areas, housing and workplaces to reduce heat exposure

(b) Public and occupational health programs that protect individuals at risk

Interventions for reducing the impacts of occupational heat stress range from engineering controls to behavioral changes. It is important to choose an appropriate intervention that can reduce the health impacts due to occupational heat stress and thereby increase the productivity and minimize the economic loss.
2.4. Occupational Heat stress: Heat strain indicators

A wide range of clinical observations and measurement have been used to indicate heat strain, ranging from perception of workers, observational parameter like skin rash to hospitalization due to heat stroke. The heat strain parameters that were measured in the previous studies include core body temperature (Dehghan et al 2012), Skin temperature (Parson 2003), Sweat rate (Bates et al 2008), Resting/working heart rate (Yamamoto et al 2007), Urinary specific gravity (Montazer et al 2014), Serum creatinine (Peraza et al 2012), Serum electrolytes (Morioka et al 2006), VO\(_2\) Max (Parson 2003) (Table 1). In the study done by Dehghan et al 2012, more than 60 % of the workers had increase in the ear canal temperature was over 1°C in post work measurements. Environmental warmth greatly influenced the sweating response (PK Nag et al 2007). In the study done by (Farshad et al 2014), there was increase in urine specific gravity in workers exposed to hot environments. In the study done by (Yamamoto et al 2007), heart rate, body temperature and scores for subjective symptoms significantly increased after 30 min heat exposure. Most of the earlier studies on assessing physiological effects have been conducted on experimental settings rather than actual field settings. Such studies although provides us with important information on the relationship, it might not be possible to use the same methodology at work place.

Assessment of heat strain from heart rate and core body temperature has a sound physiological basis and has been quantified in
the physiological strain index. Tympanic membrane core body temperature has been used in previous studies to measure core body temperature (Dehghan et al 2012). A close correlation between heart rate and core body temperature supporting the use of ambulatory heart rate monitoring as an indication of thermal strain has been reported (Brakes et al 2002).

Heart rate has been measured in various phases of work to quantify the physiological strain in previous studies. This includes resting heart rate, working heart rate and recovery heart rate (Brode et al 2009, Yamamoto et al 2007).

Sweat rate was also measured in previous studies as a marker of physiological strain which can tell about the hydration status of the individual (Bates et al 2008).

Perfusion index is the ratio of pulsatile and non pulsatile blood flow which indicates the pulse strength at the monitoring site (Lima et al 2002).

Urinary specific gravity (USG) was also measured in previous studies as a heat strain indicator (Montazer et al 2013). Testing USG has been shown to be a reliable and an important indicator of the body absolute hydration status that can be used as a single measure, which is non-invasive, easy and quick to conduct in the field work. USG could be used as an educational tool for workers about the required fluid intake before and after heat exposure (Donoghue AM et al 2000).
Table 1: List of heat strain parameters that were used in various studies done under Occupational heat stress

<table>
<thead>
<tr>
<th>S.no</th>
<th>PARAMETERS</th>
<th>RESULTS/AUTHOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Core body temperature</td>
<td>↑/(Dehghan et al 2012).</td>
</tr>
<tr>
<td>2</td>
<td>Skin temperature</td>
<td>↑/ (Ken Parson 2003).</td>
</tr>
<tr>
<td>3</td>
<td>Sweat rate</td>
<td>↑/(Bates et al 2008).</td>
</tr>
<tr>
<td>4</td>
<td>Heart rate</td>
<td>↑/( Yamamoto et al 2007)</td>
</tr>
<tr>
<td>5</td>
<td>Urinary specific gravity</td>
<td>↑ / (Montazer 2014).</td>
</tr>
<tr>
<td>6</td>
<td>Serum creatinine</td>
<td>↑ / (Peraza et al 2012).</td>
</tr>
<tr>
<td>7</td>
<td>Serum electrolytes</td>
<td>No change / (Morioka et al 2006).</td>
</tr>
<tr>
<td>8</td>
<td>Urinary catecholamine</td>
<td>↑/ (Yamamoto et al 2007)</td>
</tr>
</tbody>
</table>

2.5. Global and Indian studies on occupational heat stress

Specific heat wave events in the Northern hemisphere have been associated with marked short term increases in mortality, with reported excess mortality ranging from 4% to 142% (IPCC 2007). It is estimated that in 2003, up to 70,000 additional deaths occurred over the summer months in Western Europe as a consequence of severe heat waves (Lundgren et al 2013). An estimated 560 extra deaths were observed during the three heat waves of 2002 in Russia. Lag times of just a few days have been observed between the onset of a heat wave and the rise in mortality, suggesting that people succumb quickly to the effects of extreme heat (Revich et al 2008). Some of the deaths occurring in heat waves are due to exacerbation of preexisting illnesses particularly cardiovascular and respiratory diseases, and diseases of the nervous
system (Son et al 2016). Mortality associated with heat waves has been reported to be greatest in city areas, in conjunction with observed high night-time minimum temperatures, high levels of air pollution, and poor housing conditions (Bouchama A et al 2007). Few studies have investigated the effects of extreme hot weather on population morbidity. Hospital admissions have been observed to increase during heat waves. However studies have revealed discrepancies between the impact of heat waves on morbidity and mortality, in terms of magnitude, cause, and age group (Basu et al 2002). Reports of a lesser impact of heat waves on hospital admissions than on mortality may indicate that people die quickly during heat waves before they are able to reach hospital or be noticed by others. Studies of patients admitted to hospitals during heat waves for treatment of heatstroke have shown this illness to be associated with an outcome.

The combination of heat stress, dehydration and physical activity impose challenge for physical adjustment, with potential risk of ensuing heat related injuries and disorders, e.g., heat cramp, heat exhaustion, heat syncope (Wildeboor et al 1993). The risk of heat stroke amongst working people is well known and explained by the limits of human physiological adaptability (Parsons 2003). Significant number of working people dies due to heat stroke even in high income countries as described in a study of agricultural workers in the USA (MMWR 2008). Apart from clinical health effects, work capacity is affected by excessive heat exposure and hourly work output is reduced (Bridger 2003, Kjellstrom et al 2009). A substantial amount of body
water may be lost as sweat, including loss of fluid through respiration, gastrointestinal tract as well as kidney. Increased dehydration disturbs the homeostasis of the body, leading to decreased skin blood flow, elevated core body temperature, decreased sweat rate leading to impaired to tolerance to work resulting in increased risks of heat injuries (Sawka 1992). Continuous exposure to excessive heat may cause profound increase in heart rate which may lead to sympathetic-vagal imbalance if not treated appropriately (Dehghan et al 2012). Heart rate is useful in evaluating the exertion required by physical labour in working conditions (Eguchi et al 2011). Acclimatisation may be helpful in maintaining the core body temperature and heart rate within normal range in workers exposed to excessive heat (Bröde et al 2009). The impact of occupational heat stress is not well documented. A wide range of clinical observations & measurements have been used to indicate heat strain, ranging from perception of workers to hospitalization due to heat stroke. > 20% of people are being estimated to have health impacts of heat stress, ranging from skin rash to heat stroke (Patel et al 2006). About 28% of workers were at risk of health impairment due to high heat exposure at work place (Ayyappan et al 2009). Limited awareness among management seems to play a major role. There was a noticeable disconnect between worker’s perceptions and their ability to perform task (Balakrishnan et al 2010). Most of these studies were done in experimental set up which cannot be considered as a standard protocol for studies in field/industry. Some of the examples include rectal temperature, capsule method for core body
temperature, nude body weight measurement, etc. Apart from heat, many confounding factors also play a role in health impacts. With all this issues, it is important to identify globally acceptable heat strain parameters and methods. Such methods can be used as relevant indicators locally by the health professionals to develop health surveillance and prevention programs for workers to protect the workers health. There are only few studies done in India about Occupational heat stress and its health impacts and no studies conducted on assessment of heat stress and its physiological responses in this geographical location. So it is very essential to do more studies in India to document the health impacts of heat stress. Some of the global and Indian studies on health effects due to occupational heat stress are listed in table 2.
Table 2: Global and Indian studies on health effects due to occupational Heat stress

<table>
<thead>
<tr>
<th>S. no</th>
<th>Title of the paper</th>
<th>Author</th>
<th>Place of study</th>
<th>Journal &amp; year of publication</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Risk Factors for Heatstroke among Japanese Forestry workers</td>
<td>Takafumi Maeda et al</td>
<td>Japan</td>
<td>J occup Health 2006</td>
<td>More than 60 % of workers developed symptoms of heat stroke (p&lt;0.05).</td>
</tr>
<tr>
<td>2.</td>
<td>Association Between Occupational Heat Stress and Kidney Disease Among 37 816 Workers in the Thai Cohort Study (TCS)</td>
<td>Benjawan Tawatsupa et al</td>
<td>Thailand</td>
<td>Journal of epidemiology 2012</td>
<td>A significant association between heat stress and incident kidney disease was observed in men (adjusted odds ratio [OR] = 1.48, 95% CI: 1.01–2.16).</td>
</tr>
<tr>
<td>3.</td>
<td>Deep Body Core Temperatures in Industrial Workers Under Thermal Stress</td>
<td>Derrick John Brake et al</td>
<td>Australia</td>
<td>J Occup Environ Med. 2002</td>
<td>The results showed that miners regularly exceeded the limits in terms of maximum deep body core temperature (average, 38.3 ±0.4 C; maximum temperature rise (1.4”C±0.4”C) without reporting any symptoms of heat illness.</td>
</tr>
<tr>
<td>4.</td>
<td>Hydration status and physiological workload of UAE construction workers: A prospective longitudinal observational study</td>
<td>Graham P Bates et al</td>
<td>UAE</td>
<td>Journal of Occupational Medicine and Toxicology 2008</td>
<td>There were no changes in core temperature or average heart rate between day 1 and day 3, nor between shift start and finish, despite substantial changes in thermal stress.</td>
</tr>
<tr>
<td>5.</td>
<td>Sweat rate and sodium loss during work in the heat</td>
<td>Graham P Bates et al</td>
<td>UAE</td>
<td>Journal of Occupational Medicine and Toxicology 2008</td>
<td>Sweat rates were higher and sodium concentrations were lower in the summer (acclimatised) than the winter (unacclimatised) trials.</td>
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</table>

Ph.D Thesis Entitled "Assessment of Heat Stress and its Impacts on Health of Workers from Different Occupational Sectors"
<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Authors</th>
<th>Country</th>
<th>Journal/Source</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>Comparison of heat dissipation response between Malaysian and Japanese males during exercise in humid heat stress</td>
<td>Hitoshi Wakabayashi et al</td>
<td>Japan</td>
<td>In J Biometeorol-2010</td>
<td>Rectal temperature in Malaysian was significantly higher than those in Japanese (P &lt;0.05)</td>
</tr>
<tr>
<td>7.</td>
<td>Evaluation of the Effect of Heat Exposure on the Autonomic Nervous system by Heart Rate variability and urinary catecholamines</td>
<td>Shinji Yamamoto et al</td>
<td>Japan</td>
<td>J occup Health 2007</td>
<td>Heart rate, body temperature and scores for subjective symptoms significantly increased after 30 min heat exposure (p&lt;0.05). Nor epinephrine was increased after heat exposure (p&lt;0.05).</td>
</tr>
<tr>
<td>8.</td>
<td>Heat Stress Level among construction Workers</td>
<td>Aliasghar Farshad et al</td>
<td>Iran</td>
<td>Iranian J Publ Health 2014</td>
<td>There was a significant difference in TWL, WBGT and USG between exposed and non-exposed group (P&lt;0.01)</td>
</tr>
<tr>
<td>9.</td>
<td>The evaluation of heat stress through monitoring environmental factors and physiological responses in melting and casting industries workers</td>
<td>Habibollah Dehghan et al</td>
<td>Iran</td>
<td>Int J Env Health Eng 2012</td>
<td>Increase in the ear canal temperature in 64.7% of cases (33 persons) was over 1°C. Correlation between WBGT index with ear canal temperature and PSI index, adjusted body mass index and age, was 0.67 and 0.69 (P &lt; 0.0001).</td>
</tr>
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</table>

**Indian studies**

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Authors</th>
<th>Country</th>
<th>Journal/Source</th>
<th>Findings</th>
</tr>
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<tbody>
<tr>
<td>10.</td>
<td>Heat exposure effects among fire fighters</td>
<td>Harshad C. Patel et al</td>
<td>India</td>
<td>Int. Journal of Occupational &amp; Environmental Medicine</td>
<td>Heat exhaustion (13.8%),Heat syncope (4.2%),Heat cramps (6.1%) were reported</td>
</tr>
<tr>
<td>No.</td>
<td>Title</td>
<td>Authors</td>
<td>Location</td>
<td>Journal/Source</td>
<td>Summary</td>
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<tr>
<td>11.</td>
<td>Thermal limits of men in moderate to heavy work in tropical farming</td>
<td>PK Nag et al</td>
<td>India</td>
<td>Industrial Health 2007</td>
<td>Cardio respiratory responses and core body temperature were predominantly influenced by work severity (p&lt;0.001). Environmental warmth greatly influenced the sweating response (p&lt;0.001)</td>
</tr>
<tr>
<td>12.</td>
<td>Case studies on heat stress related perceptions in different industrial sectors in southern India</td>
<td>Kalpana Balakrishnan et al</td>
<td>India</td>
<td>Global Health Action 2010</td>
<td>There was a noticeable disconnect between worker’s perceptions and their ability to secure workplace improvements related to heat stress from the management.</td>
</tr>
</tbody>
</table>
2.6. Research in Occupational Heat Stress in India – Challenges and Opportunities (Srinivasan et al 2016)

In general research field has many challenges and constraints depending on the study. Some strategy has to be taken to overcome those challenges. Research in occupational heat stress in India is limited because of several challenges and constraints.

Some of them are,

I. Permission from Industries to publish the data: This one of the most important constraint for a researcher working in occupational heat stress. Limited awareness among management seems to play a major role. The management of the particular industry will restrict the researcher from publishing data if the results found to be against them keeping in mind about their industry future. This can be sorted out by orienting the management on benefits of research studies and also request help from government agencies to convince the industries.

II. Resistance for change from employers and workers: There is a noticeable disconnect between worker’s perceptions and their ability to secure workplace improvements related to heat stress from the management. Researcher should emphasize the health benefits and productivity improvement to the industry management.

III. Unorganized sector: There are many unorganized sectors where the heat exposure and health outcome is much worsened. The health impacts are more in informal sectors. People tend to work for more time to earn more money which causes excessive heat strain and
detioriate the health of the worker. Proper work plan should be followed by such sector like duration work, availability off water, time for rest in between work etc.

**IV. Improper record of heat/any occupational disease by the employer or worker:** The medical details of each worker should be monitored periodically and should be documented. Proper medical attention should be provided for the worker during the necessary period. Health education should be provided to the management highlighting the benefits of record keeping which can Saves Money, Manpower & time.

**V. Study Design:** Proper design should be chosen to establish association between exposure and outcome. For example cross-sectional cannot establish association between the exposure to heat stress and its health outcome. To overcome this, a pilot cross sectional study can be done to get an overall picture. Next step is to choose a cohort and follow up / Case-control study. To extend further depending on the funding and cooperation from the industry a randomized control trial with an intervention study to evaluate the health outcome of workers.

**VI. Health indicators:** A sensitive and very accurate health indicator is lagging the field of occupational heat stress. A proper study design with a good planning the time period of measurement and periodic monitoring can help to find out a sensitive health marker or an early
indicator which can detect the disease at the early stage and can reduce the morbidity.

3. LACUNAE AND NEED FOR FURTHER STUDIES

There are only few studies done on occupational heat stress in India and only limited studies with physiological parameters has been conducted in India. Limited studies have linked the environmental data with physiological parameters in this geographical location. Thermal stress may actually be higher in the mornings and late afternoons due to the high relative humidity, often exceeding 80% and the lack of air movement. Since the climate and the technology involved in occupational sectors are changing day by day, periodic studies are needed to establish the changes in health conditions of the workers.

4. RATIONALE FOR CURRENT STUDY

• The impacts on working people are generally ignored in international reviews of climate change, which is partly due to low priority given to occupational health.

• The diversity in Indian climatic systems necessitates scientific study in different regions of the country (S.K.Dash et al 2011).

• Occupational heat stress is a major health issue with several potential negative health and well-being outcomes.

• There are only few studies conducted on assessment of heat stress and its physiological responses in this geographical location.
• Statistics in occupational health sector is not well documented in this geographical location. The present study will help in providing some baseline information regarding impacts of heat stress.

5. STRENGTHS FOR CONDUCTING THE STUDY

• Department of Environmental Health Engineering (EHE) in SRU is a WHO Collaborating centre for Occupational health and also certified by International Labour Organisation (ILO).

• Occupational health and industrial hygiene consultation services are being provided to many industries by EHE so access to industries and permissions from the industries is feasible.

• Equipments required for measuring environmental and physiological parameters are available in Sri Ramachandra medical college and research institute.

• Sri Ramachandra medical college and research institute is a tertiary care hospital for the health care of referred workers-which is approved by CGHS

Occupational heat stress is a major health issue with several potential negative health and well-being outcomes. There are no studies conducted on assessment of heat stress and its physiological responses in this geographical location. Hence the present study focuses on examining the health impacts of heat stress of selected occupational groups in Tamil Nadu, South India.