DISCUSSION

There are very few studies conducted in the field of occupational heat stress in India. The present study was designed to gain an insight into the heat stress and heat strain in various occupational sectors. Heat stress was evaluated using WBGT in various locations inside the workplaces and heat strain parameters such as core body temperature, heart rate, sweat rate, perfusion index and urine specific gravity were measured in workers from various occupational sectors in Tamil Nadu.

1. ENVIRONMENTAL DATA – HEAT STRESS MEASUREMENTS

The measured WBGT ranged between 26.9°C to 41.7°C with an average of 31.5°C during summer. In winter WBGT ranged between 22.9 °C to 40 °C with an average of 26.9°C. During summer more than 80% of the workers engaged in moderate and heavy work category had higher Threshold Limit Values (TLV) than the recommended TLV as per ACGIH guidelines. During winter around 50% of the workers engaged in moderate and heavy work category had higher TLV than the recommended TLV as per ACGIH guidelines which reflect that these workers are under direct heat impact which might affect the health in later stages of work increasing the morbidity and mortality.

1. Heat stress profiles in the selected workplaces:

The measured WBGT levels in the agriculture field in our study reflected that most of the locations were above TLV values in both the seasons indicating that the farmers were at high risk of heat related illness due to continuous heat exposure and work load. Similar findings
were reported in other studies on agricultural workers (Bła ejczyk et al 2015, Maeda T et al 2006).

The heat stress measurements from the auto parts industry suggest that most of the location inside the industry had high WBGT values as per ACGIH guidelines during summer and winter. This suggests that the process involved in making auto parts generated more heat leading to increase in temperature in work locations. As a result the workers were exposed to high heat during work which may lead to health impacts due to heat stress. Similar findings were reported in previous studies done in auto parts manufacturing industry (Ayyappan et al 2009, Balakrishnan et al 2010).

The heat stress levels in the brick industry were high during summer when compared to winter. The number of locations exceeding TLV was more during summer when compared to winter. Similar finding were reported in other studies (Sett et al 2014, Hajizadeh et al 2015).

The heat stress levels in construction industry from this study described that the workers were directly exposed to hot environments throughout the work period both during summer and winter. Most of the work locations were above TLV levels both during summer and winter. Similar findings were reported in previous studies conducted in construction industry (Dutta et al 2015, Farshad et al 2014).
The heat stress measurements in garment industry highlighted that there was a difference in number of work locations with above TLV values, between summer and winter. There were only few locations with above TLV during winter when compared to summer. This explains that the environmental temperature plays a key role in determining the heat stress levels inside the industry rather than the heat production due to process involved during garment making. Workers reported similar kind of perception in the study conducted in textile industry (Balakrishnan et al 2010).

The WBGT levels were highest in steel industry during summer and winter. The heat generated from various processes and the radiation from hot surfaces of the processes added to the environmental heat levels inside the industry. Season had no major influence inside the steel industry as most of the locations inside the industry had WBGT values above TLV values as per ACGIH guidelines both during summer and winter. Workers in many areas with high heat stress levels such as coke ovens, blast furnace, continuous casting machine and blooming mills had additional risks owing to the thick layers of clothing worn by them. Workers working in coke oven and blast furnace areas used aluminum overcoat as personal protective equipment that further added to the heat stress for the workers. Similar kind of results were reported in studies conducted in melting and casting industries (Dehghan et al 2012).
The thermal comfort of a worker depends on the combination of factors like climate, clothing and metabolic heat production (Ismail A.R. et al 2010). Preliminary evidences showed that high heat exposures and heavy workload adversely affect the workers’ health and reduce their work capacities (Krishnamurthy et al 2016). India being a tropical country ACGIH recommendation for work and rest regime with respect to WBGT cannot be directly extrapolated from the guidelines given by western countries as the WBGT values were quite high in India (Dash et al 2011). The TLVs for tropical countries should be based on local climatic conditions (ACGIH 2010). Moreover, in developing and under-developed countries poverty invariably forces the workers to work for longer hours (Srivatsava et al 2000). Workplace heat is an important occupational health hazard in tropical countries, particularly for people working outdoors in the sun, and indoors in places without sufficient cooling (Kjellstrom et al 2009).

The heat stress levels in informal workplaces such as agriculture, construction and brick manufacturing were found to exceed the recommended TLVs for the observed work intensity during summer and winter months. However, seasonal variations in heat levels were minimal for workplaces with high heat generating industries such as steel industry, auto parts industry. Many indoor workplaces had higher WBGTs than outdoor irrespective of the season. This is presumably the result of heat generating processes and/or lack of proper ventilation inside the industry. These findings are similar with earlier findings from the automotive industry in India, indicating that heat stress is still
inadequately controlled in occupational sectors (Balakrishnan et al 2010).

Indoor work without process-generated heat exposures should be relatively less hazardous, because of the tropical climatic conditions in India (Venugopal et al 2015). While reliable measurements are not available in many sectors to estimate worker populations at risk, the sectors profiled in this study serve to illustrate the likely widespread prevalence of such risks. Given the large propensity of workplaces that expose workers to near or more than permissible levels of heat stress, it could be expected that even the modest increases in temperature resulting from climate change could significantly alter the distribution of exposures and related health impacts (Kjellstrom et al 2009). Work ability even at the lowest intensities of work may be severely limited if WBGT values are increased beyond the safe limit in workplaces (Kjellstrom et al 2009). These effects likely to make low economic workers more vulnerable on account of their poorer health status, limitations in accessing controlled (air conditioned) workplaces/homes. Although work-related heat stress information is frequently collected in many workplaces, many variables can influence measured heat stress values such as time of day, month, location of measurement and availability of controls (Parson 2003). It could be expected that increase in work-related heat stress may hamper productivity (for example due to increased frequency of rest breaks, diminished work output and lost work days). The quantitative exposure relationship
between heat stress and productivity remains to be characterized across work settings (Ayyappan et al 2009).

An optimal heat stress index should provide an accurate prediction of the worker’s physiological state at any time of exposure, thus allowing the occupational hygienist to assess the permissible duration of exposure and the duration of rest breaks (Webber et al 2013). The International Standard, ISO 7243 which was published in 1982, is based on the WBGT-index for evaluation of hot working environments (Parson 2006). Before the publication of the ISO 7243 standard, the WBGT-index had already been used in many countries and workplaces and threshold limit values had already been established as a basis for environmental heat stress monitoring to control heat stress casualties at military training camps (Holmer 2010). The ISO heat stress standard in general resembles the American Conference of Governmental Industrial Hygienist (ACGIH 2010) TLV for heat stress. The WBGT is widely accepted and used method for measuring environmental temperature. It is an index which represents the heat stress to which an individual is exposed. Although WBGT is not a complete calculation for the many environmental and physical factors influencing heat stress, it goes a long way in providing useful guidelines for protecting people who work in hot environment (Webber et al 2013). A limitation of this index is that the reference values are representative of the mean effect of heat over a long period of work (Parsons 2003). WBGT also provides criteria for clothing factor and
metabolic work load in addition to dry bulb temperature, wet bulb temperature, relative humidity and globe temperature (ACGIH 2010).

1.2 Identification of different heat stress zone using mapping in steel industry

Mapping done with WBGT values in steel industry showed more than half of the work locations had high WBGT values which indicates that there was more heat production in those areas due to various processes involved in steel making. Workers distribution with the help of mapping showed that more than 60 % of workers working in high heat producing areas which may affect their health. Around 30 % of the workers were exposed to moderate levels of heat. Though they were exposed to moderate levels of heat at work place, they were also at higher risk of chronic heat related illness like compromised renal function, reproductivity problems if allowed to work continuously for a longer duration (Tawatsupa et al 2012, NIOSH 2016). Mapping occupational heat stress risk zones may be useful for environmental and occupational health professionals to identify “hotspots” that may require special attention (Crider et al 2014). By mapping WBGT levels in an industry we can get pictures of potential high risk areas inside the industry (Hyatt et al 2010, Kjellstrom et al 2013). This information generated in this study will help the management to implement certain interventional measures in the areas of high heat stress levels to protect the workers health. Mapping can be used as a tool to depict high risk areas in all the industries which in turn will help the workers
and management to prevent the health impacts thereby increasing productivity and community economy (Kjellstrom et al 2013).

2. HEALTH ASSESSMENT - PHYSIOLOGICAL PARAMETERS (HEAT STRAIN)

This study included a total of 750 workers from six occupational sectors. 54% were males and 46% were females. The workers were in the age group between 20-60 yrs. About 42% of the workers were between 20 – 30 yrs of age.

2.1 Self reported heat stress related symptoms by the workers

Questionnaire was administered to assess the workers perceptions about impacts of occupational heat stress on health of workers. 67% workers felt that it was difficult to work in the hot environment. 79% of the workers felt that they were exposed to direct heat source. The workers also expressed that it was very difficult to work continuously in hot environment which also affected their mental health. They also felt that their ability to perform work decreases with high heat exposure. Similar perceptions were observed in this study (Kumar AP et al 2016). Workers felt that occupational heat stress exposure resulting from work is likely to have implications on health and productivity.

This study indicates that heat exposure is perceived as a significant problem by the workers affecting both physical and mental health. 83% of workers working in high heat stress (WBGT) locations reported excessive sweating which may lead to dehydration if not
properly treated (Krishnan et al 2015). 90% of workers reported excessive thirst. 15% of the workers working in high heat stress (WBGT) locations had skin rashes. It has been demonstrated that outdoor workers in the selected occupational settings had difficulty in coping with work in very hot conditions (Sahu et al 2013). With the prospect of increasing temperatures associated with climate change, there is a growing need to address the detrimental experiences and risks of ill health among those workers working in sun-exposed settings (Mathee et al 2010). Limited awareness on the need for preventive measures for heat stress seemed to be prevalent among management despite widespread reported discomfort by workers. There was a noticeable disconnect between worker’s perceptions and their ability to secure workplace improvements related to heat stress from the management (Balakrishnan et al 2010).

Another significant contributing factor was the clothes of the workers. More than 50% of the workers wore thick cotton clothes and nylon materials which increased the effects of heat stress by a minimum of 3.5°C experienced by each worker (ACGIH 2010, Parson 2003). The contractors should take responsibility to provide the workers with the proper clothes or at least inform the workers of what kind of clothing would be suitable for each job as recommended.

The kind of clothing the workers wore during the work category was very heavy disrupting the excessive heat loss mechanism from the body which might lead to increase in body temperature and adverse
health effects (Lundgren et al 2014). The workers did report about few coping mechanism followed by them like consumption of water and taking rest to avoid heat exhaustion during working in hot environment. These can further be enhanced by increasing awareness regarding health impacts due to heat stress.

### 2.2 Physiological measurements

The parameters used in this study for measuring heat strain were core body temperature, heart rate, sweat rate, perfusion index and urinary specific gravity. Some of these parameters were used in previous studies to measure heat strain in workers (Dehghan et al 2012, Bates et al 2008). The core body temperature exactly reflects the change in body temperature in workers due to excessive heat exposure during work (Brakes et al 2002). The heart rate explains about the change in autonomic function due to heat exposure (Yamamoto et al 2007). Sweat rate reflects the hydration status of the individual (Bates et al 2008). There was an increase in core body temperature, heart rate and perfusion index in the post work measurements which was statistically significant. Similar finding of increase in heart rate and core body temperature were reported in other studies (Dehghan et al 2012, Brakes et al 2002, Dutta et al 2015). The average difference (ΔV) in core body temperature, heart rate and perfusion index between pre and post measurements was significantly higher during summer when compared to winter. The average difference (ΔV) in core body temperature and heart rate between pre and post measurements was significantly higher in workers working in high WBGT locations (>29 °C) when compared to workers working in low WBGT locations.
(<29 °C). There was an increase in sweat rate in workers during summer and also in workers belonging to informal sectors. There was an increase in urine specific gravity in workers during summer when compared to winter. Association between heat strain indicators with WBGT, work load, season and sector was evaluated using odds ratio. The odds of developing health impacts (heat strain) among workers working in locations with WBGT values more than 29 °C is 1.5 (OR 1.5; 95% CI 1.4-2.9) times higher when compared to workers working in locations having WBGT values less than 29°C. The odds of developing health impacts (heat strain) among workers with heavy work load category is 1.2 (OR 1.2; 95% CI 1.1-2.5) times higher when compared to workers with light work load. The odds of developing health impacts (heat strain) among workers during summer is 1.3 (OR 1.3; 95% CI 1.2-3.7) times higher when compared to winter.

2.2.1 Core body temperature:

In this study there was an increase in core body temperature in post work measurements during summer and also in workers working in high WBGT locations. Similar kind of findings was reported in previous studies (Dehghan et al 2012, Brakes et al 2002, Nag et al 2007). According to NIOSH 2016, core body temperature of 37.5°C provides a safety margin for the human body. When core temperature exceeds 38°C, the risks of heat strain increases substantially. If insufficient heat is lost from the body, core body temperature will continue to rise between 38°C and 39°C that may lead to heat syncope. Heat stroke may occur when the core body temperature rise more than
41°C (Brode et al 2009, Parson 2003). Extremes in temperature (>42°C) can be detrimental to cellular and organ functions, which can threaten survival of the host. Hyperthermia can impair the central nervous system and cause systemic inflammation, tissue necrosis and multiple organ failure (Longo et al 2011). Optimal physiological function is dependent upon the maintenance of thermal homeostasis. Both the metabolic heat production and the capacity of the thermal environment to support evaporative cooling will dictate the extent to which humans can maintain homeostasis (Taylor et al 2006, Wakabayashi et al 2011). A decrease in sweating may occur as the deep body temperature continues to rise and the skin is completely wet (Parson 2003). The situation is further complicated when a worker is wearing protective clothing. During sweating, salt is lost at about 4g per litre for unacclimatised workers and 1 g per litre in acclimatized workers (Parson 2003). Prolonged exposure to heat and/or prolonged exercise almost always causes hypohydration (Bates et al 2008). Increase in core body temperature above normal range may lead to heat disorders like heat stroke and may even lead to death if not treated properly (Dehghan et al 2012).

2.2.2 Sweat Rate

The calculated sweat rate was high among the workers during summer when compared to winter and also in workers working in high WBGT locations. The sweat rate was more in workers working in informal sector when compared to formal sector. Increase in sweating leads to dehydration and other serious health disorders like renal
failure etc (Parson 2003). Excessive heat exposure causes increase in blood flow to skin to dissipate the excess heat from the body (Figure 17). As a result the sweat rate is increased (Pethick 2007). This will be more in case of summer months. A proper plan should be made to minimize the sweat rate by taking rest in between the work and by providing fluids during work (Krishnan et al 2016). It has been well documented that loss of fluids through sweating can lead to dehydration which has a detrimental effect on performance. Dehydration elevates both heart rate and core temperature, causes significant physical performance decrements (Shukla et al 2008). Strategies to minimize the effects of dehydration have also been well studied among athletes and in exercise physiology (Pethick 2006). The workers can work without adverse physiological effects in hot conditions if they are provided with the appropriate fluids and are allowed to self-pace (Bates et al 2008). The factors associated with dehydration that accelerate fatigue are increased rate of glycogen depletion, greater metabolite accumulation and decreased psychological drive for work or exercise (Parson 2003). Dehydration also has marked cognitive effects. Performance in intellectual tests is affected at 2% hypo hydration and becomes progressively worse as water deficit increases (Gopinathan et al 1988). Impaired concentration, reasoning and mood can occur due to dehydration and the concomitant increase in core body temperature (Hancock 2003). Not surprisingly, workplace accidents are more common in hot environments and are often associated with heat stress and dehydration.
Ph.D Thesis Entitled "Assessment of Heat Stress and its Impacts on Health of Workers from Different Occupational Sectors"

(Cheuvront SN et al 2008). More deleterious health effects can occur if dehydration is allowed to progress as it increases the likelihood of heat related illness. A number of conditions are associated with heat stress and dehydration, namely heat rash, heat exhaustion, heat cramps, heat edema, heat syncope (fainting) and chronic heat fatigue. Thermoregulatory failure can occur in severe cases of dehydration and hyperthermia resulting in heat stroke an often fatal condition (Donoghue et al 2000). Fluid replacement guidelines state that fluid intake after exercise should exceed fluid deficit by up to 150%. It is difficult to replace fluid loss adequately if the amount lost is unknown. The calculation of sweat rate quantifies the amount of fluids lost, providing more tangible guidelines for fluid replacement (Pethick 2007).

2.2.3 Heart Rate

In this study an increase in post work heart rate was observed. Similar finding were reported in previous studies (Dutta et al 2015, Anjos et al 2007, Yamamoto S et al 2007). Increase in post work heart rate is an indicator for heat strain (Figure 17). Heart rate is influenced by the work load and environmental heat stress in addition to several other intrinsic factors such as emotional state and body composition. The work done by the heart to increase the cardiac output to meet the extra needs due to excessive heat exposure can increase the heart rate (Anjos et al 2007, Parson 2003). Heart rate increases by 8 beats per min on exposure to hot environments for 25 to 30 minutes. This is due to parasympathetic withdrawal during exposure to hot conditions.
Ph.D Thesis Entitled "Assessment of Heat Stress and its Impacts on Health of Workers from Different Occupational Sectors"

(Yamamoto S et al 2007). The increase in heart rate due to thermal stress is further exacerbated by the loss of water through sweating because large sweat loss reduces the body’s water content (hypohydration) and therefore reduces the blood volume and may lead to sympathetic imbalance (Bates et al 2008, Sawka MN et al 1992). Continuous exposure to excessive heat may cause profound increase in heart rate which may lead to sympathetic imbalance if not managed 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).

2.2.4 Perfusion Index

Perfusion index (PI) was significantly higher in this study. This is because increase in blood flow to peripheral areas to dissipate excess heat from the body by sweating. Perfusion index is a relative assessment of the pulse strength at the monitoring site (Lima et al 2002). When a person gets exposed to excessive heat, peripheral vasodilatation occurs in tissue causing increased blood flow to the tissue leading to increase in the perfusion index (Krishnan et al 2013). PI has a high correlation with capillary refill time and central-to-toe temperature difference. The change in blood volume can be detected in peripheral parts of the body such as the fingertip or ear lobe using a technique called photoplethysmography. It can measure the change in the volume of arterial blood with each pulse beat. If the perfusion
Index level increases to more than 20 then it is pathological for which intervention has to be provided like fluid supplementation (Lima et al 2002). Perfusion index for all the workers in this study was within normal range. In this study perfusion index was used as a trial parameter but it cannot be used as an early indicator. This could be because the body utilizes the physiological reserve of fluid to protect the health at needful time.

2.2.5 Urine specific gravity

There was an increase in Urine Specific Gravity (USG) in workers exposed to occupational heat stress in a subset of population. Similar kind of finding was reported in previous studies (Farshad et al 2014, Montazer et al 2013, Morioka et al 2006). USG will give overall information about the hydration status of the individual. Increase exposure to heat leads to excessive sweating to dissipate heat from the body leading to drain in body water causing dehydration (Parson 2003). In this study the number of workers with increase in USG above permissible level was more during summer when compared to winter. This could be because of the additional heat load experienced by the worker during summer which leads to increase in sweating leading to drain in body fluid level resulting in dehydration (Parson 2003). 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 (Farshad et al 2014). USG could be used as an educational tool for workers about the required fluid intake before and after heat
exposure (Montazer et al 2013). USG is a good marker for evaluating the hydration status of workers working in low humidity environments, who need proper protection and adequate fluid supply to prevent excess water loss and its adverse health effects.

**Figure 17: Integrated regulation of heat strain mechanism**

3. STUDIES CONDUCTED IN THE FIELD OF OCCUPATIONAL HEAT STRESS:

In this study there was increase in core body temperature, heart rate and sweat rate on exposure to heat stress in various occupational sectors. Previous studies also have reported similar kind of response on exposure to heat stress. In the study done by Dehghan et al 2012 in melting and casting industry, there was an increase in core body temperature and heart rate on exposure to heat stress. In the study done
by Bates et al 2008 in construction workers, there was increase in sweat rate due to occupational heat exposure. There was increase in cardiac strain and heart rate in garbage collection workers in Brazil (Anjos et al 2007). There was increase in heart rate, core body temperature, increase in urinary catecholamine and alterations in heart rate on exposure to heat stress (Yamamoto et al 2007). In a study done by Peraza et al 2012 in farmers, there was alteration in renal function during working hours. In a study conducted by Montazer et al 2013, Farshad et al 2014 in construction workers, there was increase in USG in people working in hot environments.

3.1 Agriculture industry

Agriculture workers being involved in outdoor work predominantly were at higher risk of heat related illness due to high heat exposure during working hours. They were directly exposed to sunlight which can lead to excess heat burden inside the body. The measured WBGT levels in the agriculture field in our study reflects that most of the location were above TLV values in both the seasons indicating that the farmers were at high risk of heat related illness due to continuous heat exposure and work load. Similar finding were reported in other studies on agricultural workers (Bła ejczyk et al 2015, Maeda T et al 2006). There was an increase in core body temperature and sweat rate among farmers (Nag et al 2007). From the interviews, it is apparent that workers vulnerable to heat-related illnesses either showed no interest in or were unaware of the consequences of prolonged heat exposure. Heat-related health issues
were reported the highest in brick and agriculture sectors with more than 95% of the workers experiencing adverse health issues due to heat stress (Venugopal et al 2016). Outdoor laborers often get heat-related illnesses when they first begin working in the incessant heat (Morioka et al 2006). In the study done by Sahu et al 2013 in rice harvesters, there was an increase in heart rate in post work measurements. There was decrease in renal function among agricultural workers working in heated environments (Peraza et al 2012). In order to prevent and dissipate heat stress and the resulting symptoms, we suggested owners provide the appropriate amenities to their workers including a cool or shady place to rest, and a clean source of drinking water.

3.2 Auto parts industry:

The heat stress measurements from the auto parts industry suggest that most of the location inside the industry had high TLV values as per ACGIH guidelines during summer and winter. Similar kind of findings was reported in previous studies (Ayyappan et al 2009, Balakrishnan et al 2010). The process generated while making auto parts cause increase in temperature in work locations. As a result the workers were exposed to high heat during work which may leads to increase in morbidity. In a study done by Ayyappan et al 2009, 28% of workers employed in multiple processes were at risk of heat stress-related health impairment in automobile industry. The workers felt it is very difficult to work in hot environments. Similar kind of perceptions was noted in previous studies in automotive industry (Balakrishnan et al 2010). The major complaints from the workers as perceived by them
to be related to heat exposure included symptoms like skin rashes and acne. In a study done by Balakrishnan et al 2010, workers felt heat was affecting their ability to work due to dehydration. Lack of insulation on the roof and inadequate ventilation was cited as the chief concern for heat-related discomfort. Symptoms of dehydration, dizziness, cramps, and heat-related exhaustion were the most commonly reported. In the same study it was reported that nearly half the workers interviewed felt that provision of additional cooling mechanisms would reduce the environmental heat and reduce the frequency of minor faults/production errors. Continuous exposure to occupational heat might lead to alteration in physiological parameters such as increase in core body temperature, heart rate and sweat rate (Parson 2003). The working environment can be modified by certain interventions. Recommendations such as providing fan, adequate drinking water, acclimatization and following work rest cycle were recommended to the industry management which can improve the safety level in the working atmosphere and also decrease the morbidity (ACGIH 2010).

3.3 Brick Industry:

The heat stress levels in the brick industry were high during summer when compared to winter. The number of locations exceeding TLV was more during summer when compared to winter. The workers experienced additional heat load during summer because of the exposure to heat radiating from brick klin. The brick manufacturing involved various processes which made workers to experience
additional heat burden. The workers felt that it was very difficult to work near the brick klin during firing process. They also experienced discomfort and exhaustion when work near the brick Klin. Similar findings were reported in other studies (Sett et al 2014, Hajizadeh et al 2015). In the study done by Sett et al 2014 in brick workers, there was an increase in heart rate and increase in cardiac strain both during summer and winter. Since they had extra burden of heat stress, the physiological parameters such as heart rate and body temperature was increased at post work measurements and also a seasonal difference of changes in physiological parameters were noted. Ergonomic interventions, including rescheduling of the work rest cycle, frequent fluid intake to replace the water lost due to sweating, using PPEs to protect themselves from radiating heat and working at dawn or after sunset with sufficient lighting may help reduce the heat stress of the brickfield workers (Bridger 2003, ACGIH 2010). Moreover, this evidence can also be used to estimate the future productivity loss and economic growth of the country.

3.4 Construction Industry:

The heat stress levels in construction industry from our study described that the workers were directly exposed to hot environments throughout the work period both during summer and winter. Most of the work locations were above TLV levels both during summer and winter. The workers perceived that heat stress as a significant issue both during summer and winter. Similar finding were reported in previous studies from construction industry (Dutta et al 2015, Brakes
et al 2008). In the study done by Farshad et al 2014, there was an increase in urine specific gravity indicating that these workers were at increased risk of dehydration. There was an increase in urine specific gravity and blood sugar level among construction workers during summer (Morioka et al 2006). However, there was no significant change in blood urea nitrogen in these workers. In a study done by Bates et al 2008 in construction workers, there was no significant change in core body temperature and sweat rate.

3.5 Garments Industry:

The heat stress measurements in garment industry has highlighted that there was a difference in number of work locations with above TLV values between summer and winter. There were only few locations with above TLV during winter when compared to summer. This explains that the environmental temperature plays a key role in determining the heat stress levels inside the industry rather than the heat production due to process involved during garment making. Similar kind of findings was reported in previous study in textile industry (Balakrishnan et al 2010). The workers perceived that occupational heat stress was a seasonal problem and not related to working conditions. Similar kind of perceptions was reported in previous study. None of the workers were aware of the possible consequences of heat exposures. Their main discomfort seemed to be related to cotton fiber exposure. All workers however cited heat as a reason for not using PPEs. None reported being slowed down at work
by heat except perhaps during peak of summer (Balakrishnan et al 2010).

3.6 Steel industry:

The heat stress measurements were high inside the steel industry during both the seasons. Most of the work locations were above TLV values during both the seasons. The heat generated inside the industry could be a reason for the increase in temperature. The workers felt that it was very difficult to work in hot environment. Similar finding were reported in previous studies (Krishnamurthy et al 2016). In the study done by Dehghan et al 2012 in melting and casting industry, there was an increase in core body temperature and heart rate in post work measurements. Although the workers in the steel sector were exposed to higher WBGTs compared with workers in agriculture and brick kilns, the metabolic workload was partially compensated by automation that reduced their work intensity (Ayyappan et al 2009). In the study done by Donoghue et al 2000 in coal mine workers, there was increase in core body temperature, heart rate and urine specific gravity in post work measurements indicating that there workers were under high risk of health impacts. Health and productivity risks in developing tropical country work settings can be further aggravated by the predicted temperature rise due to climate change without appropriate interventions (Kjellstrom et al 2010, Dash et al 2011). It is evident from the results that exposure to high heat environments will impact the health and productivity of the workers unless efficient cooling methods are implemented such as air conditioners, using fans or
wearing specially designed cooling clothes (ACGIH 2010). Apart from industries enhancing welfare facilities and designing control interventions, further physiological studies with a seasonal approach and interventional studies are needed to strengthen evidence for developing comprehensive policies to protect workers employed in high heat industries. Mapping done in steel industry helps to identify the high risk areas inside the industry which can help management to implement certain interventions which can benefit workers health. The benefits of mapping inside an industry were discussed in other studies done by kjellstrom et al 2013, Crider et al 2014, Hyatt et al 2010.

4. GENERAL RECOMMENDATIONS PROVIDED TO THE STUDY PARTICIPANTS AND MANAGEMENT:

- Informed the management to provide training to the workers regarding heat strain management at the time of employment
- Advised the workers to wear light cotton clothes during work
- Health education is very important for the workers. Educated the workers on the signs and symptoms of heat stress related illnesses
- Discouraged consumption of alcohol or caffeinated beverages
- Encouraged the workers to take plenty of drinking water or butter milk during the work time. Provided recommendation for making arrangements for drinking water to be available at work place
- Advised workers to consult doctor if any health problem is noticed by the worker
Periodic health assessment of the workers (health surveillance)

Provided heat stress guide to the workers which contains information regarding heat stress and its health impacts and recommendations to prevent health impacts

4.1 Heat stress guide

Most of the workers in this study were unaware about the health impacts of heat stress. Though there are some guidelines issued by some companies it does not reach the workers effectively. So a heat stress guide was prepared and issued to the industry management and workers explaining the facts and health impacts due to heat stress and how to protect workers health (Figure 18).

Figure 18: Heat stress guide
Heat exposure levels can be lowered by use of certain control measures such as engineering intervention (Proving fan, coolers), personal protective equipments, proper ventilation, adequate rest, following work rest cycle as per ACGIH guidelines, providing adequate fluid to prevent dehydration, periodic medical checkup, etc. Special attention should be provided to aged workers and also to workers with significant medical illness. Health education to workers regarding heat related illness and ways to prevent it can help in reducing the morbidity. Studies of this kind using mapping can help in detecting the vulnerable areas inside the industry and also can protect the workers health. All workers should be made aware of the heat levels in all the areas inside the industry and should be instructed to take all precautionary measures while working in high heat generating areas. Engineering controls like by providing fan, adequate ventilation in working environment and by following work rest cycle as per ACGIH guidelines can protect the workers health. These recommendations could help the workers to protect their health from heat related illness.

5. BENEFITS OF THIS STUDY:

✓ First ever baseline job hazard exposure and health response profile for occupational heat stress among industrial workers
✓ Generated environmental real data on heat exposure levels in various industries.
✓ Generated health data (heat strain parameter) among workers from various industries
✔ Identification of indicators of health impact due to occupational heat stress

✔ Provided health education to the workers regarding fluid, food, rest & clothing-Co-benefit

✔ Provided insight to the management to implement important administrative, engineering and health interventions

✔ Can serve as a base line or pre interventional data for the implementation of interventions and to assess the efficacy of interventions

6. LIMITATIONS:

✔ Selected occupational sectors were only included in the study

✔ This study has demonstrated the health impacts due to occupational heat stress, but could not establish cause and effect relationship for which a cohort needs to be followed for a long period of time.