Work-related heat stress concerns in automotive industries: a case study from Chennai, India

Ramalingam Ayyappan, Sambandam Sankar, Paramasivan Rajkumar and Kalpana Balakrishnan*

Department of Environmental Health Engineering, Sri Ramachandra University, Chennai, India

Background: Work-related heat stress assessments, the quantification of thermal loads and their physiological consequences have mostly been performed in non-tropical developed country settings. In many developing countries (many of which are also tropical), limited attempts have been made to create detailed job-exposure profiles for various sectors. We present here a case study from Chennai in southern India that illustrates the prevalence of work-related heat stress in multiple processes of automotive industries and the efficacy of relatively simple controls in reducing prevalence of the risk through longitudinal assessments.

Methods: We conducted workplace heat stress assessments in automotive and automotive parts manufacturing units according to the protocols recommended by NIOSH, USA. Sites for measurements included indoor locations with process-generated heat exposure, indoor locations without direct process-generated heat exposure and outdoor locations. Nearly 400 measurements of heat stress were made over a four-year period at more than 100 locations within eight units involved with automotive or automotive parts manufacturing in greater Chennai metropolitan area. In addition, cross-sectional measurements were made in select processes of glass manufacturing and textiles to estimate relative prevalence of heat stress.

Results: Results indicate that many processes even in organised large-scale industries have yet to control heat stress-related hazards adequately. Upwards of 28% of workers employed in multiple processes were at risk of heat stress-related health impairment in the sectors assessed. Implications of longitudinal baseline data for assessing efficacy of interventions as well as modelling potential future impacts from climate change (through contributions from worker health and productivity impairments consequent to increases in ambient temperature) are described.

Conclusions: The study re-emphasises the need for recognising heat stress as an important occupational health risk in both formal and informal sectors in India. Making available good baseline data is critical for estimating future impacts.

Keywords: work-related heat stress; WBGT; climate change; automotive industry
temperatures (in the absence of mechanical cooling), it can be expected that both indoor and outdoor workers may experience heat stress. Even relatively modest increases in ambient temperatures could be expected to tip large worker populations exposed to ‘near limit values’ of heat stress over the threshold into the realm of experiencing heat stress-related health risks.

Work locations key: With process heat contributions – A: PTCS (varnishing oven), B: cab furnace, C: paint shop, D: fuel injection manufacturing, E: tube manufacturing, F: canteen (boiler area). Without process heat contributions – G: body shop (general shop floor), H: fuel injection manufacturing (general shop floor), I: paint shop (general shop floor), J: stamping, K: wheel alignment and engine deck, L: material storage and stores, M: PTCS (starter, armature and shaft areas), N: team meeting areas, O: plastic moulding area, P: utility areas, Q: canteen (general), R: brazing, S: trim and chassis.

Many locations with light workloads were still in excess of TLVs (indicating the need for engineering controls). Other locations with moderate workloads were close to or exceeded the TLVs (indicating opportunities for both administrative and engineering controls).

Fig. 1. Box plots illustrating the distribution of measured WBGT values at various indoor locations in automotive or automotive parts manufacturing units (dashed lines indicate the range of outdoor WBGT values across locations; dark boxes indicate locations with process-generated heat contributions and light boxes indicate locations without process heat contributions (i.e. only ambient temperature contributions), respectively, to heat stress.

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Fig. 2. Workloads at various locations in relation to WBGT indices (dark boxes indicate locations with process-generated heat contributions and light boxes indicate locations without process heat contributions (i.e. only ambient temperature contributions), respectively, to heat stress; dashed lines indicate TLV for fully acclimatised light work and dotted-dashed lines indicate TLV for fully acclimatised moderate work).

Work locations key: With process heat contributions – A: PTCS (varnishing oven), B: cab furnace, C: paint shop, D: fuel injection manufacturing, E: tube manufacturing, F: canteen (boiler area). Without process heat contributions – G: body shop (general shop floor), H: fuel injection manufacturing (general shop floor), I: paint shop (general shop floor), J: stamping, K: wheel alignment and engine deck, L: material storage and stores, M: PTCS (starter, armature and shaft areas), N: team meeting areas, O: plastic moulding area, P: utility areas, Q: canteen (general), R: brazing, S: trim and chassis.

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regulated for most occupational health and safety hazards, heat stress exposure remains quite prevalent in many processes. Chennai temperatures also range from around 21°C (between December and February) to around 37°C (between March and September). Some months record temperatures as high as 42°C. Although most processes in the automotive sector are performed indoors, lack of controls within the work environment and outdoor jobs make workers prone to heat stress from both ambient temperatures as well as process-generated heat.

We present here a case study from Chennai in southern India that illustrates the prevalence of work-related heat stress within multiple processes of automotive industries and the efficacy of relatively simple controls in reducing
prevalence of risks through longitudinal assessments. We also made limited assessments in two other sectors to estimate the likely percentages of workers at risk from heat stress in various processes. Since newly established plants have routine monitoring facilities, the choice of newly established automotive plants to conduct this pilot in a rapidly expanding sector allowed us to identify opportunities to create longitudinal baseline data for assessing efficacy of interventions as well as modelling future impacts from climate change.

**Materials and methods**

We conducted workplace heat stress assessments in automotive and automotive parts manufacturing units according to the protocols recommended by NIOSH, USA. Locations for measurements were selected based on the initial survey results; these included indoor locations with process-generated heat exposure, indoor locations without direct process-generated heat exposure and outdoor locations. Nearly 400 measurements of heat stress were made over a four-year period at more than 100 locations within eight units involved with automotive or automotive parts manufacturing in the greater Chennai metropolitan area. Since most workplace locations were not air-conditioned and therefore likely to be influenced by outside temperature and time of day/season, measurements were always made during the hottest part (11:00–14:30) of the day in the months of May or June, with repeated annual assessments. Measurements were used to recommend interventions at selected locations in the automotive units and multiple longitudinal measurements were made at locations where controls were implemented in order to assess their efficacy.

In addition, cross-sectional assessments were made in multiple processes in glass manufacturing and textile industries. We then collected information on workforce strengths in all three sectors to estimate likely percentages in each sector that were likely to be at risk from work-related heat stress.

The measurements were carried out using an area heat stress monitor (Model Questemp, Quest Technologies, USA) that calculates the wet bulb globe temperature (WBGT) to assess heat stress. The instruments used for the measurements comply with the standards set out by American Conference of Governmental Industrial Hygienists (ACGIH). The necessary information on workload, clothing worn, worker’s time-activity pattern and acclimatisation was collected on-site, to make appropriate adjustments to the measured WBGT value. The threshold limit value (TLV) was computed by taking spot readings throughout the work-shift and on the basis of worker description of workload, using a ‘clo’ factor of 0.6 for summer work uniforms. This ‘clo’ factor contributes to a WBGT correction factor of 0°C. For light workloads and full acclimatisation of the workers, a

| Location | Work-load | Mean WBGT (in °C) 2005 | Mean WBGT (in °C) 2006 | Mean WBGT (in °C) 2007 | Mean WBGT (in °C) 2008 |
|----------|-----------|-------------------------|-------------------------|-------------------------|-------------------------|
| Stamping (n = 30) | Moderate | 29.6 | 28.2 | 27.1 | 27.5 | Improvement of cross-ventilation by installing more windows on the wall |
| Body shop | Moderate | 29.9 | 30.7 | 28.9 | 27.5 | Improvement of cross-ventilation by installing more windows on the wall |
| Paint shop (loading/unloading) (n = 54) | Light to moderate | 32.2 | 31.2 | 29.1 | 29.5 | Provision of lime juice and milk during the hot season |
| Paint shop (oven operations) (n = 24) | Light | 34.2 | 33.2 | 31.4 | 29.5 | Thermoinsulation of the oven |
| Engine/chassis/wheel alignment (n = 34) | Light | 33.0 | 32.0 | 30.4 | 28.9 | Increasing the number of breaks during summer |
| Batch and hold yard shed (n = 38) | Light | 33.3 | 32.2 | 31.7 | 29.5 | Installation and maintenance of air cooler |

Note: WBGT measurements were made during the hottest part of the day.

*Table 1. Improvements in heat stress-related exposures at select locations*
Table 2. Exposure profiles for heat stress in select processes of automotive, glass and textile manufacturing sectors in southern India

| Industrial sector | Location | Name of the process | Physical workload | Number of workers | Average WBGT (in °C) | TLV for WBGT (in °C) | Exceeding TLV | Estimated % of population at risk |
|-------------------|----------|---------------------|-------------------|-------------------|----------------------|---------------------|--------------|----------------------------------|
| Automobile/automotive parts manufacturing | Indoor with process heat | Paint shop | Moderate | 178 | 30.4 | 27.5 | Yes | 100 |
| | Indoor without process heat | Stamping | Moderate | 90 | 29.1 | 27.5 | Yes | 51.3 |
| | | Body shop | Moderate | 340 | 28.9 | 27.5 | Yes | |
| | | TCF | Moderate | 312 | 31.3 | 27.5 | Yes | |
| | | Engine plant | Moderate | 172 | 30.6 | 27.5 | Yes | |
| | | Launch | Moderate | 15 | 30.2 | 27.5 | Yes | |
| | | MP & L | Light | 45 | 29.4 | 29.5 | No | |
| | | | Moderate | 100 | 29.3 | 27.5 | Yes | |
| | | P & D | Light | 100 | 28.2 | 29.5 | No | |
| | | | Moderate | 26 | 28.3 | 27.5 | Yes | |
| | | Admin | Light | 1,000 | 25.6 | 29.5 | No | |
| | | Maintenance | Moderate | 150 | 29.7 | 27.5 | Yes | |
| | Outdoor | Maintenance | Moderate | 50 | 30.9 | 27.5 | Yes | 100 |
| | | Gardening | Moderate | 25 | 30.9 | 27.5 | Yes | |
| | | | Heavy | 50 | 30.9 | 26 | Yes | |
| Glass manufacturing | Indoor with process heat | Furnace area | Light | 25 | 31.9 | 29.5 | Yes | 100 |
| | | Port 3 | Light | 14 | 37.8 | 29.5 | Yes | |
| | | Bay 1 | Light | 12 | 38 | 29.5 | Yes | |
| | | Bay 2 | Light | 25 | 40.9 | 29.5 | Yes | |
| | | Bay 17 | Light | 48 | 34.9 | 29.5 | Yes | |
| | | Annealing area 1 | Light | 7 | 35.6 | 29.5 | Yes | |
| | | Annealing area 2 | Light | 6 | 38 | 29.5 | Yes | |
| | | Cold end | Light | 9 | 32.4 | 29.5 | Yes | |
| | | Mirror plant – hot | Light | 7 | 29.8 | 29.5 | Yes | |
| | Indoor without process heat | Mirror plant – wet | Light | 12 | 28.5 | 29.5 | No | 31.2 |
| | | Bay loading area | Moderate | 76 | 29.3 | 27.5 | Yes | |
| | | Admin | Light | 200 | 26 | 29.5 | No | |
| | | Maintenance | Moderate | 20 | 29.8 | 27.5 | Yes | |
| | Outdoor | Maintenance | Moderate | 10 | 31 | 27.5 | Yes | 100 |
| | | Gardening | Moderate | 18 | 31.2 | 27.5 | Yes | |
| | | | Heavy | 10 | 31.1 | 26 | Yes | |
| Textile manufacturing | Indoor without process heat | Blowing | Moderate | 19 | 26.8 | 27.5 | No | 28.1 |
| | | Carding/drawing/roving | Moderate | 15 | 28.8 | 27.5 | Yes | |
TLV of 29.5°C was used and in case workstations did not require workers to stay permanently, a TLV of 29.5°C was used assuming light work (e.g., inspection work) and full acclimatisation. The adjusted values were compared to the prescribed TLVs recommended by the ACGIH.

Descriptive statistical analysis was done using the software ‘R’.

Results

Heat stress exposure in various processes of automotive and automotive parts manufacturing

Fig. 1 shows the distribution of measured heat stress indices across locations. Many indoor locations were found to be close to or exceeded the recommended TLVs. Further, indoor WBGT indices were observed to be largely driven by outdoor temperatures as they were uniformly high even in locations with no process-generated heat components.

Workloads prevalent at each of the locations shown in Fig. 1 (that were used to compute the corresponding WBGT index) are illustrated in Fig. 2.

Qualitative assessment of work practices and implementation of controls

In order to make specific recommendations to the units for heat stress exposure reduction, we undertook an observational qualitative assessment for existing work practices and existing controls. A number of recommendations ranging from provision of hydration breaks to improved natural ventilation and installation of air cooling devices were made. Based on longitudinal measurements at the same facilities, some of the key post-intervention improvements are shown in Table 1.

Estimating potential for work-related heat stress across select sectors

As an attempt to understand the potential scale of impacts related to work-related heat stress, in order to understand possible ramifications for climate change-related exacerbation, an estimate of the proportion of workers at risk are provided for selected sectors. This is based on measurements that were made and information collected as part of the routine occupational hygiene monitoring services provided by the investigators’ University department. While the case study summarised above had the single largest set of longitudinal measurements, the other sectors had a smaller number of cross-sectional measurements. The exposure implications for select processes in three such sectors, namely automotive parts manufacturing, glass manufacturing and textiles are detailed in Table 2.
Discussion

Results from over 400 measurements across multiple locations and industries clearly indicate that many processes even in organised large-scale industries have yet to control heat stress-related hazards adequately. Although a systematic review is not available, studies conducted in many other sectors in India reveal a high prevalence of heat-related exposures in both the formal and informal sectors, including farming, glass manufacturing, stone quarrying and crushing, mining, etc. (4-6).

While indoor work without process-generated heat exposures should be relatively less hazardous, because of the tropical climatic conditions in India, and particularly in the south, and the lack of controlled built environments, ambient temperatures influence work-related heat exposures even in indoor settings. This is further compounded by manual handling and other ergonomic hazards, also widely prevalent and poorly controlled in many industrial processes. Outdoor work is very common in India. Many jobs in the service sector (transport and local trade), construction, municipal administration and small businesses, in addition to specific processes in manufacturing and mining, are performed outdoors and here the impacts of high ambient temperatures can be particularly detrimental.

Exposure information available from selected studies in India is summarised in Table 3 along with estimates of worker populations employed in these sectors. While reliable measurements are not available in many sectors to estimate worker populations at risk, the sectors profiled in this paper serve to illustrate the likely widespread prevalence of such risks. Although the measured values reported in many studies, including this one, have not been able to capture the full range of exposures that may be experienced across seasons and at different times during the day, the observed prevalences of work-related heat stress reported in Table 2 are likely to be at the low end of exposure spectrum as they were limited to large scale and relatively newly established units.

As illustrated by the efficacy of relatively simple controls in the units included for assessment, there exist several options to install and/or improve existing controls. It is particularly important to recognise that while administrative controls appear more attractive (as they do not require initial large capital investments), the loss in productivity could be substantial if one were to genuinely implement controls to ensure health and comfort of workers. The cost–benefit thus should duly address health and quality of work impacts while comparing across control strategies. In developing countries there is also a socio-cultural dimension of ‘risk perception’ that argues against provision of air-conditioned workplaces in the shop floor. The added value of having comfortable work spaces insulated from external climate vagaries for health and productivity thus remain largely uncharacterised.

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 modest increases in temperature resulting from climate change could significantly alter the distribution of exposures and related health impacts. Work ability at even the lowest intensities of work may be severely limited if WBGT indices are increased beyond the already high values recorded in workplaces. The effects are also likely to make poorer workers even more vulnerable on account of their poorer health status, limitations in accessing controlled (air-conditioned) workplaces/homes and greater likelihood of engaging in heavy work. Although work-related heat stress information is frequently collected in many workplaces, many variables can influence measured values and accompanying heat stress such as time of day, month, location of measurement, workloads and availability and efficacy of controls. While 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 characterised across work settings. In order to maintain adequate surveillance on workplaces, modelling approaches are needed that could use routinely collected weather station data in relation to

Table 3. Heat stress and worker profiles for selected industry sectors in India

| Sector                  | Range of heat stress values (WBGT) measured (°C) | Estimated worker population in 1,000s (as per Indian National Sample Survey, 2000) | Reference                          |
|-------------------------|-------------------------------------------------|---------------------------------------------------------------------------------|------------------------------------|
| Agriculture             | 34.4–42.2                                       | 237,786                                                                         | Nag et al. (5)                     |
| Glass manufacturing     | 30–40                                           | Not available                                                                   | Srivastava et al. (6)              |
| Ceramics                | 43–54                                           | Not available                                                                   | Parikh et al. (7)                  |
| Mining                  | 25–31                                           | 2,263                                                                           | Mugerjee et al. (8)                |
| Tanning                 | 28–41                                           | 1,081                                                                           | Conroy et al. (9)                  |
| Textiles                | 27–39                                           | 10,480                                                                          | Sankar et al. (10)                 |

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measured WBGT indices at workplaces over a local region to estimate population level impacts on productivity and health. The development of such Population Heat Exposure Profiles (PHEPs) are being explored (Kjellstrom and Lemke, unpublished) and will likely allow monitoring of trends in ambient temperature and related implications for work-related heat stress across space and time as well as across multiple work place configurations in developing country settings, where routine workplace data is not always available and accessible.

Conclusions
The present case study serves to re-emphasise the need for recognition of heat stress as an important occupational health risk in both formal and informal sectors in India. Control of heat stress may have multiple co-benefits in terms of better health, improved productivity, lower rates of accidents, lower rates of morbidity and improved sense of comfort and social well-being. With the threat of climate change-related impacts looming large on developing countries including India, there is an imminent need to include this set of heat-related impacts while modelling health effects related to climate change. Making available good baseline data is critical for estimating future impacts and the case study presented here represents one such pilot effort in southern India.

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Kalpana Balakrishnan
Department of Environmental Health Engineering
Sri Ramachandra University
Porur, Chennai 600116, India
Tel: 91-44-2476-5608
Email: kalpanasrmc@vsnl.com