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Case studies on heat stress related perceptions in different industrial sectors in southern India

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Linkages between thermal loads and its physiological consequences have been widely studied in non-tropical developed country settings. In many developing countries like India, despite the widespread recognition of the problem, limited attempts have been made to estimate health impacts related to occupational heat stress and fewer yet to link heat stress with potential productivity losses. This is reflected in the ubiquity of workplaces with limited or no controls to reduce exposures. As a prelude to understanding the feasibility of alternative interventions in different industrial sectors, we present case studies from 10 different industrial units in Tamil Nadu, Chennai, which describe perceptions of occupational heat stress among the workers and supervisors/management.

Units were selected from among those who had previously requested an assessment of workplace heat stress exposure at select locations as part of routine industrial hygiene services provided by the investigators. Since the earlier measurements were performed in response to a management request, all units were revisited to generate a simple job and process profile using checklists in order to understand the overall heat exposure situation in the concerned unit. This was followed by a simple questionnaire administration to a small subsample of employees to evaluate the perceptions of workers and supervisors/management. Finally, we retrieved available quantitative data from previous measurements of heat stress at these units to correlate prevalence of exposures with respective perceptions.

Results indicate that the existing level of controls may not be sufficient for managing work-related heat stress in any of the sectors studied, with wide variations in perceived risks. There was a noticeable disconnect between worker's perceptions and their ability to secure workplace improvements related to heat stress from the management. Wider availability of engineering and administrative controls in the industries may be facilitated by monitoring worker discomfort, disability, and performance in more intensive ways so that the top management is able to justify the associated cost benefits.

Given the potential implications of future climate change related increases in ambient heat stress that are likely to translate into workplace exposures in developing country settings, concerted efforts are needed to integrate exposure assessments with assessments of productivity as well as health impacts. This will likely build the momentum for much needed interventions for large worker populations in the developing world.

Keywords: *heat stress*; *perceptions on heat stress*; *productivity loss*; *health effects of heat stress*

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Heat stress has been identified as a widely prevalent health risk in many industrial sectors in India (1–6). Combined effects due to excessive heat stress and ergonomic hazards (like heavy lifting, physical exertion, and others) pose great challenges for workers in being able to optimize their productivity, with the potential risk of ensuing heat-related disorders like heat stroke, heat exhaustion, heat cramps, and heat

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syncope. However, limited attempts have been made to create detailed job exposure profiles for various sectors that may facilitate such hazard recognition. With most workplace settings in developing countries being heavily influenced by outdoor temperatures (in the absence of mechanical cooling), it can be expected that both indoor and outdoor work may contribute to greater than recommended levels of heat exposure. Inadequate recognition of this hazard potential has hampered efforts to assess health impacts related to heat stress and/or implement controls to reduce exposures.

Building on earlier efforts in single industrial units to control heat stress exposures (7), an assessment of risk perceptions among workers and management across different sectors was conceptualized to provide a deeper understanding of factors that influence the investment in heat stress reduction strategies in individual companies. Such an exercise would also provide insights into how health risks and/or productivity losses in relation to heat stress may be assessed on a routine basis to facilitate risk communication and subsequent management. Finally, heat stress associated with climate change has been most often examined in relation to heat wave effects on the general population and have overlooked working populations. Recognition that climate change may precipitate occupational heat-related health risks with related impacts on productivity especially in developing countries is yet to develop. The need for the design of effective intervention strategies thus becomes even more important in the face of current and future climate change.

With a view to capturing perceptions that may play an important role in determining the availability/accessibility of control (preventive) measures for management of occupational heat stress, we present case studies from 10 different industrial sectors in Tamil Nadu in India that describe a range of perceptions on occupational heat stress. These case studies describe the nature of the job processes, available exposure information, an overview of the available control measures, and perceptions of workers and supervisors/management on heat stress in these sectors.

Materials and methods

Perceptions were assessed among workers, managers, and other health and safety professionals in area industries where heat stress measurements had been previously made as part of routine industrial hygiene monitoring by the same investigators. Ten such companies that were involved in automobile assembly, automobile parts manufacturing, heavy truck manufacturing, heavy vehicle (lorry) manufacturing, automobile parts (wheel) manufacturing, leather manufacturing, glass manufacturing, textiles, fertilizer, and electricity (power) generation were selected for the present assessment.

A simple job and process profile was first generated for all facilities to allow an overall understanding of the prevalence of heat exposure situations in companies. A small subsample of workers (~1–5% of the total worker strength) from select work locations where heat stress monitoring had been performed were first selected for administration of a questionnaire to assess perceptions (some of the units assessed have had a long history of routine heat stress monitoring while others have been assessed only on a single time basis). In addition, select workers from other locations, the safety and/or medical officer (if available), and work supervisors/senior management were included for the assessment. The selection of the participants from other categories was based on the premise that they would be able to respond to management relevant questions and would be aware of company policy on the issue. The response rate ranged from 60% among workers to 95% among other categories. The questionnaire elicited responses pertaining to how workers perceived the heat stress problem in terms of symptoms experienced, productivity/performance changes, the availability of controls, their awareness on heat stress management, and the availability of specific company policies for management of heat stress.

Heat stress exposure was assessed (during previous visits to the same companies) through measurements of the Wet Bulb Globe Temperature (WBGT) index. The WBGT index primarily estimates the environmental contribution to heat stress and is influenced by air temperature, radiant heat, air movement, and humidity. Since the WBGT index primarily reflects environmental contributions, recommended exposure criteria are adjusted for the contributions of work demands and clothing.

Measurements for WBGT were carried out using an area heat stress monitor (Model QuesTemp°34, manufactured by Quest Technologies, USA). The instruments used for the measurements comply with the standards set out by the American Conference of Governmental Industrial Hygienists (ACGIH). Additional information on workload, clothing worn, worker's time-activity pattern, and acclimatization were collected on-site by the trained industrial hygienists and occupational health specialists to make appropriate adjustments to the measured WBGT value.

A total of 242 questionnaires were administered and heat stress measurement data on nearly 80 work locations were retrieved to assess perceptions in relation to prevalent exposure situations and generate initial recommendations for next steps. All questionnaires were administered by research assistants with experience/special training on occupational hazard recognition and control.

Results

Results of quantitative and qualitative assessments conducted at the 10 facilities are furnished in Table 1.

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Table 1. Results on worker's and management's perceptions

Industry sector	Description of unit	Heat stress measurement results	Worker's perceptions	Management's perceptions
Automobile assembly (Case 1)	The unit employs around 4,800 workers. Work locations assessed for heat stress exposure included stamping, body shop, printing, Trim Cum Chassis (TCF), and quality testing areas. Except for quality testing that involved partial exposure to sunlight, other work processes were located indoors. All work areas were found to be well designed from an ergonomic point of view with little evidence of physical strain. The company was in possession of ISO 14001 (EMS) and OSHAS 18001 certification.	The unit had a long history of heat stress monitoring conducted as part of routine industrial hygiene monitoring activities with measurements of heat stress made at multiple locations since 2003. Many work locations consistently exceeded the recommended levels for heat stress exposure during peak summer months. The paint shop recorded some of the highest levels (with averages around 32.4°C).	Based on responses provided by around 40 workers from different work locations, heat stress is perceived as a seasonal problem that recurs every year. The term 'heat stress' was understood as being synonymous with the term 'summer.' Though there were no reports of severe symptoms related to heat exposures, the arrival of the summer season always signaled heightened concern about heat stress in the workers' minds. The major complaints from the workers, as perceived by them to be related to heat exposure, included symptoms like skin rashes and acne. Some also perceived chicken pox to be related to heat exposures. The placement of select preventive measures including provision of water, electrolytes, and fans within the facility had resulted from repeated complaints from workers of discomfort. 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.	Management had available an occupational safety and health policy with specific provisions for management of heat stress. This included conduct of routine environmental measurements for heat stress, provision of controls (that included fluid and electrolyte supplementation for workers), and conduct of routine trainings/awareness raising. However, of the 5 senior supervisors who responded, most felt that the majority of heat stress complaints are from new workers who are not acclimatized, or limited to those who engage in heavy work outdoors such as maintenance and gardening. They perceived that the available engineering controls (such as blowers, air coolers, air conditioners, ventilators, man coolers, and fans) that have been installed as a result of workplace monitoring to be adequate. While 3 of the 5 interviewed reported that the workers took long rest breaks, sometimes up to twice as long during summer months, they admitted not knowing if there was an impact on productivity. An on-site occupational health center was available and although no systematic surveillance of heat stress was being maintained. No incidents of extreme heat-related disorders such as heat stroke and heat exhaustion were reported. Non-specific complaints of cramps suggestive of dehydration were found to be more commonly reported in summer months.

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Table 1 (*Continued*)

Industry sector	Description of unit	Heat stress measurement results	Worker's perceptions	Management's perceptions
Automotive parts manufacturing (Case 2)	The unit employs around 700 workers. Work locations assessed for heat stress measurements included the starter assembly, alternator, solenoid, and gardening areas. All work processes are performed indoors except for gardening. No heat generating processes were identified. The company was in possession of ISO 14001 (EMS) and OSHAS 18001 certification.	The unit had a long history of heat stress monitoring, with measurements made at multiple locations since 2004. Most work locations exceeded the recommended levels for heat stress exposure during peak summer months. The alternator area recorded some of the highest levels (with averages around 33. 2°C). In addition workers employed in the gardening area experienced high levels of outdoor exposure (with averages around 34.4°C).	All of the 30 workers interviewed reported discomfort throughout the year. Despite no process-related heat contributions and with all work locations being indoors, workers felt heat was affecting their ability to work. 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 itchy skin were the most commonly reported.	There was no specific policy available for management of heat stress. Recommendations from workplace monitoring were only partially implemented. The factory medical officer reported several fainting episodes from heat exposure over the last 2 years. The rest rooms for workers were well ventilated and were provided with water coolers. Apart from job rotation and fluid replacement, there were plans to change the clothing material and working hours during summer.
Heavy truck manufacturing (Case 3)	The unit employs around 1,500 workers. Work locations assessed for heat stress measurements including sector fabrication, assembly, painting, testing, and yard areas. All work processes are performed indoors except in testing and yard areas where workers were exposed to direct sunlight for considerable hours during the day. No heat generating processes were identified. The company was in possession of ISO 14001 (EMS) and OSHAS 18001 certification.	Based on the request from the occupational health team of the industry, heat stress measurements were being routinely made during peak summer months of May since 2006. Most locations exceeded the recommended exposure values with some of the highest levels recorded in the in the yard (31.6°C) followed by testing area (31.3°C).	Of the 28 workers interviewed, most were not aware of the consequences of heat stress and reported being well acclimatized to heat. Heat stress complaints were primarily received from workers who had recently started. Skin rashes were the most commonly reported symptom. None of the workers reported heat affecting their performance.	Heat stress did not seem to be a main concern for the management. Even though no heat strokes or other extreme heat-related health events such as heat stroke/exhaustion had been recorded, 2 of the 5 supervisors interviewed agreed that workers slowed down when it was hot and took longer to complete tasks. Normal rest breaks and fluid replacement facilities were available. The rest rooms for workers were provided with water and air conditioners. An on-site occupational health center is accessible with beds for workers who get dehydrated.

Table 1 (*Continued*)

Industry sector	Description of unit	Heat stress measurement results	Worker's perceptions	Management's perceptions
Heavy vehicle (lorry) manufacturing (Case 4)	The unit employs around 5,500 workers. Work locations assessed for heat stress measurements included chassis assembly, front axle assembly, gear box assembly, frame assembly, engine assembly, rear axle assembly, fabrication, tool room, and yard areas. All work processes are performed indoors except for the yard area where workers were exposed to direct sunlight for considerable hours during the day. No heat generating processes were identified. The company was in possession of ISO 14001 (EMS) and OSHAS 18001 certification.	The assessment for environmental heat stress started in May 2007 in order to satisfy requirements related to the Occupational Health and Safety (OSHAS 18001) certification program of the industry. Most locations exceeded the recommended exposure values with some of the highest levels recorded in the yard (31.8°C) followed by the fabrication unit (30.2°C).	Even though many work locations exceeded the recommended heat stress exposure values, workers were mostly unaware of the heat stress related problems. Of the 42 workers interviewed most reported discomfort while working with oil mists and felt if the oil was removed they wouldn't feel the heat as much. Symptoms such as skin rash were reported but perceived to be linked to oil mist exposures. Symptoms such as dehydration and heat exhaustion were recognized only upon prompting.	The management did not seem to be aware of the direct impacts that heat stress could have on productivity, and seemed unwilling to engage in additional preventive measures. They perceived that current measures such as insulation and ventilators provided in the roof, job rotation, and fluid replacement and provision of air-conditioned rest rooms to be adequate. The occupational health center is well equipped with beds for workers who may need urgent treatment for dehydration.
Automobile parts (wheel) manufacturing industry (Case 5)	The unit employs around 3,000 workers. Work locations assessed for heat stress measurements included die casting, machine shop, and maintenance areas. All work processes are performed indoors. No heat generating processes were identified. The company was in possession of ISO 14001 (EMS) and OSHAS 18001 certification.	The assessment for environmental heat stress was performed once in 2008 in order to satisfy requirements related to the Occupational Health and Safety (OSHAS 18001) certification. Most locations exceeded the recommended exposure values with some of the highest levels recorded in the die casting area (35.3°C).	All of the 15 workers interviewed reported discomfort throughout the year. Despite no process-related heat contributions and with most of the operations being indoors, 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.	There was no specific policy available for the management of heat stress. Recommendations from workplace monitoring were being implemented but only partially so. The factory medical officer available on-site reported several cases of workers being overcome by heat exposure over the last 2 years. However none were found recorded in the register. The rest rooms for workers were well ventilated and were provided with water coolers.

Table 1 (*Continued*)

Industry sector	Description of unit	Heat stress measurement results	Worker's perceptions	Management's perceptions
Leather manufacturing industry (Case 6)	The unit employs around 300 workers. Work locations assessed for heat stress measurements included degreasing, splitting, dyeing, drying, sizing, and product inspection areas. All work processes are performed indoors. Oven drying was the only work location with process generated heat. The company was in possession of ISO 14001 (EMS) certification.	The assessment for environmental heat stress was performed once in 2009 in order to satisfy requirements from a prospective buyer. Most locations exceeded the recommended exposure values with some of the highest levels recorded in the drying area (33.9°C). followed by splitting (32.7°C).	Of the 8 workers interviewed most were not aware of the consequences of heat stress and reported being well acclimatized to heat. None of the workers reported heat affecting their performance. Workers reported the discomfort while working with volatile organic compounds in the dyeing area. They were however not ready to accept Personal Protective Equipments (PPEs) like the half face chemical cartridges and aprons provided as they felt that increased the discomfort from sweating and heat.	There was virtually no recognition of heat stress as a major concern. There were some cases of absenteeism during the peak summer months in the past and the HR manager cited excessive heat as a possible explanation. There was no heat protection policy available. With no OHS professional available, no information could be gathered on how engineering controls would be implemented following workplace monitoring recommendations. Normal rest breaks and liquid replenishment (water) was being provided and perceived to be adequate for heat stress management.
Glass manufacturing industry (Case 7)	The unit employs around 900 workers. Work locations assessed for heat stress measurements included furnace, float bath, annealing, paint coating, storage, and dispatch areas. All work processes are performed indoors and generate heat with the exception of storage and dispatch. The company was in possession of ISO 14001 (EMS) and OSHAS 18001 certification.	The unit has a long history of heat stress monitoring, with measurements made at multiple locations since 2004. Most work locations exceeded the recommended heat stress exposure during peak summer months. The furnace area recorded some of the highest levels (with averages around 31.8°C).	Based on responses provided by around 30 workers from different work locations, heat stress is perceived as a seasonal problem that recurs every year. Most felt they would be able to work more with better ventilation but admitted they were seldom able to slow down on account of heat. They did not report specific symptoms except for feeling tired. Summers increased the level of concern about heat stress in the workers' minds.	Management did have available an OHS policy on maintenance of occupational standards that included measurement of heat stress, monitoring the impacts on workers, providing engineering, and administrative controls. However, the 2 senior safety supervisors who responded felt that the majority of the heat stress complaints were received from newcomers who were not acclimatized or were limited to those who engaged in heavy work in the furnace area and outdoors, such as maintenance and gardening. They perceived that the available controls (such as blowers, air coolers, air conditioners, ventilators, man coolers, and fans) that have been installed to be adequate. An on-site occupational health center was available, although no systematic surveillance on heat stress was being maintained.

Table 1 (*Continued*)

Industry sector	Description of unit	Heat stress measurement results	Worker's perceptions	Management's perceptions
Textiles manufacturing industry (Case 8)	The unit employs around 70 workers. Work locations assessed for heat stress measurements included bale opening, carding, drawing, roving, and spinning. All work processes are performed indoors with no process generated heat at any of the work locations. The company had not sought any certifications (such as the ISO 14001 (EMS) and OSHAS 18001 certifications).	The assessment for environmental heat stress was performed once in 2003 as part of a pilot research project aimed at heat stress exposure profiling. Most locations exceeded the recommended exposure values with some of the highest levels recorded in the spinning area (31.8°C) followed by the bale opening area (28.5°C).	Of the 7 workers interviewed from different workplaces, workers perceived heat stress to be a seasonal problem and did not link it to the occupational environment. 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 in the middle of summer.	There was no recognition of heat being a major concern and the management expressed that if some buyers had not stipulated it, they would not have engaged in an assessment. It was not clear how they proposed to convince the buyers with the results of the workplace monitoring without installation of any engineering controls.
Fertilizers industry (Case 9)	The unit employs around 150 workers. Work locations assessed for heat stress measurements included storage, feeding, milling, mixing, and bagging areas. All work processes are performed indoors with no process generated heat at any of the work locations. The company was in possession of the ISO 14001 (EMS) and OSHAS 18001 certifications.	The assessment for environmental heat stress started in May 2007 in order to satisfy requirements related to the Occupational Health and Safety (OSHAS 18001) certification. Most locations exceeded the recommended exposure values with some of the highest levels recorded in the material storage area (32.7°C) followed by the bagging area (32.6°C).	Based on the response provided by around 32 workers from the different workplaces, most of the workers were well acclimatized to the working environment. There were no reports of any major heat stress related symptoms except for a few reported skin rashes during the peak of summer. Most of the workers seemed to be unaware of the symptoms of heat-related disorders. New workers (who are also perhaps unacclimatized) reported feeling discomfort during peak summer.	Though the workers did not seem to perceive heat stress as a major concern, OHS specialists perceived heat stress to be a major problem. There was, however, no recognition of the possible links between heat stress and productivity losses. No heat protection policy was available in this company. Cooling technologies like blowers, air coolers, air conditioners, ventilators, and man coolers had not been installed in most of the process areas despite the workplace monitoring recommendations. Normal resting breaks and liquid replenishments (cold water, milk) were provided.

Table 1 (*Continued*)

Industry sector	Description of unit	Heat stress measurement results	Worker's perceptions	Management's perceptions
Electricity generation industry (Case 10)	The unit employs around 800 workers. Work locations assessed for heat stress measurements included stock pile loading, ground hopper loading, crushing house, boiler, turbine, and utilities (pump house, compressor, and generator) areas. All work processes are performed indoors with the exception of the stock piling area that exposes workers to direct sunlight throughout the day. There was no process generated heat at any of the work locations. The company was in possession of the ISO 14001 (EMS) and OSHAS 18001 certifications.	Based on a request from the management of the unit, WBGT measurements were conducted once in March 2008. Most locations exceeded the recommended exposure values with some of the highest levels recorded in the utilities area (33.2°C)	Of the 10 workers interviewed, all perceived heat to be a problem year-round with the summer months of April through June and outdoor work being reported to be intolerable. All workers complained about the lack of adequate ventilation. Symptoms reported included dehydration, extreme exhaustion, frequent skin rashes, and acne. Chicken pox was perceived to be a symptom of heat exposure. All workers felt that their productivity was seriously compromised because of the heat and that no measures were being taken to reduce or mitigate the effects of heat exposures.	Despite wide spread recognition among workers about the prevalence of heat stress, there was no policy for management of work-related heat stress. A factory medical officer was available on-site and reported several episodes of fainting and cases of heat stroke in the past. Three of the 5 supervisors interviewed did admit needing more people and time to accomplish heavier tasks in summer. Although workplace monitoring had been undertaken and engineering controls recommended, none had been implemented. Administrative controls had been partially implemented, which included periodic rest breaks with fluid replacement and provision of well-ventilated resting rooms for workers with water coolers. Health education and awareness programs on the effects of heat stress were being conducted.

Discussion

The results described in the previous section clearly convey the wide variation in the nature of perception prevalent among workers and management across multiple industrial sectors. Despite the range of differences, listed below are some summary observations that convey the overall results of the assessment.

All companies (with the exception of one) assessed were in possession of some form of environmental or occupational health certification indicating a general awareness among local companies for occupational safety issues (especially since such certifications are not required for local legal compliance). However, the importance accorded for heat stress as an occupational health issue was rather low. Although in many cases measurements were requested to satisfy certification requirements, there was little correlation between the prevalence of the problem and the level of follow-up of recommendations for implementation of appropriate exposure mitigation strategies.

The levels wherever and whenever measured usually exceeded recommended exposure levels, but there was little or no integration with either control or health surveillance efforts. This was despite the availability of a well-equipped health center being available at many facilities.

Most locations where heat stress was measured were indoors with no process generated heat components indicating that heat stress exposure may be a facility wide problem and not limited to the locations monitored (as a result of primary contributions from high ambient temperatures). This has important implications for the scale of expected exposures and related impacts that could be grossly underestimated by including only industrial processes with process generated heat as sources of occupational heat stress. There were also a few cases of personal protective equipments (PPEs) not being used to avoid excess heat indicating potential for risks from heat stress spilling over to additional risks from chemical exposures.

Most workers recognized the problem and wanted some improvements but had limited abilities to influence their management. Some workers in fact felt this would allow them to maintain/enhance their productivity. Management often felt that the levels of controls in place were adequate and that in the absence of extreme health events (such as heat stroke or exhaustion) there was little need for additional measures to reduce exposures. There were few facilities that despite several heat stress related incidents did not engage in additional exposure controls but instead were satisfied with their health center being able to manage the episodes. Possible links to productivity losses were not recognized until prompted. While many workers felt they were not able to slow down, management was either unaware or surprised at the possibilities of such impacts on productivity as opposed to health.

Finally, heat was perceived to a 'common' and a 'general' problem, an issue of special concern for risk management in tropical settings. High levels of ambient heat are encountered in occupational and non-occupational settings. Since in many work locations this heat is not process generated, management does not feel obligated to control an exposure that the workplace did not generate. The linkages to health and welfare remain distal and it seems to be expected that workers would need to bear the heat and maintain productivity.

A summary that consolidates the main results and the ensuing discussion are provided in Table 2.

Conclusions

While many previous studies (1–7) have reported prevailing heat exposure levels in India, to our knowledge a perception survey has not been carried out thus far. The preceding discussion emphasizes the fact that the existing levels of exposure mitigation do not appear to be sufficient for managing work-related heat stress in any of the sectors studied. 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. Wider availability of engineering and administrative controls in the industries may be facilitated by monitoring worker discomfort, disability, and performance in more intensive ways so that the top management is able to justify the associated cost benefits. In some sectors, management did express interest in collecting data relevant to absenteeism and examining its relationship with heat stress especially during peak summer and this may afford an important opportunity to establish linkages to productivity. Linkages to productivity have been recently demonstrated in other countries (8–10). Similar quantification of such productivity losses may allow leveraging of worker interests with that of the management in feasible ways.

It needs to be emphasized that this assessment was carried out in large organized manufacturing units, a work environment setting that eludes millions of workers who are largely employed in the unorganized or small and medium enterprise (SME) units within industrial and non-industrial sectors. The magnitude of the problem as presented here may thus just represent the tip of the iceberg for a much larger and deeper impact. It is in this context that examination of this issue from a climate change point of view becomes important. Even relatively modest increases in ambient temperatures (such as the current lower end projections of 2–3°C) could be expected

Table 2. Results on the status of heat stress exposure in different industrial sectors

Nature of process	Heat stress exposure	Heat stress perceptions	Potential for impacts on productivity
1. Assembly (automotives and automotive parts manufacturing)	Mostly non-air conditioned workspaces; few heat generating processes; ergonomically well designed in large firms but not in small firms; heat exposures exceed limit values mainly in the yard, utility, and some painting operations.	Workers are well aware and have been responsible for most low cost engineering and administrative improvements. Workers see the need for improvements but management is mostly satisfied with efforts taken.	Being largely automated batch processes, potential for productivity losses are high. However, workers often stretch their work abilities to compromise. Management is willing to engage in assessment of potential productivity losses
2. Manufacturing large organized sector firms (glass manufacturing)	Non-air conditioned workspaces, many operations expose workers to process generated heat, limited workload contributions, heat exposures exceed limit values in many process locations.	Workers are well aware and perceive it as a well-known seasonal risk. Management too is well aware and engages in routine monitoring.	Potential for productivity losses not recognized and/or reported. Management is willing to enhance training efforts to increase awareness and avoid risks.
3. Manufacturing semi-organized firms (textiles, leather manufacturing)	Non-air conditioned workspaces; although no heat generating processes are involved, workplaces are poorly designed and ventilated and are often accompanied by exposures to mists, vapors, and dust that are aggravated by heat stress exposures. Most processes have high workload contributions with heat stress exposure exceeding in several process locations.	Workers are generally aware of risks related to heat stress. Many reported not wearing required personal protective clothing as the heat loads become unbearable. Many also perceive that removal of the chemical exposure will improve their ability to tolerate heat. Management is unaware and mostly disinterested in additional control efforts.	Potential for productivity losses and losses from health impacts very high as efforts for recognition, evaluation, and control are rather minimal. Management is not very willing to engage in additional efforts to assess productivity losses, but presumably could be motivated with results from other units/sectors.
4. Manufacturing medium sized firms (fertilizer production, power gration)	Non-air conditioned work spaces; only limited monitoring efforts have been made and, hence, only few high exposure areas recognized. Many processes involve substantial workload contributions.	Workers largely unaware of the problem. Management was aware of the problems, especially on account of several heat-related worker incidents during summer months. However, they were largely unwilling to engage in additional controls.	Potential for productivity losses and health impacts very high as limited efforts for control have been taken despite several reported incidents. Considerable ground work may be needed to initiate in-house efforts to assess productivity losses and/or health impacts.

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. The reduction of physical 'work ability' due to increasing heat exposure has been well documented in international guidelines such as ISO, 1989. Pilot studies have shown that there is not much work ability left between the hours of 10:00 and 17:00 during typical May days for construction workers in New Delhi, who often have to take 5 h rest breaks to cope with the heat (8). It could be easily expected that many workers are already losing substantial hours to reduced or no productivity and this would only worsen if ambient temperatures were to rise.

The National Institute of Occupational Health in India has undertaken extensive research on the physiology of heat exposure and preventive approaches of relevance for Indian work settings. Using experimental exposure chambers, their studies quantify the 'tolerance time' of work at different intensities until core body temperature reaches 39°C. At a WBGT of 34°C, the tolerance time for heavy work goes below 1 h and it reduces by 4–5 min per 1°C increase of WBGT (2). Given the propensity of workplaces at this or in excess of this threshold of exposures, any increases that climate change may precipitate could be expected to have serious impacts on workers health and productivity.

Concerted efforts would thus be needed to profile exposures in multiple work settings and link it with potential impacts on productivity and health. It is hoped that the results of this exercise serves as a pilot to scope larger efforts that can build the momentum for much needed interventions for large worker populations in the developing world.

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