

## Perspective

# Climate conditions, workplace heat and occupational health in South-East Asia in the context of climate change

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## Abstract

Occupational health is particularly affected by high heat exposures in workplaces, which will be an increasing problem as climate change progresses. People working in jobs of moderate or heavy work intensity in hot environments are at particular risk, owing to exposure to high environmental heat and internal heat production. This heat needs to be released to protect health, and such release is difficult or impossible at high temperatures and high air humidity. A range of clinical health effects can occur, and the heat-related physical exhaustion leads to a reduction of work capacity and labour productivity, which may cause substantial economic losses. Current trends in countries of the World Health Organization South-East Asia Region are towards higher ambient heat levels during large parts of each year, and modelling indicates continuing trends, which will particularly affect low-income individuals and communities. Prevention activities need to address the climate policies of each country, and to apply currently available heat-reducing technologies in workplaces whenever possible. Work activities can be adjusted to reduce exposure to daily heat peaks or seasonal heat concerns. Application of basic occupational health principles, such as supply of drinking water, enforcement of rest periods and training of workers and supervisors, is essential.

**Keywords:** climate, heat stress, occupation, South-East Asia, wet bulb globe temperature

## Background

Climate conditions of direct importance to human health include air temperature, humidity, air movement (wind speed) and heat radiation.<sup>1</sup> These have been known as occupational hazards for more than a century, based on evidence from field observations, epidemiological studies and physiological laboratory experiments. They were described in a detailed World Health Organization (WHO) technical report series in 1969,<sup>2</sup> and in the first substantive WHO/World Meteorological Organization/United Nations Environment Programme review of the impacts of climate change on human health in 1996.<sup>3</sup>

The ongoing and projected future climate change<sup>4</sup> has given new impetus to the study, analysis and prevention of climate-related occupational health hazards. The WHO South-East Asia Region is an area with substantial future threats to health from the changing climate.<sup>5</sup> As the environmental heat levels slowly increase, it is clear that working people are a vulnerable group.<sup>6</sup> This paper briefly discusses the special risks to, and the health policies and strategies to protect, the populations living in this region of the world.

## Occupational health hazards related to climate

Any occupational health hazard that is associated with climate factors can naturally also be linked to climate change. Table 1 summarizes the most likely hazards and their effects in vulnerable groups, based on a recent review of a large

number of epidemiological and laboratory studies.<sup>7,8</sup> The most predictable impact of climate change is an increase in environmental heat levels,<sup>4</sup> because the modelling of future climate starts from the influence of greenhouse gases on air temperature. Health effects, such as heat exhaustion, heat stroke, chronic kidney disease and chemical poisoning (see Table 1), are therefore part of the occupational health impacts occurring in countries of the WHO South-East Asia Region. Thus, countries or areas with very long periods of hot weather are at particular risk for the heat effects. All of the tropical countries of the region are in this category. The risks of kidney disease<sup>9,10</sup> and chemical poisoning<sup>10,11</sup> will depend on other factors at the workplace, but the local heat levels are a key feature. Extreme weather, particularly strong storms or heavy rainfall, can create serious injury and drowning hazards (see Table 1) and emergency workers are a vulnerable group,<sup>12</sup> as the frequency and strength of extreme weather events is likely to increase with climate change.<sup>4</sup>

The other health effects mentioned in Table 1 (vector-borne diseases, infectious diseases, noncommunicable diseases and mental health issues) are indirectly linked to climate change via factors such as ecological conditions, local food-production possibilities, worsened clinical status and displacement from home locations. Climate change involves effects on access to water and water quality, as well as changes in the ecology that may bring disease vectors to new locations. Local changes in climate conditions may be so extreme that continued habitation becomes difficult, as exemplified by a 21-year longitudinal study of weather-related displacement in rural Pakistan.<sup>13</sup>

**Table 1. Climate-related occupational health hazards, vulnerable groups and health effects<sup>a</sup>**

Climate hazard	Vulnerable groups	Health effects
High heat exposure (temperature and humidity)	Workers carrying out physically demanding tasks; outdoor workers exposed to direct sun Workers in heat-stress situations who do not hydrate enough Workers exposed to highly evaporative chemicals, e.g. organic solvents; high heat leads to higher workplace chemical exposures	Heat exhaustion, heat stroke Chronic kidney disease Chemical poisoning
Extreme weather, wind	Outdoor workers in affected areas; emergency workers; all workers when their workplaces are closed due to weather	Injuries, drowning
Ecological conditions indirectly related to climate	Outdoor workers, particularly farmers needing to work at dawn and dusk	Vector-borne diseases, diseases related to ecological change
Other indirect climate-related hazards	Low-income groups with limited health protection; workers with existing non-climate health problems affected by heat	Infectious diseases, noncommunicable diseases, mental health issues, etc.

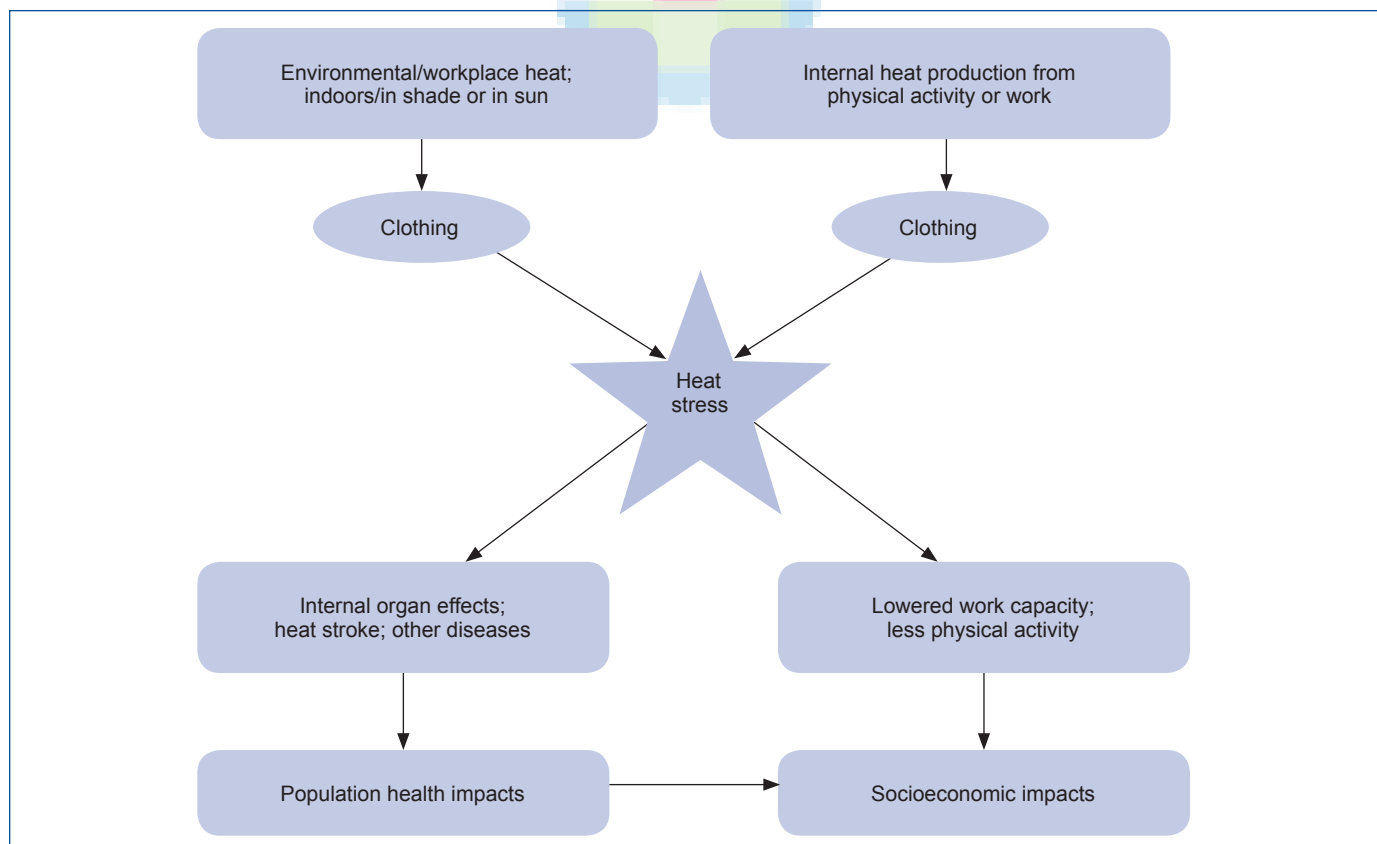
<sup>a</sup>Further details are provided in Kjellstrom et al., 2013<sup>7</sup> and 2016.<sup>8</sup>

## Specific risks related to workplace heat

High heat exposure creates a risk of heat exhaustion and heat stroke and is subjectively perceived as unpleasant or dangerous.<sup>1</sup> People working or involved in heavy physical activity are particularly affected,<sup>6</sup> because physical activity produces additional intra-body heat that must be dissipated. A working person's natural reaction to heat is to reduce physical activity, which reduces the body's internal heat production.<sup>6</sup> This may be called "self-pacing" or "autonomous adaptation".<sup>14</sup> An outcome of this preventive reaction is reduced hourly work capacity and reduced economic productivity during exposure to heat.

Fig. 1 outlines the different components of heat stress and its impacts, as well as the different pathways for different health and social effects, most of which can affect working people. The starting point is heat exposure due to environmental/workplace heat. In addition, physical activity leads to internal heat production, which adds to the heat stress. Tight-fitting work clothing reduces the possibility for sweat to evaporate and cool the body, so clothing is a factor in heat stress (see Fig. 1). The pathways to the ultimate negative impacts of heat follow physiological and psychological tracks. This explains the variety of effects of heat that have been reported in reviews.<sup>1</sup>

**Fig. 1. Population health and social impacts of heat: components and pathways**



Physiological heat strain is not only the result of high air temperature, but is also affected by air humidity, air movement (wind speed) and heat radiation (in outdoor work mainly from the sun).<sup>12</sup> The human body needs to keep an internal temperature close to 37 °C, and when the external temperature is higher, the body temperature may increase. Heat radiation also increases the heat load on the body.

The main mechanism for maintaining a healthy body temperature at high heat loads is evaporation of sweat. This evaporation is reduced when air humidity is high (even if sweating is profuse), while air movement over the skin increases the evaporation. Thus, in order to quantify heat exposure that is linked to the physiological heat strain, an index that combines temperature with the other heat variables is of great importance. In the 1950s, the United States (US) Army developed the wet bulb globe temperature (WBGT) as a tool for protecting army recruits from heat stress,<sup>12</sup> and this has become the most widely used index for occupational heat stress at global level.<sup>1</sup> A WBGT value of 37 °C corresponds to an air temperature of 37 °C if the relative humidity is 100%. At lower humidity, the WBGT level will be lower than the value of the air temperature.

A key question for prevention of heat effects is “what level of WBGT is dangerous?”. Table 2 summarizes the maximum WBGT values recommended by different occupational health agencies and organizations in the United States of America (USA), the standards of the International Organization for Standardization (ISO), and proposed limits in India. It is seen that an hourly WBGT of 30 °C or higher will create health risks in some workers, and at a WBGT of 27–28 °C, people in moderate work are at risk. These levels are already exceeded during parts of the year in several countries of the WHO South-East Asia Region. With climate change, the situation will get worse.

An enterprise can compensate for the effects of workplace heat by carrying out heat-sensitive work during the cooler night hours, or by scheduling such work into the cooler season. However, as climate change continues, the availability of “cool periods” is likely to diminish. Another factor influencing heat stress is the humidity level, which often goes up during night hours, reducing the impact of cooling. Many jobs have to be carried out during daylight, which reduces the availability of “cool hours”. For instance, many agricultural workers need to work outdoors in the sun and their pay is based on their product output. In order to maintain income, they may work beyond safe heat-exposure limits and a few die of heat stroke each year, as has happened even in the USA.<sup>19</sup> The problem

lingers on in the USA,<sup>20</sup> but for other countries such detailed reports are not available. Publications on heat mortality or morbidity in the general population are available,<sup>21</sup> but do not specifically analyse the effects on working people.

## Climate conditions in the WHO South-East Asia Region

The WHO South-East Asia Region already experiences particular problems with heat exposure for working people. Currently, a monthly mean WBGT as high as 30 °C occurs in Bangladesh, the Ganges valley of India and Nepal, but generally not outside that area in the region. This can be seen in the heat maps in Intergovernmental Panel on Climate Change (IPCC) reports.<sup>4,5</sup> The mean WBGT, in the shade, of the hottest month until the end of this century (2071–2099 average) has been modelled.<sup>22</sup> This modelling presents the mean of two widely used models, the Hadley Centre Global Environment Model (HadGEM) from the United Kingdom of Great Britain and Northern Ireland (UK),<sup>23</sup> and the Geophysical Fluid Dynamics Laboratory (GFDL) model from the USA,<sup>24</sup> while the future pathway is the Representative Common Pathway (RCP) 6.0, which has been estimated based on current global policies for mitigation of climate change.<sup>25</sup> The estimates of heat levels would be 2–3 °C higher in the sun during the middle of a day.<sup>26</sup> Thus, most of Bangladesh, India and Thailand, and large parts of other Member States of the region reach heat levels that will have negative effects on working people, unless they are protected with air conditioning. As noted above, an hourly WBGT level above 30 °C would create a risk of health effects in moderate-intensity work, unless the worker takes regular rest within every hour, as per the USA or ISO guidance (see Table 2).<sup>15</sup> Records of the monthly mean levels reaching such high levels imply that a large proportion of the work hours are too hot to carry out continuous work.

The past and projected heat conditions in the WHO South-East Asia Region are summarized in Table 3. It shows the afternoon air temperatures (monthly means of daily maximum temperatures,  $T_{max}$ ) during the coolest and hottest months in the geographical grid cell (0.5 × 0.5 degrees) around the capital city of each Member State of the region. In most of these countries, this area is one of the most populated, but there are, of course, other grid-cell areas with different climate from the capital. The climate in Bhutan is relatively cool (see Table 3), and the afternoon WBGT value ( $WBGT_{max}$ ) in the hottest month does not reach close to the risk values listed in Table 2. In the Democratic People's Republic of Korea, the

**Table 2.** Examples of occupational hourly heat-exposure limits (WBGT, OC)<sup>a</sup>

Work intensity	Metabolic rate (W)	ACGIH <sup>b</sup>	AIHA <sup>b</sup>	NIOSH <sup>b</sup>	OSHA <sup>b</sup>	ISO	India, Nag, 1996 <sup>c</sup>
Resting	117	—	32	—	—	33	37
Light	118–233	30	30	30	30	30	35
Moderate	234–349	27	27	28	28	28	33.5
Heavy	350–465	—	—	26	26	25	31.5
Very heavy	466–580	25	—	25	—	23	28

ACGIH: American Conference of Governmental Industrial Hygienists; AIHA: American Industrial Hygiene Association; ISO: International Organization for Standardization, Geneva, Switzerland;<sup>15</sup> NIOSH: National Institute of Occupational Safety and Health, United States of America (USA); OSHA: Occupational Safety and Health Administration, USA; WBGT: wet bulb globe temperature.

<sup>a</sup>Heat-exposure limits to prevent health risks among 90% or more of acclimatized workers at different work intensities.

<sup>b</sup>USA data from NIOSH, 2016.<sup>12</sup>

<sup>c</sup>Proposed in Nag, 1996;<sup>16</sup> these values are higher than all the others, owing to different prevention criteria. The Indian Factories Act governs standards,<sup>17</sup> and each state may prescribe a standard of adequate ventilation and reasonable temperature for any factory. Although the use of WBGT in India has been advocated,<sup>18</sup> there are no standard values for India, and states do not prescribe WBGT levels.

WBGT value reaches the limit for heavy labour (see Table 2). All the other countries reach higher values, which implies that workers' health may be threatened unless protective measures are implemented. The range of estimates of the hottest month in 2071–2099 for the five models used in the ClimateCHIP website<sup>27</sup> are usually 2–5 °C hotter than the heat levels in 1981–2010. India (New Delhi area) shows the highest temperature levels among the cities in 2071–2099.

## Threats to occupational health and productivity in the WHO South-East Asia Region

The heat effects on working people in the WHO South-East Asia Region were already the focus of research at the National Institute of Occupational Health in India decades ago.<sup>28,29</sup> In their more recent work, Nag et al. produced very important analysis of the heat concerns in relation to climate change.<sup>30</sup> Most studies have been conducted in India,<sup>31–37</sup> but Thailand<sup>38,39</sup> and Nepal<sup>40–42</sup> are also represented among the journal publications. Most of the studies demonstrate the health and productivity risks associated with high workplace heat exposures. Historical data on this topic from India and other countries of the region have also been reviewed by Hollowell,<sup>43</sup> who noted that early research was focused on heat problems in defence forces and the need to protect army recruits from extreme heat exposure.

Analysis of the heat situation in South-East Asia and the likely impacts on workers has also been reported with numerous heat maps,<sup>26</sup> and a summary of the only multicountry analysis of the economic consequences of the increasing heat exposures in workplaces has also been published.<sup>44</sup>

One way to quantify the impacts on labour productivity – in itself an outcome of the heat impact on physiology and work capacity – is to estimate the levels of heat exposure, as WBGT, for every month in the grid-cell areas of a country. The daily modelling data produced by climate scientists, such as the IPCC models, can be used to estimate daily variation of heat levels during each month, and models for hourly variation within a day produce hourly frequency distributions of different heat levels (for details of this method, see Kjellstrom et al., 2017).<sup>22</sup>

Based on the different IPCC pathways (RCPs) and estimates of global mean temperature change (GTC),<sup>4</sup> and using the current authors' methods,<sup>8,22,45</sup> changes in the average lost work hours for typical workers at three different levels of work intensity and different RCPs in India can be calculated (see Fig. 2). The starting points (that is, current losses) are 0% for light work, 2% for moderate work and 6% for heavy work (see Fig. 2). The losses based on WBGT level<sup>22,45</sup> increase substantially as GTC rises. The overall impact on a large population will depend on the workforce distribution into different types of work with different heat exposures and work intensities. The first economic analysis of these impacts estimated that projected losses in India will be US\$ 450 billion (purchasing power parity) per year by the 2030s.<sup>46</sup> A more detailed and validated analysis of such losses is urgently needed.<sup>44</sup>

Using the type of calculations presented for India in Fig. 2, the potential annual loss of work hours was calculated for five countries in the region (see Table 4) and for a number of other countries outside this region.<sup>45</sup> These data represent the modelling results for the policies of the Paris Agreement (similar to RCP 6.0)<sup>25</sup> and the situation for moderate-intensity work (300 W). Losses as high as 5–9% may have major impacts on the annual economic outputs from local enterprises and could reduce a country's gross domestic product in a significant manner. Such analysis for the countries in South-East Asia is lacking.

## Prevention policies and strategies

A fundamental strategy to reduce the risk of health effects and productivity losses in workplaces in the WHO South-East Asia Region is to ensure that future emissions of greenhouse gases from the largest emitters are constrained beyond the current national plans. Prior to the United Nations Framework Convention on Climate Change meeting in Paris in December 2015, countries published their post-2020 climate plans, known as their intended nationally determined contributions (INDCs). However, adherence to the INDCs would still result in average GTC reaching 2.7 °C, which is higher than the goal of a maximum increase in GTC of 2.0 °C adopted by the assembled governments.<sup>25</sup> Thus, additional efforts towards

**Table 3. Past and projected heat conditions in the WHO South-East Asia Region<sup>a</sup>**

Capital city, country	1981–2010, coolest month	1981–2010, hottest month	1981–2010, hottest month	2071–2099, coolest month	2071–2099, hottest month
	$T_{\max}$	$T_{\max}$	WBGT <sub>max</sub>	$T_{\max}$	$T_{\max}$
Dhaka, Bangladesh	25	33	29	27–30	35–38
Thimphu, Bhutan	7	17	14	8–13	18–20
Pyongyang, Democratic People's Republic of Korea	–3	28	25	0–2	31–33
New Delhi, India	20	38	30	22–25	38–43
Jakarta, Indonesia	31	32	29	32–34	34–36
Male', Maldives	31	32	29	32–33	33–35
Nay Pyi Taw, Myanmar	28	37	29	30–32	38–40
Kathmandu, Nepal	18	29	25	20–22	32–35
Colombo, Sri Lanka	30	33	28	32–33	34–35
Bangkok, Thailand	32	36	31	33–36	37–40
Dili, Timor-Leste	30	31	26	31–32	32–34

<sup>a</sup>Monthly afternoon temperatures ( $T_{\max}$  and WBGT<sub>max</sub>, °C) in grid cells (0.5 × 0.5 degrees) containing the capital city for each Member State of the WHO South-East Asia Region. Data from the ClimateCHIP website.<sup>27</sup>

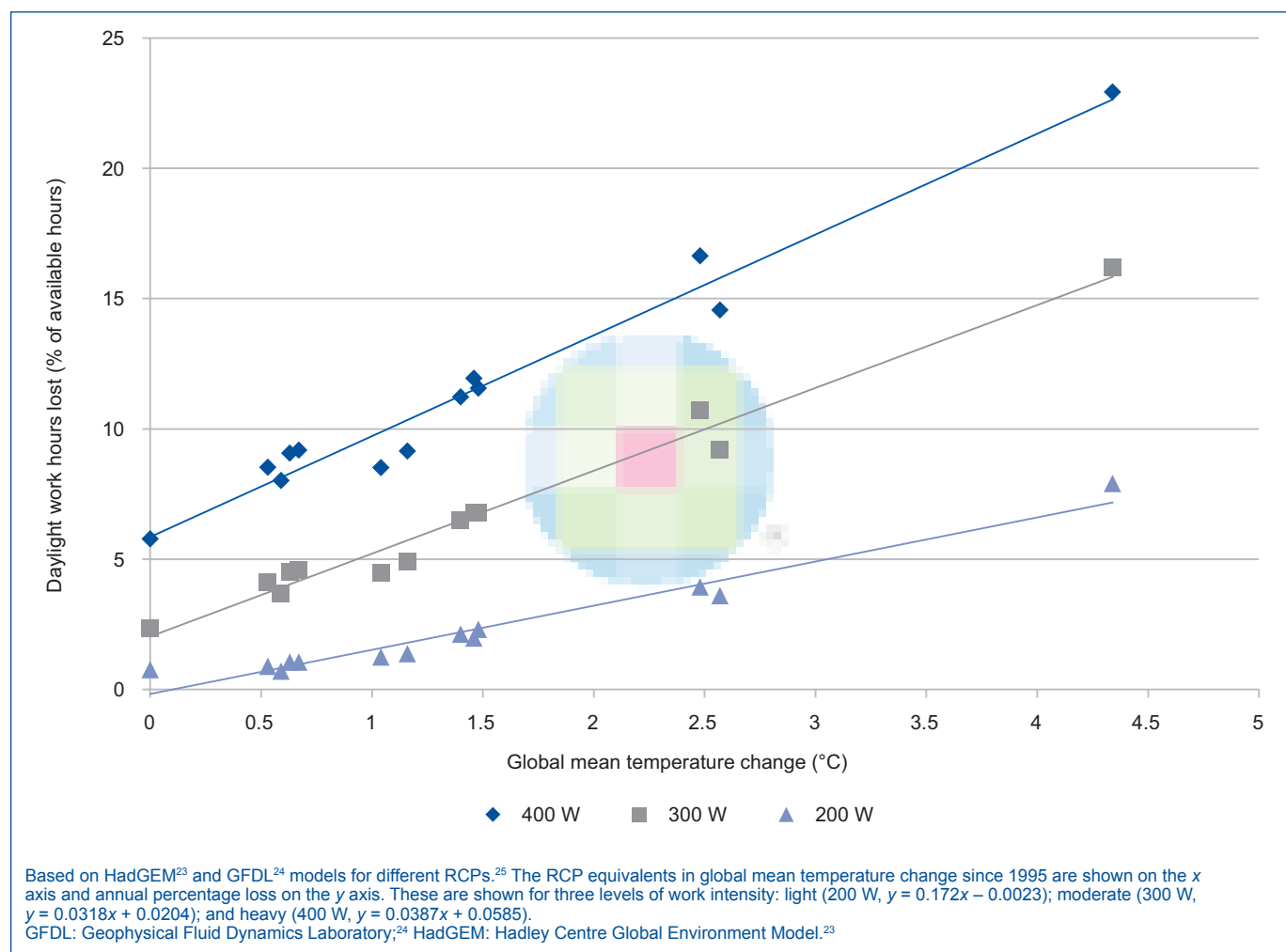
further reductions of emissions of greenhouse gases are needed to reduce the impacts described above and protect working people in the countries of the region.

Many workplaces in hot tropical countries need heat monitoring at some stage, in order to assess the level of health risk. Reductions of workplace heat stress can be achieved by providing shade covers for people who need to work outdoors. Reduction in the work intensity via use of mechanical devices would also reduce heat stress, as a result of reduced internal heat production. Indoor work environments can be air conditioned or cooled in other ways, and fans that increase air flow are often the simplest initial approach to protection.

In many countries, advice on heat protection in workplaces is available in local languages from government agencies.

Basic occupational health management should also be applied to work that may involve heat stress. This includes access to sufficient clean drinking water to replace the body liquid lost via sweating. Daily dehydration is a serious health threat, and rehydration is essential for occupational health. It is also essential that work supervisors and the workers themselves receive training on the risks of heat stress, the symptoms to look out for, and the methods for prevention. Further details can be found on a number of websites,<sup>48</sup> or in the handbook by Parsons.<sup>1</sup>

**Fig. 2.** Annual daylight work hours lost owing to heat in India



**Table 4.** Potential percentage annual daylight work hours lost due to environmental heat levels for moderate work (300 W) in the shade<sup>a</sup>

Country	Population, millions <sup>b</sup>	Daylight work hours lost (%)			
		1981–2010	2011–2040	2041–2070	2071–2099
Bangladesh	161	1.1	2.5	4.6	8.6
India	1311	2.0	3.6	5.2	8.0
Indonesia	258	0.33	1.2	2.6	5.5
Maldives	0.4	0.42	1.9	4.5	9.2
Nepal	29	0.61	1.3	2.0	3.4

GFDL: Geophysical Fluid Dynamics Laboratory model;<sup>24</sup> HadGEM: Hadley Centre Global Environment Model;<sup>23</sup> RCP: Representative Common Pathway.<sup>25</sup>

<sup>a</sup>In shade, moderate (300 W) work intensity, RCP 6.0.<sup>25</sup> HadGEM/GFDL mid-point.<sup>23,24</sup>

<sup>b</sup>2015, World Health Organization Global Health Observatory data repository.<sup>47</sup>



There are also publications that report health-protection effects of “self-pacing”, in which workers have freedom to choose their own work pace.<sup>49</sup> However, in many work situations, self-pacing will reduce the hourly work output for each heat-affected worker, and this may create negative conflicts between maintaining output and income on the one hand and protecting health from heat on the other hand. There is a need for further research on how these different protective approaches can best be implemented.

## Analysis of national impacts as a tool in prevention

Climate change and the related increasing environmental heat situation will not develop in the same way in all countries, and will impact on health and social conditions in different ways, depending on workforce distributions and currently applied approaches to heat protection. An important way forward towards effective prevention of workplace heat stress and its effects is therefore a detailed assessment of the problem and its most feasible solutions in each country. A national analysis and report on the impacts of climate change should ideally include the following information:

- a background statement and listing of any publications on the topic of heat effects on work, including materials from WHO and the World Meteorological Organization, International Labour Organization and International Organization for Migration;
- a quantitative description of the current and future heat-index levels (e.g. WBGT) during different months and in different parts of the country (or province), including maps (such material is available on the ClimateCHIP website);<sup>27</sup>
- analysis of the health risks and productivity impacts at the identified heat-index levels, using exposure–response relationships or heat-prevention guidelines or standards;
- listing of potential heat-effect prevention methods and discussion of how best to develop interdisciplinary strategies and actions to deal with the heat threats (involving the health sector, labour authorities, enterprises, trade unions, meteorology service, and other likely partners);
- a step-by-step plan for country-level policies and programmes.

## Conclusion

Climate change will create a variety of direct and indirect occupational health hazards. These include effects of environmental heat, injuries during extreme weather events, risks of vector-borne diseases, and other indirect effects as the climate is changing. The most prominent hazard is heat stress, and the underlying mechanisms and pathways of the health impacts are well known from thermal physiology. The WHO South-East Asia Region is a vulnerable area because the current heat situation in many countries is already creating important occupational health risks. Climate change will make the situation worse and each country is recommended to develop a local occupational health impact analysis and prevention plan to protect their workers.

**Acknowledgements:** We appreciate the research on this topic carried out in the region, and have been inspired by many local scientists to carry out analysis and produce reports on the climate and occupational health issues in South-East Asia. We acknowledge the valuable analysis work contributed by Ms Lauren Lines for this project, and are grateful to the two anonymous reviewers who provided valuable comments and some missing information.

**Source of support:** A consultancy grant was received in 2016 from the World Health Organization Regional Office for South-East Asia, to produce a report on climate conditions and chronic kidney disease. This new manuscript is an extension of that work.

**Conflict of interest:** None declared.

**Authorship:** TK developed the design of the work, interpreted results and drafted and finalized the manuscript. BL contributed expertise in heat physiology, collected climate data from the web, developed analysis methods and contributed text. MO developed the database for the analysis, designed software applications for the work, carried out analysis for different locations and contributed text.

**How to cite this paper:** Kjellstrom T, Lemke B, Otto M. Climate conditions, workplace heat and occupational health in South-East Asia in the context of climate change. WHO South-East Asia J Public Health. 2017;6(2):15–21.

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