

Effects of Heat Stress Exposure and Climate Change on Health and Safety of Outdoor Workers

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The studies carried in the world regarding the possible significant influence of climate change on the health and safety of outdoor workers has not been given the due consideration (especially in the least developed and developing countries). Hundreds and thousands of outdoor workers are exposed to elevated temperatures, humid environments and climate extremes in combination with urban air pollution; which is ultimately impacting their safety and well-being. The statistics show that in the past few years, due to the rise in temperature on earth and frequent heat waves within urban settlements, an abrupt increase has been observed in the rate of heat-related health problems. Exposure to extreme heat (exceeding 40 °C) causes many direct and indirect health hazards, which include vector-borne diseases and exposure to certain harmful chemicals. Currently, the climatic and heat-related effects are decreasing the working capacity of workers and in the future it is projected that the frequency and magnitude of these effects will increase. With the rise in temperature and the occurrence of frequent heat waves in urban areas, the number of health issues due to high (maximum average) temperature have increased rapidly. This article discusses the impacts of heat exposure and climatic change on productivity, health and safety of outdoor workers by summarizing findings from the literature, and eventually recommends control measures for reducing heat exposure at the outdoor work areas and climatic adaptations. In addition, it argues that there is a need for more research about the impacts on health and economic conditions due to heat and climate change in the workplace on global level (especially in developing countries).



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Introduction

Outdoor workers are the front-liners who are exposed to various physical, biological, chemical, ergonomic and psychological occupational hazards. Among these hazards, one of the most prominent ones are the environmental stresses and severe climatic conditions. They are mostly exposed for a longer period to high levels of heat and other stresses like UV radiation, atmospheric pollutants, and urban heat island (UHI) effect.¹ This chronic exposure can produce severe as well as frequent known occupational health hazards.^{2,3} In past studies, it has been reported that the rise in outdoor temperature can result in health issues for outdoor workers. The frequent, severe, and long-term exposure to UV radiations causes severe health effects in workers such as eye problems, skin cancer, and immune dysfunction.^{1,4,5,6,7} In addition to these health effects, heat stroke, heat syncope, heat rash, heat exhaustion, and rhabdomyolysis are some of the most common heat related health issues which occur due to long-term exposure to frequent and intense heat or high temperature. Exposure to high temperature can also affect the focus of workers on their work, and this result in higher risk of injury and lapse in their safety. Further more, due to prevalent global climatic changes and Urban Heat Island (UHI), the levels of atmospheric pollutants, particularly ground level ozone, are increased. The exposure of outdoor workers to such air pollutants has chronic health effects (like allergic reactions and various respiratory problems).^{8,9,10,11,12}

Heat exposure and climatic effects cause objective and subjective health related symptoms like heat cramps, heat rash, heat edema, synope etc.¹³ These are in line with hypothesis that the exposure to heat increases the risk of occupational ill health, accidents, and injuries. It is reported in Taiwan and Thailand that temporary workers suffered from intense heat strain due to working in hot and physically demanding works at the construction sites along with hot living conditions in sites near residences.¹⁴ According to Campbell (2018) heat waves have caused an increase in the hospitalization rate due to upsurge in the rate of cardiovascular diseases during the high temperature periods in Vietnam and Puerto Rico.¹⁵ By improving the living and working conditions of workers at workplace, the heat related issues can be eliminated or minimized.¹⁴ Climate extremes are some of the most

evident environmental problems of this century, which are impacting human's health in one way or another. Along with this, the prevailing situation of air pollution and urban population growth, which according to the United Nations is expected to increase to about 57% in 2050, are exacerbating the situation especially in developing countries.¹⁶ Keeping in mind this scenario, World Health Organization (WHO) has asked the members states to take significant measures to curtail the impacts of climate change associated with human health.¹⁷

Although climate change is one of the most familiar global environmental issues of the present and future, yet its harmful effects on occupational health and safety of human resources (workers and employees) have not been given much consideration.¹⁸ Owing to the rapid expansion of cities globally, the urban island heat effect (UHI) has become an effect of climate change due to human induced activities.¹⁹ Climate change impacts have altered the ambient environment for workers, due to which new hazards have been added to already existing ones in the workplace. As a result, outdoor workers will have to face harsh working conditions; extreme heat, toxic substances, and higher risk of infectious and vector borne diseases.^{1,7} In addition to these impacts, there will be risk of damage to infrastructure and ultimately humans like community members, workers, and emergency crew from extreme weather conditions.²⁰ According to International Labor Organization (ILO), fire fighters, farmers, emergency responders, health care staff, transportation workers, and utility workers will be more vulnerable to climate change.²¹

Furthermore, climate change intensifies the health and safety issues and their severity of risk to workers in workplaces. It is anticipated that workers will be more affected by climate change than public as they will be frequently exposed to harsh weather conditions. Exposure to heat and effects of climate change and their severity will be more for outdoor workers (migrant workers, day laborers, or any other who has social or economic problems). This article summarizes the current information on relevant health effects of climate change, exposure to extreme temperatures on outdoor workers. It also offers various available adaptation plans to reduce the impacts of climate change and to enhance capacities of outdoor workers.

The current study focuses only on tropical developing countries, and the main aim of this study is to draw the attention on evolving research areas because of their relevance to the effects of extreme heat exposure, health and safety concerns and climate change adaptation actions of outdoor workers. It encompasses the chances of effects of climate change and exposure to heat that will at the end affect the productivity of outdoor workers. Accordingly, not only direct but also indirect hazards of increasing heat to health and safety of vulnerable groups of outdoor workers, exposure to harmful chemicals, vector borne diseases and infectious are discussed. Moreover, the principle methodology

for compiling this study is the literature search (including research papers, review papers and organizational reports) relevant to the core areas of this study.

This study will aid the policy makers, researchers, decision makers, academicians, and regulators to undertake efficient measures to tackle the adversities of climate change and exposure to heat. Exposure to humid and harsh environment, extreme weather conditions, biological and air pollutants are some of these adversities of climate change on occupational health and safety of workers or occupational hazards.

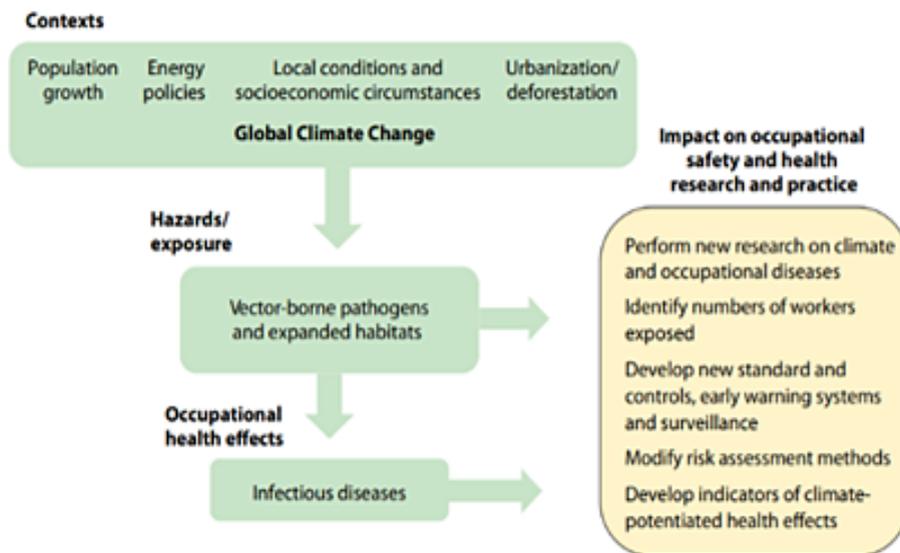


Fig.1: Climate change and occupational health and safety, adopted and modified from Schulte and Chun, 2009.²⁰

Typical Climate of Tropics, Heat and its Effects

Tropics refer to the regions that lie between tropic of Cancer (23.45 °N) and tropic of Capricorn (23.45 °S), different regions have difference in their climate and temperature patterns.²² The areas adjacent to tropical rainforests (like Philippines, Cebu, Mactan etc) have mean temperature of 22 to 28 °C with high humidity, while areas like Bangladesh adjacent to seasonal tropical forests often reach 40 °C and even more.²³ Moreover, tropics have dry regions as well, which include the areas adjacent to hot deserts where the temperature in summer exceeds 40 °C in the afternoon and drops up to 30 °C at night or early morning.²²

Just like the rest of the world, climate change is occurring in the tropics as well, and the warming of 0.7 to 0.8 °C has been noted.²⁴ Singapore is an example of this warming, and it is estimated that it may become the warmest place till the next century.²⁴ This rise in temperature has initiated many impacts in the tropics which include frequent floods, drought, glacial melting, coral bleaching etc.²⁴ Moreover, according to fifth report of IPCC, not only the frequency and intensity of heat waves are increasing but also their length of prevalence is increasing, which is an adverse impact of climate change.²⁵ It has been found that these heat waves are influencing the health of populations in tropical regions. In Vietnam, which is located within

latitude of 10°-23° N, heat waves have caused an increase in the hospitalization rate due to upsurge in the rate of cardiovascular diseases during the high temperature periods in this country.¹⁵ Puerto Rico (located at 18 °N), which is an island; its population has reported increase in mortality rates due to stroke and cardiovascular diseases during the high temperature periods.¹⁵

Exposure to Heat and Hot Environments at Workplace

Workers exposed to intense heat, hot work environment for extended time, or involved in exhausting physical works might be at risk of heat stress. Some of the most common and adverse effects of heat exposure are heat stroke, heat exhaustion, rhabdomyolysis, and often death of individual.³ Work related exposure to heat also increases the risks of traumatic injury. The increased induration, frequency, and intensity of exposure to heat elevates the risk of illness and death.^{26,27}

Besides outdoor workers, goods delivery men, utility workers, farm workers, construction workers and all those who have to work in unsuitable outdoor work environment such as lack of ventilation system are at high risk of various hazards related to heat.²⁸ In general, workers in all those workplaces have inadequate welfare facilities; like access to water, availability of rest area, and cool space are at high level of risk.²⁹ The rise in atmospheric temperature due to climate change increases the risk of exposure and their effects on workers of certain toxic chemicals.³⁰ Volatilization of certain chemicals occurs due to rise in temperature, which increases the risk of exposure to these environmental pollutants. It means that the toxicity (ability of a chemical to cause harm) and the mobility of chemical pollutants are increased due to climatic changes. This leads to transportation of airborne particles to remote areas.³¹ For instance, the alteration in food webs, melting of ice cover and changes in carbon cycle increase the concentration of Persistent Organic Pollutants (POPs) in soil, water and biosphere.³² The high atmospheric humidity and temperature enhances persevere of the chemicals for a longer time in atmosphere.

Extreme Weather Conditions And Air Pollution

Natural disasters or extreme weather events (floods, droughts, landslides, storms, lightning, wildfires

etc) are often responsible for injuries, diseases, mental stress, and death of workers at workplace. During and after the disaster, the staff involved in rescue and rehabilitation operations is at risk of exposure to different hazards at the site. Further more, acute and chronic health problems like cardiac diseases, pulmonary disorders, and various allergic problems are aggravated by air pollution.^{33,34} Moreover, there are some factors that affect the exposure to air pollutants like location of workplace or site, weather conditions, and materials being used at the site. Generally, warmer temperature creates greater chance of air pollutant's exposure (such as particulate matter and ground-level ozone).^{35,36,37} Furthermore, workers are presumably affected by increased air pollution during pollen production season. These affected workers include the outdoor workers (such as drivers, fire fighters etc.) and the indoor workers inhaling unfiltered air.²

Biological Hazards

Frequent changes in average temperature and rainfall patterns badly affect the spread of pathogens, vectors, plants, and allergens. The overall rise in the temperature due to climate change has been affecting the human health in a number of ways. One of them is the frequent outbreak of epidemics (infectious/contagious diseases). The infectious agents like bacteria, viruses and protozoa along with the vectors like ticks, flies and mosquitoes are influenced by climatic variability. Therefore, the climate change boosts their production and increases the extent of disease transmission in human beings. The health issues caused by such pathogens can be food borne diseases, water borne diseases (e.g:typhoid), vector borne diseases (e.g: Zika, Dengue, Lyme,Chikungunya etc.), asthma (due to molds and pollens), and health effects caused by poisonous plants (e.g: skin and lungs irritation) Apart from health impacts linked with biological hazards, multiple adverse occupational health disorders are related to pesticides exposure. For instance, organochlorine pesticides can cause chronic bronchitis, insecticides can result in sarcoidosis and bipyridyl herbicides can develop allergic rhinitis.³⁸ As compared to the indoor workers, outdoor workers are more vulnerable to these effects.

Outdoor Workers Exposure to Heat Stress and its Health Outcomes

Studies have revealed that thousands of workers can become ill every year due to exposure to working environments characterized by high temperatures.⁵ Most of the people exposed to high level of heat develop chronic illnesses while others become allergic to heat conditions.⁴ Workers tend to perform ineffectively when the working conditions are not favorable. According to Roghanchi and Kocsis (2018), workers perform differently when exposed to diverse conditions. When working in a hot environment, there is a high likelihood of heat increase because of the normal metabolic activities and heat from the sun. Generally, the impact of heat on health is measured in terms of mortality or hospital admissions.⁵³ Aged workers and those

with impaired health are particularly at risk when exposed to heat and elevated temperature due to climate change. Heat stroke is an impact that can also occur in physically healthy workers who carry out intensive heavy work in longer exposure to heat due to social and economic problems. The heat related illnesses come from exposure to hot temperatures or prolonged heat. In order to cause cooling effect within human body during prolonged heat exposure, blood rushes and reaches to the surface of the skin. Thus, less blood comes to the brain, muscles, and different organs. This could interfere with both physical strength and mental capacity leading sometimes to risks that may damage the health, and causes disorders such as heat induced rash, stroke and cramps, heat syncope and rhabdomyolysis.

Table 1: Health issues related to heat stress

Main health issues related to heat stress	Associated impacts	References
Heat stroke	<ul style="list-style-type: none"> • Death or permanent disability • Less blood flow to brain, muscles and different organs 	4,44
Skin damage	<ul style="list-style-type: none"> • Skin burns • Skin cancer 	42,43
Dehydration	<ul style="list-style-type: none"> • Loss water and minerals • Muscles cramps or heat cramps • Pain sensation in voluntary muscles (mainly arms, legs, or torso) 	44
Psychological set-back	<ul style="list-style-type: none"> • Lowering of cognitive performance • Loss of productivity, 	42,43

At many outdoor working sites, workers reported that those who experienced heat stress often had to stop working, and the results were fatal in some cases. Therefore, thermal stress is the major cause of health complications among such workers.⁵ The fatalities in thermal stress often increase during summer when the temperatures are extremely high. Since most countries do not have heat stress regulation methods, heat prevention and treatment of symptoms could be an option that could help construction companies to deal with heat stress.⁴⁰ The effects of heat stress on normal body functioning can be measured using the rate of heartbeat, body consumption of oxygen, expenditure of energy, fatigue, and minute ventilation.⁴¹ These measurements are brought out via case control studies. There exists strong evidence that heat has

physical, psychological, and mental effects on the health of these construction site workers due to exposure to heat stress. Among the effects is the exhaustion and skin burns, lowering of cognitive performance, psychological impacts, loss of productivity, and the build up of these conditions develop to severe illnesses like skin cancer and thermal stress.^{42,43}

Heat stroke is a significant heat related health issue, and it should be treated as a prioritized medical emergency. The occurrence of heat stroke is caused by the condition when the human body does not effectively dissipate heat and lose the ability to regulate the body temperature.⁴⁴ The mean body temperature quickly raises, homeostasis mechanism

stops working, and the body becomes unable to lower the temperature. At the time of heat stroke, body temperature reaches to 106°F or higher within ten to fifteen minutes. Heat exhaustion mostly leads to heat stroke which occurs after being exposed to high temperatures accompanied by elevated core body temperatures around 100.4°F–102.2°F, and it often is escorted by dehydration.⁴⁴ The normal range of human body temperature is 36.5 to 37.5 °C, but when exceeding from 40 °C or 40.5 °C (equivalent to 104 and 105 °F respectively) it may leads to heatstroke.¹³ Generally, if environmental temperature is between 40 °C or 54 °C (between 105 and 130 °F), then human beings can experience heat exhaustion. Moreover, if this environmental temperature exceeds 54 °C (130 °F), then it leads towards heat stroke.⁴⁵ Heat stroke results in death or permanent disability if emergency medical treatment is not provided timely. The main signs of heat stroke are slurred speech, hot dry skin, confusion, clumsiness, fainting/unconsciousness, profuse sweating, seizures, and high body temperature. Due to over sweating, body losses enough water and minerals, which causes muscles cramps (that occur in a hot environment or during or after exercise) or spasms called heat cramps. This results in pain and spastic contractions in voluntary muscles (mostly in the arms, legs and torso).

Role of Governments and International Standards

The temperature on the Earth is increasing at an alarming rate, which in future will demand governments, employers, and workers to be more prepared for facing the health risk of climate change. It will be a prerequisite to take critical steps to follow adaptation and to manage various health risks of climate change particularly impacts of high temperature. This could be achieved by proper regulatory frameworks like labor-related agreements, standards, regulations and rules. The role of international labor standards in the promotion of adaptation to reduce the impact of rising temperature is very helpful around the world. These international standards provide various tools for the management of health-related issues related to extreme heat stress, and to safeguard the decent work conditions in workplaces. The Occupational Safety and Health Convention, 1981 (No. 155) and its associated Recommendation, (No. 164) both consider heat stress as a significant hazard at workplace. The C155 and R164, international labor standards, both provide direction to the states for formulation and execution of national occupational safety and health policy. In addition to other workplace hazards, this policy will specifically address heat stress in accordance with the requirements and consultation of stakeholders, i.e., individuals, employers, and workers' organizations.

Table 2: International standards for the management of health-related issues related to extreme heat stress

Standards	Purpose
Occupational Safety and Health Convention, 1981 (No. 155)	Provide direction to the states: For formulation and execution of national occupational safety and health policy
Associated Recommendation of C155 (No. 164) Workers' Housing Recommendation, 1961 (No. 115)	Suggest regulations: For managing heat stress risk and guiding about adaptation efforts by workers, employers and government organizations
Protection of Workers' Health Recommendation, 1953 (No. 97) Hygiene Recommendation, 1964 (No. 120)	

Additionally, according to Occupational Safety and Health Convention No. 155, prevention of illness, injuries and accidents occurring at the workplace is the responsibility of national occupational safety and health safety policy. The

complementary Recommendation No.164 requires national Occupational Safety and Health policy to include actions taken for regulating physical factors such as humidity, temperature, light and ventilation at the workplace. Moreover, other

international labor standards such as the Workers' Housing Recommendation, 1961 (No. 115), the Protection of Workers' Health Recommendation, 1953 (No. 97) and the Hygiene Recommendation, 1964 (No. 120) suggest regulations for managing heat stress risk and adaptation efforts by workers', employers' and government organizations. Furthermore, Recommendation No. 97 demands that employers should carry out all necessary actions to eliminate, reduce, mitigate and prevent all possible hazards and risks at the workplace and provide sufficient and suitable protection to the workers including excessive heat and sudden temperature variations.

Governments are the main bodies that are involved in controlling environment that affect the behavior of employers and workers. They also provide guide lines for the different actions to be carried out for the control of adversities of heat stress and climate change on a workplace. A regulatory framework is very necessary to be implemented for these issues. An early alarm system for heat extremes is very important to mitigate such extreme temperature problems.^{35,46} In developing countries, the main constraints are financial and technical restrictions. These should have to be considered prior to the development of such a mechanism. It is crucial to promote international cooperation, information sharing and joint action under the umbrella of International Labor Organization (ILO) to attain the overall development of the infrastructure needed to adapt to heat stress. It would help in strengthening resilience and adaptive capacity of workers who are the most vulnerable to heat stress like farm workers.^{21,47} Social protection instruments can compensate for the loss of income and employment due to environmental hazard at work. Regulatory interventions are required for the promotion of special technologies, advancement in technical standards for infrastructure and strengthening of public employment policies to tackle the problem of migration of workers from rural areas to cities or to facilitate migration due to future impacts of climatic events on vulnerable works group. Sometimes temporary or permanent migration is the only adaptation strategy to mitigate the effects of climate change.

Heatexposure Mitigation

The laborers, working outdoors or in an open environment that are prone to long-term heat exposure include construction, agricultural workers, road cleaners and municipality, fire fighters, window cleaners, fueling and service station attendants etc. In urban areas with climatic and weather conditions along with air pollution, Urban Heat Island may further aggravate the situation and impact outdoor working conditions. To adequately address heat stress, it is best to manage this holistically and implement a variety of measures including assessment of the on site risks and determination of hazards, implementation of suitable effective engineering control measures, devising effective heat stress program for workers effected from heat stress, implementation of mid-day break, working hours, facilities provision regulations during the summer months for outside employees.

A comprehensive risk assessment and acclimatization program, an effective communication system, onsite welfare facilities, provision of appropriate body cooling devices, pre-employment screening and medical clearance can be considered for outdoor heat exposure managing techniques. Moreover, personal protective gadgets, administrative and engineering measures are always viable options in reducing the impacts of working outdoor, especially in extreme summer and extreme winters. Studies have identified that thermal stress is among the leading heat-related illness and prolonged exposure to the sun without breaks hampers the performance and effectiveness of an employee.^{5,46} Therefore, depending upon work site conditions, shortening of working periods, job rotation, frequent rests, improvement of ventilation, and provision of air conditioning facility can be very effective. Along with this, using sunscreen, light clothes on head, goggles, putting on hats, and construction of movable shades are proven best safety and health practices according to literature.⁴⁸

Climate Change Adaptation

In order to ensure minimization of the impacts of climate change on occupational health and safety (work related illnesses and injuries) of

outdoor workers, multiple approaches would be required. Employers' and employees' readiness in mitigating the impacts of climate change can not only be evaluated by recognition and anticipation of potential occupational safety and health hazards and climate change, but also their mitigation methods.⁴⁹ For example, adaptation and mitigation policies of climate change could result in changes in building design and energy consumption which can have positive impacts on health and safety of workers. The scope of occupational health surveillance should be expanded to incorporate health and safety impacts caused by climate change on workers.⁴⁹



Fig.2: Framework of the Centers for Disease Control and Prevention (CDC), Building Resilience against Climate Effects (BRACE), Adopted and modified from Centers for Disease Control and Prevention.³⁹

A holistic method which is adopted to address the possible influence of climate change on health and safety of employees and workers includes integrated hazard recognition, coordination and response.⁵⁰ The vulnerability assessment leading to mitigation action and evaluation can be utilized to reduce occupational health and safety hazards and risks making the workplace environment safe for the workers, according to the "Building Resilience against Climate Effects Framework of the Centers for Disease Control and Prevention".^{49,51}

The commitment of the top management, workers' participation in hazard identification, risk assessment process and taking control measures are some

of the main procedures for the management of health and safety. These practices should focus on existing and additional health hazards which arise from climate change. The BRACE framework (an adaptive management approach) can help employers and workers to adapt to the new normal. Following is the list showing employer's preparedness:

- Allocation of resources for identification of hazards
- Identification of vulnerable groups in workplace
- Ensure the execution of control measures in accordance with policies, procedures, and equipment

Employer readiness consists of amendments in building safety, scheduling, work operations and interactions and integration with other preparedness such as involving the fire department in process safety management or launching a communication system to reach workers at home.⁵² National Institute for Occupational Safety and Health (NIOSH) provides recommendations that emergency responders must be protected under any circumstances and facilitates the integration of health monitoring system into incident command structure for long-term monitoring of potential health effects after exposure of emergency-response (The Emergency Responder Health Monitoring and Surveillance Framework).⁴⁴

Conclusion

It is evident that due to intense climatic and weather conditions, severe workplace heat exposures increase the rate of incidents and health illnesses in developing countries and fast-paced working places. General public's health is the most addressed research and policy issue till date in climate change research; however, much evidence is also present regarding the influence of climate change on occupational health and safety of employees and laborers in outdoor environments. Workplace heat exposure along with the climatic extremes result in rise in heat related injuries to manual workers, especially in tropical regions. If effective climate adaptation and heat exposure avoidance procedures are taken in the workplace, such effects can be reduced. Owing to the lack of reporting system of heat-related disorders and the lack of awareness, the possible impacts of workplace

heat exposure are miscalculated globally. From the studies considered, it is evident that safety and health of outdoor workforce are influenced by many factors like socio-demographic variables, policy and regulations, prevailing working conditions, availability and provision of facilities at workplace, and worker's own attitude. The workers' attitude, behavior, ideas, perceptions, and beliefs however are proved to be the significant factors in many studies as they shape workers' orientation towards safety, hazards, and risks. Along with the consideration of procedures for the protection of human resources (employees and workers) from extreme heat exposure because of climate change, the development of appropriate surveillance programs is unavoidable. These may help in suitable occupational heat exposure assessment and mitigation of the

injuries and ill-health effects that occur due to high temperature caused by climate change extremes.

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Conflict of Interest

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