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Heat index trends and climate change implications for occupational heat exposure in Da Nang, Vietnam

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ABSTRACT

Occupational extreme heat exposure can lead to a number of detrimental heat-health impacts on workers. Excessive night-time temperatures following hot days do not allow for workers to recover and can compound work heat-health impacts. A number of heat indices have been developed to estimate thermal comfort – how hot it feels – based on meteorological, physiological, and working conditions. We investigated potential changes in day and night-time ambient temperatures and heat indices for Da Nang, Vietnam over the period 2020–2049 when compared with 1970–1999 after downscaling daily minimum and maximum temperatures and humidity variables from six CMIP5 climate models. Two heat indices were employed, the U.S. National Weather Service Heat Index for day and the indoor Apparent Temperature for night. The Vietnam Ministry of Health (MOH) sets thermal comfort thresholds for particular workloads and rates. By 2050, daytime heat index values breach the average 32 °C MOH threshold for light work nearly continuously during the months of April to October. The number of nights per annum in which the heat index exceeds 28 °C is likely to range between 131 and 170 nights per year. Occupational heat exposure in Da Nang for outdoor workers or indoor workers without adequate ventilation, breaks or other cooling and heat precautionary and treatment measures will be exacerbated by climate change.

Practical implications

Heat waves, particularly the combination of locally above-average day and night-time temperatures with high humidity many days in a row, negatively impact human health. The human body cannot tolerate conditions exceeding 37 °C. At temperatures of 27 °C and a relative humidity of 40%, some healthy individuals may begin to experience heat stress with prolonged activity or exposure. Heat stress causes fatigue, headache and muscle cramps, while heat stroke can lead to death, even among healthy people. Certain groups of people – those with chronic health conditions like diabetes or high blood pressure, and farmers, construction workers, and other outdoor laborers – are at greater risk of suffering heat stress and heat stroke during heat waves. Consecutive days and nights of extreme heat sap workers' strength, exacerbate underlying health conditions, and can lead to heat stress and increased risk of death.

The number of heat waves is increasing worldwide due to climate change and land-use development. Cities magnify the effects of heat waves by concentrating heat emissions (and air pollution) from vehicles and air conditioning units, and by trapping and absorbing heat between buildings and the pavement. This combination of development and land-use leads to urban heat islands where urban temperatures may be up to 10 °C warmer than surrounding suburban areas or farmland. Thus, heat waves in cities can have an even worse impact on occupational heat exposure than in peri-urban or rural areas.

Heat indices are tools issued by public health departments and meteorological agencies to notify the public when dangerous temperatures and humidity have been reached. There are a number of commonly used heat indices; which one is used depends on the availability of certain meteorological observations, ease of use and historical precedence at the location.

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This article discusses historical trends and future climate projections in day and night-time heat indices for the city of Da Nang, Vietnam. The analysis was conducted as climate services in support of an occupational heat health and safety project led by the Center for Community Health and Development (COHED) as part of the larger Asian Cities Climate Change Resilience Network (ACCCRN) initiative. COHED worked with the Labor Safety Department of the Ministry of Labor, Invalids and Social Affairs (MOLISA – national level ministry) and the Department of Labor, Invalids and Social Affairs of Da Nang (DOLISA) to evaluate heat-health safety conditions and awareness at three enterprises, develop workplace educational materials, and train the enterprises on heat safety activities.

The Vietnam Standard and Quality Institute (SQI) and the Ministry of Health (MOH) have issued general heat-humidity threshold guidelines for workplaces throughout Vietnam. The study used day and night-time temperatures and humidity projections from multiple climate models to calculate how many times per year the heat index might exceed the safety thresholds specified by the MOH by 2050. The daytime thresholds were set as: 1) 32 °C from the MOH average thermal comfort temperatures for light work; 2) 28 °C for average MOH thermal comfort temperatures for heavy labor; and 3) 37 °C as the absolute physiological threshold. The night-time temperature threshold was set at 28 °C as prolonged exposure at this value following excessively hot days can contribute to fatigue and heat cramps (NWS, 2014), and many of Da Nang's workers report a lack sufficient cooling mechanisms in their homes (Dao et al., 2013).

By 2050, Da Nang's workers and populations are at serious risk of suffering heat stress and heat stroke without additional adaptation assistance by the government and employers. The study revealed the following:

- The average heat index during the day is continually above 37 °C during April through October, with some days approaching this absolute threshold as early as March and as late as November. The hot season may be two to three months longer than it was over the period of 1970–2011.
- During the hottest months (June to August), the average nighttime heat index averages around 29.4 °C.

Da Nang is a rapidly growing port city on Vietnam's central coast. Significant amounts of land are being developed for buildings and roads to accommodate a thriving tourism sector, growing industries and universities. Previous research by the Institute for Social and Environmental Transition-Vietnam (ISET-VN) and the Centre for Health Education and Development (COHED) found that the city is home to a number of low-income, migrant laborers employed in construction, self-employed workers (e.g. street vendors), and small businesses. These populations often do not have air conditioning during the day while at work and are reluctant to take rest breaks for fear of lost wages or business incomes. At night, these poorer populations already have a difficult time finding respite from the heat, as they tend to live in lower quality housing with little insulation, poor ventilation and reduced access to air conditioning. Public awareness about the risks of heat stress and heat stroke remains low, even among employees of mid to large-scale businesses.

Climate change, plus Da Nang's rapid urban development, will greatly increase the number of days and nights in which the heat index safety thresholds are exceeded. The lack of cooling at night will negatively impact recovering capacities while people sleep, exacerbating pre-existing health conditions and reducing their labor capacities during the day. Construction workers, street vendors, police and fishermen (all outdoor workers), and indoor workers engaged in manufacturing or sewing, or those in poorly ventilated and constructed buildings will be particularly hard hit. COHED, along with MOLISA and DOLISA, are working together to deliver education and outreach campaigns to businesses around occupational heat exposure, the dangers of heat stress and stroke to employees during heat waves, and what measures should be taken to reduce risks.

1. Introduction

Hot weather is recognized as detrimental to human health and labor productivity when temperatures and humidity exceed physiological thresholds (Huang et al., 2011; Smith et al., 2014). Previous research demonstrates that particular groups are more susceptible to suffering negative heat impacts – manual laborers and those working outside (Hanna et al., 2011; Kjellstrom et al., 2009; Kjellstrom, 2009); those with low incomes and/or socially isolated who may be living in poorly insulated buildings, lack air conditioning and/or living on the upper floors (Chapman et al., 2009; Curriero et al., 2002; Rey et al., 2009; Jabeen and Johnson, 2013); the elderly, young and those with pre-existing health conditions (Green et al., 2001; Zeng et al., 2012); and, some urban dwellers (Harlan and Ruddell, 2011; Mueller et al., 2014).

The combination of high ambient temperatures with humidity can lead to conditions exceeding the human physiological heat tolerance limit of 35–37 °C, at which the body can no longer cool through sweating (USGCRP, 2016). High ambient temperatures, particularly when accompanied by high humidity, can place tremendous stress on the human body. During periods of heat exposure, the body responds with thermoregulatory functions, sweating being the primary mechanism. If core body temperature exceeds 37 °C (skin surface temperature of 35 °C) for sustained periods, hyperthermia can ensue (Sherwood and Huber, 2010). At ambient temperatures of 27 °C and a relative humidity of 40%, healthy individuals may begin to experience increasing fatigue and irritability with prolonged activity or exposure (Kovats and Hajat, 2008). Individuals with underlying health conditions may have reduced heat tolerance due to impaired physiological thermoregulation and can experience heat stress and stroke at lower thresholds than healthy individuals (Semenza et al. 1999; Kenny et al., 2010). The actual thermal comfort of a particular individual is determined through a number of factors such as air temperature, humidity, radiant temperature, wind, level of physical activity and metabolism, clothing, and underlying health conditions (Segal and Pielke, 1981; Parsons, 2006).

Weather conditions in conjunction with health status, workload and rate, outdoor worker exposure to sunlight and wind, indoor workers exposure to radiant heat sources or without adequate ventilation, or those workers not acclimatized can lead to heat stress and stroke in the workplace (Lucas et al., 2014; USGCRP, 2016). Consecutive days and nights of extreme heat can further exacerbate heat-related health risks, as workers without access to adequate cooling at night may have a harder time recovering from daytime exposure. Despite this scientific and medical recognition, general business awareness of extreme heat exposure and occupational health risks remains low, and regulatory standards for heat illness prevention programs for different occupations in various countries may be lacking or inconsistent (Gubernot et al., 2014; Arbury et al., 2014).

Climate change is projected to increase the number of hot days and nights, extend the length of the hot season and lead to a greater number of heat waves in many urban areas throughout Asia (Mishra et al., 2015; Ma et al., 2016; IPCC, 2012). The implications of current extreme heat exposure on occupational health and