



## Review

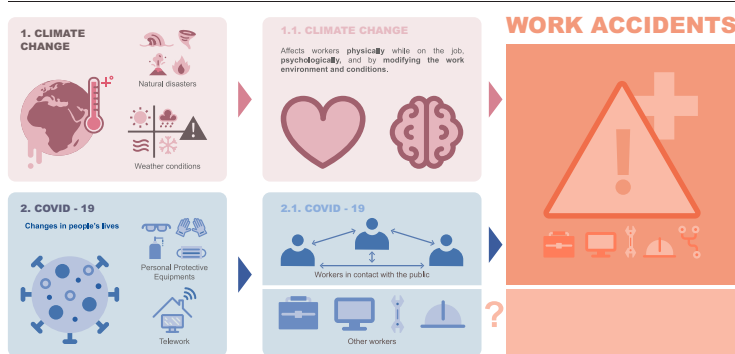
## Work accidents, climate change and COVID-19

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## HIGHLIGHTS

- Climate change manifestations are an occupational health risk.
- Few researchers have studied the impact of the pandemic on occupational health.
- The mental effects of the pandemic increase the risk of suffering a work accident.
- Climate change and the pandemic have a synergistic negative effect on work accidents.

## GRAPHICAL ABSTRACT



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## ABSTRACT

The effects brought by climate change and the pandemic upon worker health and wellbeing are varied and necessitate the identification and implementation of improved strategic interventions. This review aims, firstly, to assess how climate change affects occupational accidents, focusing on the impacts of extreme air temperatures and natural disasters; and, secondly, to analyze the role of the pandemic in this context. Our results show that the manifestations of climate change affect workers physically while on the job, psychologically, and by modifying the work environment and conditions; all these factors can cause stress, in turn increasing the risk of suffering a work accident.

There is no consensus on the impact of the COVID-19 pandemic on work accidents; however, an increase in adverse mental effects on workers in contact with the public (specifically in healthcare) has been described. It has also been shown that this strain affects the risk of suffering an accident.

During the pandemic, many people began to work remotely, and what initially appeared to be a provisional situation has been made permanent or semi-permanent in some positions and companies. However, we found no studies evaluating the working conditions of those who telework.

In relation to the combined impact of climate change and the pandemic on occupational health, only publications focusing on the synergistic effect of heat due to the obligation to wear COVID-19-specific PPE, either outdoors or in poorly acclimatized indoor environments, were found.

It is essential that preventive services establish new measures, train workers, and determine new priorities for adapting working conditions to these altered circumstances.

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## 1. Introduction

Occupational Safety and Health (OSH) is a basic part of the Decent Work Agenda of the International Labour Organization (ILO). ILO defines “Decent Work” as the right to productive work in conditions of freedom, equity, security and human dignity, and states that “work can only be decent if it is safe and healthy” (Forastieri, 2014). However, according to the WHO/ILO Global Monitoring Report, during 2016 1.9 million deaths globally were caused by work-related diseases and injuries, and most were due to respiratory and cardiovascular disease (WHO/ILO, 2021).

Occupational accidents and work-related illnesses not only damage the individual and his or her family but also have important economic impacts on society. The International Social Security Association (ISSA) estimates that costs related to nonfatal workplace accidents alone equal approximately 4 % of world gross domestic product (GDP) each year (Abdalla et al., 2017).

In recent years, some studies have described a downward trend in occupational accidents (Rusli, 2014), which has been attributed to the preventive efforts and policies enacted by companies and public administrations, as well as to increases in the proportion of the population employed in the service sector (where the risk of work accidents is lower) (Vega-Calderón et al., 2021). However, these gains in worker health may be at risk. In particular, the manifestations of climate change could reverse this downward trend (Adam-Poupert et al., 2013), due to worker exposure to extreme weather conditions and natural disasters, but also due to the psychological impact and uncertainty caused by this phenomenon. Further, the COVID-19 pandemic has greatly impacted worker health (Baek et al., 2021; Giorgi et al., 2020) and may continue to do so.

Although health prevention and promotion policies have been implemented in most countries, the changes brought by climate change and the pandemic affect workers' health and wellbeing and make it necessary to define and apply new strategic interventions. As a consequence, studies of the effects of climate change and COVID-19 on occupational health are needed, and such research will need to account for changing labor conditions (such as the increased number of employees working remotely), lockdowns, and new classification rules (some countries have recognized COVID-19 as an occupational disease in some professional sectors). The goals of this review are to assess how climate change affects occupational accidents, focusing on the impact of extreme air temperatures and natural disasters; and secondly, to analyze the role of the pandemic in this context.

## 2. Occupational accidents and climate change

Although the effects of climate change on human health have been widely analyzed, few researchers have studied its impact on occupational health.

In 2009, Schulte and Chun (2009) proposed a Preliminary Framework based on a review of the published scientific literature from 1988 to

2008. They defined seven categories of climate-related hazards: (1) increased ambient temperature, (2) air pollution, (3) ultraviolet exposure, (4) extreme weather, (5) vector-borne diseases and expanded habitats, (6) industrial transitions and emerging industries; and (7) changes in the built environment. In their conclusions, they recommended further research into risk control systems, as well as new acclimatization procedures.

Four years later, Adam-Poupert et al. (2013) published an updated review focusing on the impact of climate change in Quebec, Canada. They identified 5 categories of hazards that can impact OSH in northern industrialized countries: heat waves, air pollution, UV radiation, extreme weather events and vector-borne diseases. They suggested that not only outdoor jobs, but also indoor work, would be affected and emphasized that regional micro-climates and local socio-economic characteristics would be a crucial factor moderating the impact of climate change.

Subsequent to these two reviews, Kiefer et al. (2016) reported that workers represent one of the most affected population groups (affected earlier, more intensely and for a longer time) by the effects of climate change, particularly those in agriculture, construction, hospitality, and emergency and health services; moreover, they claimed that some of the dangers populations would face are still unknown and appealed for further research to better assess the risks in each labor sector and implement effective preventive actions.

In line with these analyses, the National Institute for Occupational Safety and Health (NIOSH), a federal agency of the United States, reported that climate change could lead to new unanticipated hazards in workers and identified low socioeconomic groups, migrant workers and day laborers as especially vulnerable, given that the effects of their exposure to climate manifestations at their work sites might be exacerbated if they had inadequate housing and were exposed to similar dangers after labor (NIOSH, 2016).

However, as indicated above, few studies have yet been carried out to assess the impact of climate change on occupational accidents. The following two sections will delve into the relationship of work accidents with weather and natural disasters.

### 2.1. Weather

Weather has been associated with many types of accidents (for example with slip and fall accidents in children or with car crashes) (Otte im Kampe et al., 2016; Parks et al., 2020). Given the scope of this review, including traffic accidents is relevant, given that, in some countries, commuting accidents are recognized as an integral component of work accidents (Rusli, 2014).

A recent study published by Davis and Rohlman (2021) showed that winter weather was more likely to contribute to crashes in the early morning. Another study performed by Hou et al. (2022) demonstrated a

relationship between car accidents and extreme air temperatures (both high and low). Moreover, Saha et al. (2016) found an association between fatal motor vehicle crashes and rain/wet conditions; however, the association of fatal accidents with meteorological conditions varied geographically, possibly in line with geographic differences of climate and infrastructure.

The effects of weather on working conditions, in particular in outdoor settings, have been studied by several authors. For example, Finnis and Reid-Musson analyzed the impact of weather on fishing safety (Finnis and Reid-Musson, 2022); Jackson and Roserberg evaluated the measures taken by agricultural workers to prevent heat illness (Jackson and Rosenberg, 2010); and Karthick et al. examined the effects of extreme weather conditions on construction workers (Karthick et al., 2022).

Regarding work accidents, some authors have described a seasonal pattern of occupational accidents (Chia-Wen, 2012); others have evaluated the influence of wind (Makowiec-Dąbrowska et al., 2019); however, most studies have focused on the role of air temperature and heat stress.

Human internal temperature ( $36.8\text{ }^{\circ}\text{C} \pm 0.5$ ) is typically not affected by the outdoor environment. When external heat is absorbed through the skin from the environment, the body can leverage a number of physical processes—radiation, convection, evaporation and, to a lesser extent, conduction—to regulate internal temperature and limit heat stress (Hanna and Tait, 2015). Physiologically, the response to heat stress has two main manifestations. First, blood flow can be redistributed towards the skin (vasodilation) to improve heat transfer from muscles to skin and then to the environment. Second, sweat can be secreted onto the skin, which subsequently evaporates, removing body heat (Ebi et al., 2021).

A number of studies have explored the limits of human adaptability to high temperatures (Sherwood and Huber, 2010; Pal and Eltahir, 2015). Ebi et al. (2021) concluded that human heat tolerance is finite, and several factors can reduce that tolerance substantially. The authors also highlighted the increasing number of studies showing a relationship between heat and worker morbidity and mortality.

Temperature is therefore considered an occupational health risk. Physiologically, it is estimated that human productivity declines above approximately  $26\text{ }^{\circ}\text{C}$ ; however, not only are work capacity or production affected: extreme temperatures can reduce cognitive function and increase the risk of making a mistake or suffering an accident (Otte im Kampe et al., 2016).

In 2016, a review reported that three studies had analyzed the effects of hot weather on occupational injuries with two of them finding an increase in work-related accidents during increased temperatures (Otte im Kampe et al., 2016). Subsequently, Rameezdeen and Elmualim (2017) performed an analysis focusing on construction workers in South Australia. The researchers analyzed 29,438 compensation claims reported during 2002–2013 and compared those reported during heat waves against a control period; workers with at least 1 year of experience, male workers, and those younger than 25 and older than 55 were slightly over-represented among accidents during heat wave periods, although no significant association was found. However, there was a significant relationship between heat waves and the severity of the accident among older workers (over 55 years old) and also a significant difference in the average expenditure for accidents (AUS\$26,381 during heat waves compared to AUS\$12,747 during the control period).

In northeastern Italy, Riccò (2018) evaluated the association between high air temperatures and occupational injuries during summer. He found the peak of work-related accidents was reached under extreme thermal conditions (incidence rate ratio = 1.09, 95 % confidence interval (CI): 1.02–1.17,  $p = 0.0165$ ).

Also in Italy, Marinaccio et al. (2019) collected daily work-related injuries data in the industrial and service sectors at a municipal level. Between 2006 and 2010 a significant correlation between work accidents and heat and cold temperatures was found. The highest risk of injuries appeared on hot days in construction workers and on cold days for fishing, transport, electricity, gas and water distribution workers.

Finally, in 2021 a new study analyzed the effects of heat exposure on the working Korean population by collecting data from the Korean National

Health Insurance Service between 2002 and 2015. Heat exposure was identified as a risk factor for death both for indoor and outdoor workers (Yoon et al., 2021).

Collectively, discussions from the abovementioned articles indicate that to prevent morbidity and mortality due to exposure to air temperature, the involvement of workers, companies and governments is necessary. Workers must be educated to be aware of the risks brought on by extreme temperatures, working conditions (infrastructure, working hours, etc.) must be adapted to the particular environment and to the personal characteristics of each worker (e.g. age, sex, medical history), and new policies must be implemented as conditions change under climate change.

## 2.2. Natural disasters

The frequency and intensity of natural disasters is increasing, in part due to climate change. A paper published by Fang et al. in 2018 showed that, since 1970, there had been 13,386 natural disasters worldwide (including droughts, earthquakes, epidemics, extreme temperatures, floods, insect infestations, landslides, mass movements, storms, volcanic activity, and wildfires), which caused 3.6 million deaths, affected 7.7 billion people, and produced economic losses of up to \$3.3 trillion (Fang et al., 2019). Natural disasters can affect workers in different ways: 1) by occurring in the workplace itself (some sectors, such as agriculture or fishing, have a higher risk of this); 2) by changing area and work conditions; 3) by having a negative impact on assist and rescue teams dispatched to a disaster site; and 4) by having a psychological impact on people in proximity to a natural disaster (even when not directly affected), which can affect work activity, in turn increasing the risk of errors and associated injuries. Although very few studies have been conducted on these topics, we discuss them in the following paragraphs.

Regarding natural disasters occurring in the workplace, a 2012 review of emergency room visits to the 16 Hong Kong public hospitals with Emergency Departments and their association with tropical cyclones between January 1, 2004 and December 31, 2009 was performed. The authors found 460 tropical cyclone related injuries with 25.4 % of them being work related (Rotheray et al., 2012).

Some studies have analyzed the effect of natural disasters on the work area and/or conditions. For example, Wheaton et al. (2008) studied how unprecedented drought conditions in Canada impacted the agriculture and water sectors. Specifically, in Alberta and Saskatchewan (provinces in western Canada) below-normal precipitation generated crop loss of around \$1.33 billion and \$1.49 billion, respectively, during 2002. Moreover, workers were faced with pests, which thrived during drought conditions. Another study performed by Chau et al. (2013) assayed the effect of extreme floods on agriculture using a geo-spatial model for the Quang Nam province of Vietnam. Agricultural land in Vietnam is developed in low lying regions where the soil is most fertile for growing rice, and where normal flooding brings nutrients that increase soil fertility. This, however, makes this land susceptible to extreme flooding, leaving crops vulnerable to destruction. The study predicted that the proportion of flooded arable land would grow over the years with important losses in agricultural production.

As stated above, work accidents or work-related diseases are also suffered by professionals tasked with tending to victims (Igarashi and Mori, 2015; Skaiaa and Thomassen, 2016; Nukui et al., 2018). Ochsner et al. (2018) interviewed 23 stakeholders involved in the cleanup after a hurricane along the northeast coast of the U.S. and identified important gaps in training and preparedness. In addition, storm-downed trees, electrical hazards, and fatigue were highlighted as specific risks.

These risks extend to the psychological, even if workers had not been present at the natural disaster site. The distress caused by the indirect process of aiding disaster victims, or secondary traumatic stress, is linked to dispositional empathy (Nagamine et al., 2018). Moreover, volunteers have higher mental health complaint levels than professional workers (Thormar et al., 2010), which emphasizes the importance of pre-

screening participants and providing all workers (professional or otherwise) with necessary training.

### 3. Work accidents and COVID-19

COVID-19 pandemic has broadly impacted population worldwide; it has not only affected health, but also daily routine (Al Halbusi et al., 2022; Ge et al., 2022) and working life (Como et al., 2021). These impacts can in turn affect occupational health.

For analysis of the relationship between occupational health and COVID-19, it is necessary to consider two different vantages: a legal perspective recognizing the infection as an occupational accident or as a work-related disease; and a public health perspective in which the change generated by the pandemic on people's lives and working conditions might have occupational health-related implications.

In general, the legal definitions of work accidents and occupational diseases, and the notification processes and administrative recordkeeping procedures, are different between countries, so data are not strictly comparable (Besserman and Mentzer, 2017). The classification system of the disease and its economic effects in the case of medical leave due to COVID-19 are not homogeneous either.

In some countries, when employees are infected at their place of work, COVID-19 is recognized as an occupational disease (with an increasing number of countries moving in this direction [e.g.: European Commission, 2022; OSHA, 2021; U.S. Department of Labor, 2022]). Other countries have defined specific criteria that must be met for such a classification, and some have guaranteed medical and economic coverage equivalent to that of an occupational accident even when it is not recognized as such (Sandal and Yildiz, 2021).

Studies on the impact of the pandemic on occupational health are limited, and the impact documented is varied. One study carried out in Austria described a decrease in accidents during the pandemic (Huber et al., 2022); another performed in Korea showed that, while accidents decreased in some professional sectors during 2020 (in part due to remote working), in others in which the workplace remained active and/or working from home was not possible, accidents actually increased (e.g. occupational accidents increased in men who worked in the transportation industry) (Baek et al., 2021).

Other studies have shown that the COVID-19 pandemic has caused psychological distress, insomnia, alcohol and drug misuse, and suicidal thoughts in healthcare workers, especially in those working directly with patients, migrant workers, and workers in contact with the public (Giorgi et al., 2020). In most cases, however, these effects have not been considered work-related illness.

Finally, some authors have described how the mental consequences of the pandemic have increased the risk of suffering a work accident (Del-Aguila-Arcentales et al., 2022). This effect must be taken into account by companies in order to implement measures that enhance the physical and mental well-being of workers.

### 4. Work accidents, climate change and COVID-19

Some of the measures put in place early during the pandemic decreased rates of fossil fuel combustion and thus mitigated the accumulation of greenhouse gases in the atmosphere, decreased air, water and noise pollution, and replenished ecosystems (Liu et al., 2021); moreover, the implementation of green technologies and innovative strategies is an increasing priority for improving workforce safety in the face of infectious disease threats and climate change (Wei et al., 2022; Jiakui et al., 2023). However, the pandemic has also brought negative environmental impacts, especially derived from waste generation (Ukhurebor et al., 2021). Several articles have described an association between meteorological factors (e.g. Ma et al., 2021; Nottmeyer et al., 2022; Sanchez-Lorenzo et al., 2021), particulate matter and SARS-CoV-2 transmission (Santurtún et al., 2022). Further, exposure to extreme air temperature has been shown to favor SARS-CoV-2 transmission (Xie and Zhu, 2020) and to exacerbate clinical manifestations

and the risk of death in infected people (Meo et al., 2020; Ukhurebor et al., 2021; Yu et al., 2021).

In the following sections, we assess the direct impact of the interaction of COVID-19 and climate change on the health of workers.

#### 4.1. Heat stress

Few studies have focused on the combined impact of climate change and the pandemic on workers' health. Morabito et al. (2020) explained that, during the first summer of the pandemic, outdoor workers were made to wear COVID-19-specific Personal Protective Equipment (PPE) (commonly facemasks and gloves) while exposed to heat waves. They described that, because PPE was not made of materials intended to be worn for long periods of time or in outdoor environments, it could limit heat exchange and increase thermal stress (Shi et al., 2021). In addition, they noted that infected people in the recovery phase, who on many occasions had to return to their jobs as soon as possible, were more vulnerable to heat and to suffering an accident (Morabito et al., 2020).

Another study analyzed workers' perceptions of occupational heat stress in Italy during COVID-19 (between June and October 2020) using an online questionnaire. All participants (345 workers from different professional sectors: scientific and technical activities [25.2 %]; construction [15.7 %]; public administration and armed forces/military [11.9 %]; manufacturing [8.1 %]; and health and social works [8.1 %]) declared that heat was a significant contributor to productivity loss, and 83 % indicated that they had not received heat warnings from their employer. Additionally, 64.6 % of the respondents identified working in the sun without access to shaded areas, working indoors without adequate ventilation, and proximity to fire, steam, and hot surfaces, as the main risk factors for injuries. The authors concluded that, to safeguard the health and productivity of workers, heat stress in the workplace must be regarded as a serious occupational hazard (Bonafede et al., 2022).

A third article assayed the effect of wearing PPE in hot environments. The study focused on nurses and nursing assistants in Germany. On hot days (32 °C or higher for at least two consecutive days), 93.0 % of the 428 participants reported having suffered from breathing problems, and 85.8 % reported difficulties focusing on their work. The authors also highlighted that many institutions are not prepared for situations of extreme heat (Jegodka et al., 2021).

Finally, during the pandemic, many people began to work remotely and what initially appeared to be a provisional situation has been made permanent or semi-permanent in some positions and companies (Ceurstemont, 2020; Choma et al., 2020; Galanti et al., 2021). Because housing thermal conditions are in many cases not optimal or even favorable (Barbosa et al., 2015; Domínguez-Amarillo et al., 2019; Mavrogianni et al., 2012), this brings into question the suitability and safety of these new individual work sites. However, we found no studies that focused on evaluating the working conditions of those who telework.

#### 4.2. Mental health

The higher frequency of extreme weather events, the worsening of air quality, as well as the forecasted impact of climate change across the planet have all been linked to mental health problems such as anxiety, depression or post-traumatic stress (for example, after facing a natural disaster) (Clayton, 2021). Palinkas and Wong (2020) explained that climate change is harmful to human health both directly (e.g. heat stress) and indirectly (economic loss, threats to well-being, displacement and forced migration, collective violence and civil conflict, and alienation from a degraded environment). During the pandemic, the incidence of mental health disorders increased. People with previous diagnoses experienced exacerbations (Hao et al., 2020; Quittkat et al., 2020), and previously healthy individuals were newly diagnosed with mental health conditions (COVID-19 Mental Disorders Collaborators, 2021). Mental health diseases have been specifically linked to SARS-CoV-2 infection (Hossain et al., 2020; The Lancet Psychiatry, 2021) but also to changes in people's lives due to lockdowns



and changes in daily routine, mobility restrictions, isolation, and economic stress (Gimbrone et al., 2021; Gloster et al., 2020).

Marazziti et al. (2021) published a review integrating the impact of climate change, pollution, and the pandemic on mental health. However, at the time of writing, no publications evaluating the effect of the sum of these factors on the mental health of workers could be found. Still, we hypothesize that the combined mental effects of both climate change and the pandemic could have repercussions on worker concentration, precision, and efficiency, increasing the risk of suffering a work accident.

## 5. Conclusions

Society is facing the consequences of climate change and the COVID-19 pandemic simultaneously, which are affecting daily routine, well-being, health and working life. Numerous studies have analyzed the effects of climate change on human health, although few have focused on the health of workers. This review shows that the manifestations of climate change affect workers physically while on the job (e.g. through exposure to extreme temperatures), psychologically (e.g. increasing anxiety after being exposed to a natural disaster), and by modifying their work environment and conditions; all these being factors can cause stress, in turn increasing the risk of suffering a work accident.

There is no consensus on the impact of COVID-19 pandemic on work accidents; however, an increase of adverse mental effects on workers in contact with the public (specifically in healthcare) has been described. It has also been shown that this strain also affects the risk of suffering an accident.

In relation to the combined impact of climate change and the pandemic on occupational health, only publications focusing on the synergistic effect of heat due to the obligation to wear COVID-19-specific PPE, either outdoors or in poorly acclimatized indoor environments, were found. From the conclusions of these studies, we can deduce that it is essential that preventive services establish new measures, train workers, and determine new priorities to adapt working conditions to these altered circumstances.

Finally, given the increase of telework during the pandemic, evaluation and/or control of environmental conditions in employees' homes should be made a priority for prevention services in the context of climate change.

## CRedit authorship contribution statement

A.S.: conceptualization, investigation, project administration, data acquisition and analysis, writing - original draft, writing - review & editing. J.S.: conceptualization, investigation, project administration, supervision, data analysis, writing - original draft, writing - review & editing.

## Data availability

No data was used for the research described in the article.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Jeffrey Shaman reports a relationship with SK Analytics that includes: equity or stocks. Jeffrey Shaman discloses consulting for BNI.

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