Air Quality, Energy and Health
Science and Policy Summaries

The synergies of heat stress and air pollution and their health impacts

Technical brief

Key messages

Projections indicate that climate change will result in more frequent and intense extreme weather events in the coming decades. Among these, an increase in frequency, duration, intensity and magnitude of heatwaves and prolonged excess heat conditions are already being observed globally.

Heat impacts health directly and acutely. Increases in mortality associated with high temperatures, particularly heatwaves, have been documented around the world. Vulnerable population groups include infants, young children, pregnant women, persons with chronic conditions and older people. Additionally, outdoor and manual workers and civil protection personnel are exposed to excessive heat, making them vulnerable to exertional heat stress.

Heat increases the levels of some air pollutants, such as ozone. In addition, recent studies indicate that high levels of fine particulate matter and ozone augment the health impacts of heat. The joint effects of heat stress and air pollution exposures have been documented for all-cause mortality as well as mortality and morbidity due to cardiovascular and respiratory diseases, and for exacerbating noncommunicable and infectious diseases.

Priority actions for short-term health benefits include adaptation measures and protection of the vulnerable; and for long-term health benefits, they include reducing ambient air pollution and mitigating the occurrence of extreme heat.

World Health Organization

Key definitions

Heatwave: A period where local excess heat accumulates over a sequence of unusually hot days and nights *(1)*.

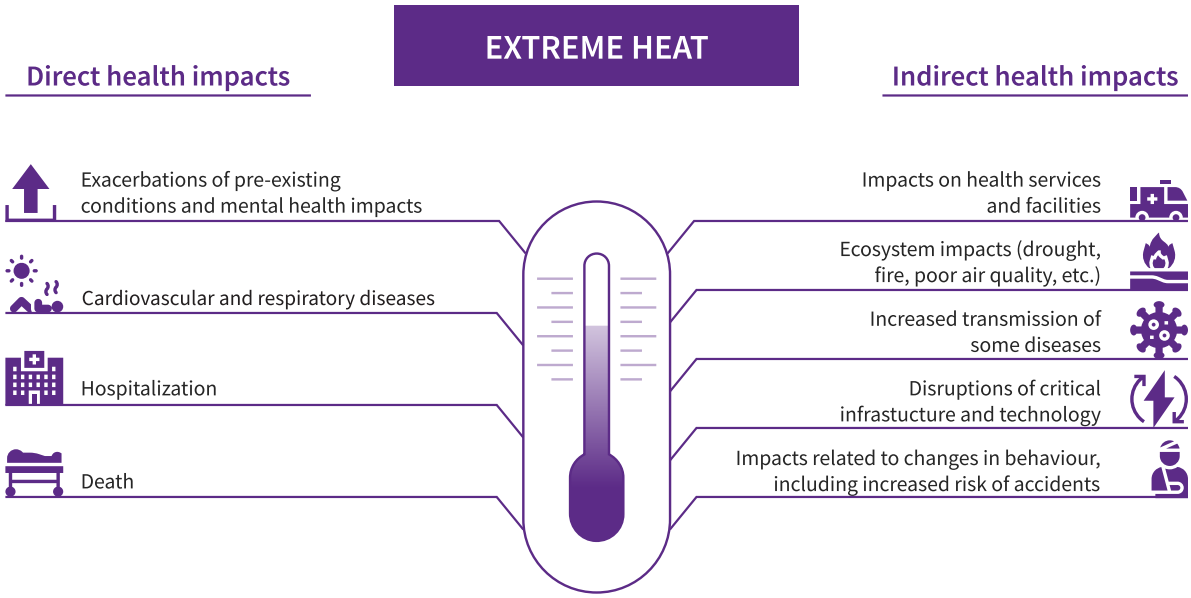
Heat stress: This occurs when the body cannot effectively eliminate excess heat, leading to an increase in core body temperature and heart rate. It is the leading cause of weather-related deaths and can exacerbate underlying illnesses including cardiovascular disease, diabetes, mental health, and asthma, and can increase the risk of accidents and transmission of some infectious diseases *(1)*.

Overview

Current status

Heat impacts health directly and acutely as well as indirectly: Increases in mortality associated with high temperatures and heatwaves have been observed consistently and globally *(2–4).* Heat increases the risk of heat exhaustion and heatstroke, affecting the heart and kidneys and worsening health risks from pre-existing conditions, especially cardiovascular, mental, respiratory and metabolic-related conditions. As examples, heat can trigger cardiovascular and respiratory deaths. Heat induces kidney injury and counteracts the benefit of treatment in the case of hypertension. Heat is also associated with indirect health effects such as impacts on health services and facilities and an increased risk of accidents (Fig. 1).

Fig. 1. Health impacts of heat



Source: WHO; 2024.

The health effects of heat are especially severe among vulnerable population groups, including infants, young children, pregnant women, persons living with diseases and disabilities, and older people *(4, 5).*

Outdoor and manual workers and civil protection employees are exposed to excess heat because of their work and are also susceptible to exertional heat stress. Additionally, the urban and rural poor face higher heat exposure due to factors such as low-quality housing and lack of cooling. Gender can also affect heat exposure, for example, where women are primarily responsible for cooking indoors during hot weather *(1)*.

The health impacts of heat are expected to increase due to ageing societies and growing urbanization; increased frequency, intensity and duration of heat events; and increasing social inequalities.

Air pollution is a major risk factor for noncommunicable diseases: Air pollution is a complex mixture of gases and particulate matter with clearly demonstrated health impacts, especially regarding fine particles (particles with aerodynamic diameter of 2.5 µm or smaller [$PM_{2.5}$]). Air pollution affects health acutely during hours and days of harmful levels and chronically over years and decades *(6)*. The acute and long-term health impacts are not limited to the lungs, where air pollutants first interact with the human body, but extend to almost all organs, including the heart, brain and reproductive system *(6).*

See SPS[1]: *Health effects of air pollution – evidence and implications*

Heat itself increases the levels of some air pollutants: Such pollutants include fine particulate matter (e.g. black carbon) and ozone. During heatwaves or hotter periods, ozone levels are higher because the increased temperature and sunlight accelerate the chemical reactions between ozone precursors (such as methane, carbon monoxide, volatile organic compounds and nitrogen oxides), leading to higher ozone formation at the ground level. Heatwaves can also significantly increase the risk of wildfires, alter particulate matter formation and properties, and amplify dust storms, as higher temperatures can increase the amount of dust lifted into the atmosphere.

See SPS: *The impacts of wildfire smoke on health*

See SPS: *Understanding the health impacts of sand and dust storms*

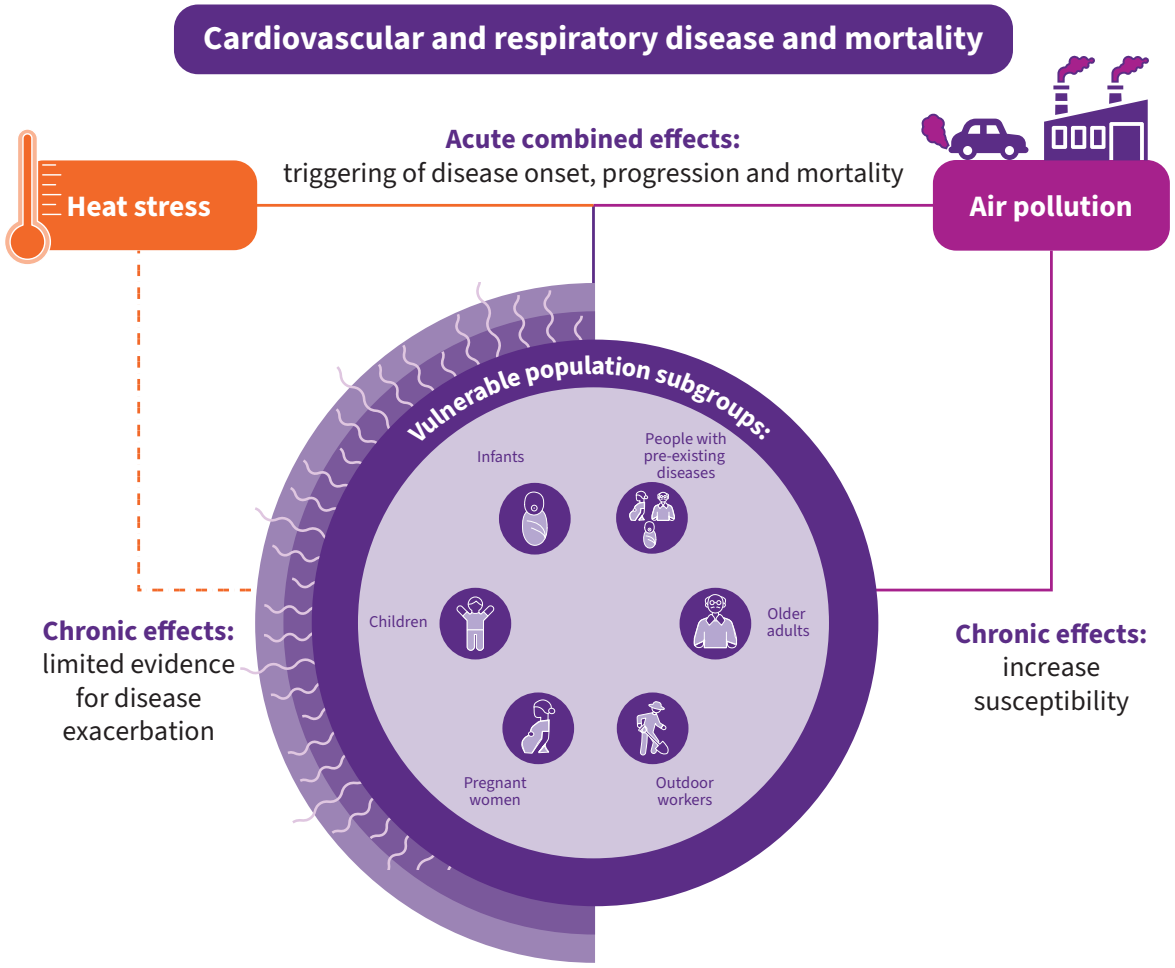
Some air pollutants, such as ozone and black carbon, are known as short-lived climate pollutants (SLCP) as they possess a high warming potential, significantly contributing to climate change. Ozone is also a greenhouse gas.

See SPS: *Health and air pollution co-benefits of climate change mitigation*

Heat stress and high levels of fine particulate matter or ozone can amplify health impacts: The joint effects of heat stress and air pollution exposures have been documented for cardiovascular and respiratory disease as well as mortality, with the strongest relative effect of heat on respiratory diseases *(6–9).* Heat and increased air pollution concentrations jointly trigger the onset of diseases such as acute myocardial infarctions and exacerbate other noncommunicable diseases, leading to death in extreme cases *(10).* In addition, long-term exposure to air pollution increases heat vulnerability by inducing noncommunicable diseases such as cardiovascular, respiratory and kidney disease (Fig. 2).

[1] Science and Policy Summary

Fig. 2. Joint health effects of heat stress and air pollution



Source: WHO; 2024.

Barriers, drivers and enablers of action

Barriers: Effectively addressing heat stress and air pollution may be challenging due to the diverse priorities, timelines and approaches of stakeholders across different sectors and organizational levels. This variability can hinder coordination and make it difficult to develop and implement unified, comprehensive strategies. Cities, for example, often experience higher levels of air pollution and heat than rural areas, exposing residents to both risks. Reducing this exposure is challenging due to urban design that fails to minimize heat accumulation, and the use of inappropriate housing materials, inadequate ventilation and insulation.

See SPS: *Land use planning – sectoral solutions for air pollution and health*

Drivers: An important driver are the updated World Health Organization (WHO) air quality guidelines that call for improved air quality standard settings around the world. These ambitious goals can only be achieved by reducing the use of fossil fuels and promoting massive usage of renewable energy sources and access to clean energy for all. Such actions would also have co-benefits for climate change mitigation. Other drivers include the increasing attention and funding given to heat-related health impacts, which individuals, health and social care providers and the public directly witness.

Enablers: Enablers are becoming active among intergovernmental and nongovernmental organizations, national and city-level policy-makers, urban planners, funding and research organizations, and patient and health professional organizations. They build on the vast amount of evidence on the joint effects of heat and air pollution that can be used to inform both adaptation plans to climate change and air quality management plans.

Success stories and progress to date

Recent scientific reports such as the Intergovernmental Panel on Climate Change (IPCC) *Sixth Assessment Report (11)* and the 2023 *Report of the Lancet Countdown on health and climate change (12)* highlight the importance of both heat stress and air pollution. Dedicated research projects, e.g. the European Union funded EXHAUSTION project, have elucidated the joint impacts of heat stress and air pollution and developed guidance *(13).* These results are now considered in updating the guidelines for establishing heat health action plans by the WHO Regional Office for Europe and in the WHO health and climate change country profiles.[2] In China, a new composite air health index (AHI) has been proposed to describe the health risks from co-exposure to high/low temperatures and air pollution simultaneously *(14)*.[3]

[2] WHO health and climate change country profiles (https://www.who.int/teams/environment-climate-change-and-health/climate-change-and-health/evidence-monitoring/country-profiles).

[3] Air health index, China (https://www.airhealthindex.org/).

Aerial view of a green industrial park featuring rooftop gardens.
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Way forward

To achieve joint mitigation of heat stress and air pollution associated health effects, implementation of joint actions from various sectors and stakeholders are needed. Scientific evidence is sufficiently robust to issue policies and build surveillance and impact assessment tools to provide strong evidence on progress at global, national and regional levels. Such assessment includes implementing accurate black carbon measurement, conducting studies of health and air pollution benefits, and cost-effectiveness analysis of policies.

Priority actions for short-term health benefits should focus on adaptation measures and protection of the most vulnerable populations. Heat health action plans need to consider meteorological early warning systems and environmental health surveillance systems for extreme heat and air pollution, effective at regional and local levels, as well as health promotion strategies to protect vulnerable population groups. Health care services should be prepared structurally and operationally to provide emergency support during extreme events, for example, when heatwaves and wildfires or sand dust storms occur. The construction of heat shelters should avoid co-exposure to air pollution from all sources. Public health surveillance and health monitoring practices to assess health impacts from multiple environmental stressors on a routine basis are missing in many low-, middle- and even high-income countries. Further, health care professionals should consider joint exposure to heat and air pollution as an important factor in providing treatment and lifestyle advice, and advocate for prompt action and management of acute increases in hospitalization associated with heatwaves.

Priority actions for long-term health benefits should consider all possible measures to achieve the ambient air pollution levels recommended by the WHO air quality guidelines in 2021, as well as reducing indoor air pollution. Land use, agricultural and forestry practices need to consider the impact of extreme weather events to avoid wildfires or dust storms during heat episodes.

The planning of residential buildings and industrial and service facilities, including the health and social care sectors, should consider protecting against weather extremes, including heat, while simultaneously aiming at reducing their greenhouse gas emissions.

See SPS: *Land use planning – sectoral solutions for air pollution and health*

See SPS: *Agriculture – sectoral solutions for air pollution and health*

All measures that reduce fossil fuel combustion with the goal of mitigating climate change will have co-benefits and reduce the combined harms of heat and air pollution.

WHO works to address climate change – imperative to limiting the magnitude and costs of extreme heat. WHO will continue to develop and report evidence on the risks and solutions to address extreme heat. This should be integrated into WHO's guidance documents and support for air pollution reduction. WHO partners with the World Meteorological Organization on the development of heat health warning systems; and will continue working with the health sector to enhance governance, preparedness and response regarding the acute impacts of heatwaves, including developing heat action plans, early warning systems, advisories and emergency response plans that identify risks, vulnerable populations and available resources.

Member States should integrate the topic into their heat health action plans and associated early warning systems. Emergency response plans need to be developed and updated that map the risks, vulnerable populations, available capacities and resources for heat, air pollution and other extreme weather events. Health surveillance should consider the joint impacts of heat stress and air pollution. Technical solutions used for heat adaptation of populations, vulnerable subgroups and health services should consider the importance of air pollution reduction. Updates of national and subnational climate change adaptation plans should incorporate Health in All Policies. Land use and urban and rural development projects should consider the joint impacts and future projections. As indicators of progress, experts in the field suggest indicators developed as part of the Lancet Countdown monitoring *(12).*

Academia/researchers should further substantiate the findings on interlinkages between heatwaves and air quality levels, and close the existing knowledge gap with respect to the impacts of joint long-term exposure to heat stress and air pollution, for example, by adding evidence for less studied health outcomes. While certain medications can increase the health impacts of heat *(15),* potential interactions with air pollution are unknown. There is a need to improve health impact assessment of non-optimal temperatures *(16)* and to develop approaches for health impact assessment of joint effects, develop training courses on the health effects of heat and air pollution, and conduct implementation research highlighting the benefits of actions jointly reducing heat stress and air pollution. An example of the latter would be to work with practitioners and policy-makers to test real-life interventions that might mitigate the risks of these joint exposures.

The medical and public health community should develop guidance on how to treat vulnerable patients, protect vulnerable subgroups, train the current and next-generation medical and public health professionals, alter existing and design future health care infrastructures considering the joint impacts, implement smart workforces as responders to heat and air pollution emergencies, and aim to reduce greenhouse gas emissions from the health system.[4]

[4] WHO Member States and other stakeholders are involved with the Alliance for Transformative Action on Climate and Health (ATACH), which aims to build climate-resilient and sustainable health systems.

Individual stays hydrated with bottled water during a heat wave in India.
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Methodology

WHO defined the scope of the document and collaborated with its advisory groups (Scientific Advisory Group on Air Pollution and Health (SAG); and the Global Air Pollution and Health – Technical Advisory Group (GAPH-TAG) members, which cover a wide range of expertise, and prepared the initial draft – led by a key expert in the field of air pollution, heat stress and health – based on an overview of the health impacts of heat stress and air pollution, supplemented by expert advice. This consisted of exploring the most recent evidence and selecting key documents as reference for the development of the SPS, prioritizing systematic reviews and metanalysis.

The draft underwent peer review by specialists from various research institutes, universities, public organizations and UN agencies. And feedback was addressed by the main contributors. Finally, WHO staff and consultants from the WHO Air Quality, Energy and Health Unit reviewed the report to ensure alignment with the WHO requirements for the collections of WHO Air Quality, Energy and Health SPS. This series synthesizes current knowledge and evidence on air quality, energy access, climate change links and health, primarily to inform intergovernmental discussions.

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Declarations of interest

All external experts submitted a declaration of interest to WHO disclosing potential conflicts of interest that might affect, or might reasonably be perceived to affect, their objectivity and independence in relation to the subject matter of the report. WHO reviewed each of the declarations and concluded that none could give rise to a potential or reasonably perceived conflict of interest related to the subjects covered by the report.

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