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Introduction to chemicals in the world of work and the environment

Session objectives

At the end of the session, you will be able to:

1. Understand how occupational chemical emissions are impacting the environment.
2. List the top ten polluting industries.
3. Explain how chemicals are contributing to climate change.
4. Identify the key impacts of climate change on worker health.
5. Recognize how climate change is affecting chemical use in the work of work.
6. Pinpoint the worker groups who will be most vulnerable to the impacts of climate change.

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Introduction

Introduction to chemicals

Chemicals are integral to almost all areas of society and are used in numerous industries globally.

- They provide multiple benefits, including **preventing diseases** and increasing agricultural productivity.
- The chemical industry is the **second largest manufacturing industry** in the world, with more and more chemicals produced every year.
- However, many have **hazardous properties** and can **adversely impact human health.**
- They can also cause **devastating and irreversible damage** to the environment.

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Chemicals and worker health

Every year >1 billion workers are exposed to hazardous substances in the workplace, including pollutants, dusts, vapours and fumes.

- Workers are exposed to **higher concentrations of chemicals**, over **longer periods**.
- One worker **dies every 30 seconds** due to occupational chemical exposure *(UN 2018)*.
- Many lives are lost due to **fatal diseases, cancers and poisonings**, or from fatal injuries following fires or explosions.
- The burden of non-fatal injuries, resulting in **disability and debilitating chronic diseases**, must also be considered.

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Chemicals and environmental health

- **Anthropogenic chemical pollution** has **devastated the environment**, **endangering global ecosystems** upon which life depends *(Persson et al. 2022)*.
- Greenhouse gases, climate change and contaminants in the air, water and soil are largely caused by chemicals.
- Industrial sources of hazardous chemicals contribute significantly to this burden, which now poses **one of the largest environmental threats to humanity** *(Naidu et al. 2021)*.
- The sound management of chemicals and waste is directly linked to the world of work and ultimately the natural environment.
- Urgent action is needed to **protect the health of workers and the planet**, whilst maintaining a **resilient global economy**, employment opportunities and **decent work for all**.

Environmental Science & Technology

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Policy Analysis

Outside the Safe Operating Space of the Planetary Boundary for Novel Entities

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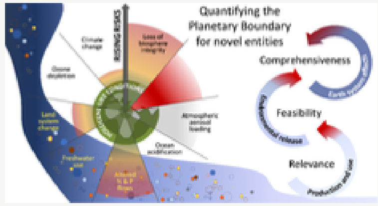

ABSTRACT: We submit that the safe operating space of the planetary boundary of novel entities is exceeded since annual production and releases are increasing at a pace that outstrips the global capacity for assessment and monitoring. The novel entities boundary in the planetary boundaries framework refers to entities that are novel in a geological sense and that could have large-scale impacts that threaten the integrity of Earth system processes. We review the scientific literature relevant to quantifying the boundary for novel entities and highlight plastic pollution as a particular aspect of high concern. An impact pathway from production of novel entities to impacts on Earth system processes is presented. We define and apply three criteria for assessment of the suitability of control variables for the boundary: feasibility, relevance, and comprehensiveness. We propose several complementary control variables to capture the complexity of this boundary, while acknowledging major data limitations. We conclude that humanity is currently operating outside the planetary boundary based on the weight-of-evidence for several of these control variables. The increasing rate of production and releases of larger volumes and higher numbers of novel entities with diverse risk potentials exceed societies' ability to conduct safety related assessments and monitoring. We recommend taking urgent action to reduce the harm associated with exceeding the boundary by reducing the production and releases of novel entities, noting that even so, the persistence of many novel entities and/or their associated effects will continue to pose a threat.

KEYWORDS: *chemical pollution, plastic pollution, unknown planetary boundary threats, Earth system impacts, cap on emissions, chemicals management capacity*

INTRODUCTION

Chemical pollution has the potential to cause severe ecosystem and human health problems at different scales,[1] but also to alter vital Earth system processes on which human life depends. "Chemical pollution" was included as one of nine planetary boundaries,[2] in response to this understanding. Steffen et al.[3] renamed the "chemical pollution" boundary to "novel entities" (NE), defined as "new substances, new forms of existing substances and modified life forms", including "chemicals and other new types of engineered materials or organisms not previously known to the Earth system as well as naturally occurring elements (for example, heavy metals) mobilized by anthropogenic activities". Steffen et al.[3] argued that the anthropogenic introduction of novel entities to the environment is of concern at the global level when these entities exhibit persistence, mobility across scales with consequent widespread distribution and accumulation in organisms and the environment, and potential negative impacts on vital Earth System processes or subsystems.

So far, no quantitative boundary has been defined for the novel entities boundary, although, some specific chemicals are quantified under other planetary boundaries, such as greenhouse gases and CFCs. Conditions where chemicals may pose a planetary threat have been specified,[4,5] and ways in which cascading systemic effects come to represent a planetary-scale problem have been explored, for example, for plastics[6] (mixtures of nonpolymeric and polymeric chemicals). The high costs to society associated with current use and environmental releases of novel entities[1,7−11] offer a strong additional arguments for pursuing prompt action addressing

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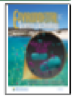

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Chemical pollution has passed safe limit for humanity, say scientists

Study calls for cap on production and release as pollution threatens global ecosystems upon which life depends

Firefighters take part in an emergency drill against winter chemical hazards and accidents in China's Inner Mongolia Autonomous Region. Photograph: Xinhua/Rex/Shutterstock

The cocktail of chemical pollution that pervades the planet now threatens the stability of global ecosystems upon which humanity depends, scientists have said.

Chemicals and worker health

Modes of entry

- **Inhalation** (breathing in).
- **Absorption** (through skin or eyes).
- **Ingestion** (eating, swallowing).
- Transfer across **placenta** (pregnant woman to the unborn child).
- Transfer across **breast milk** from mother to infant.

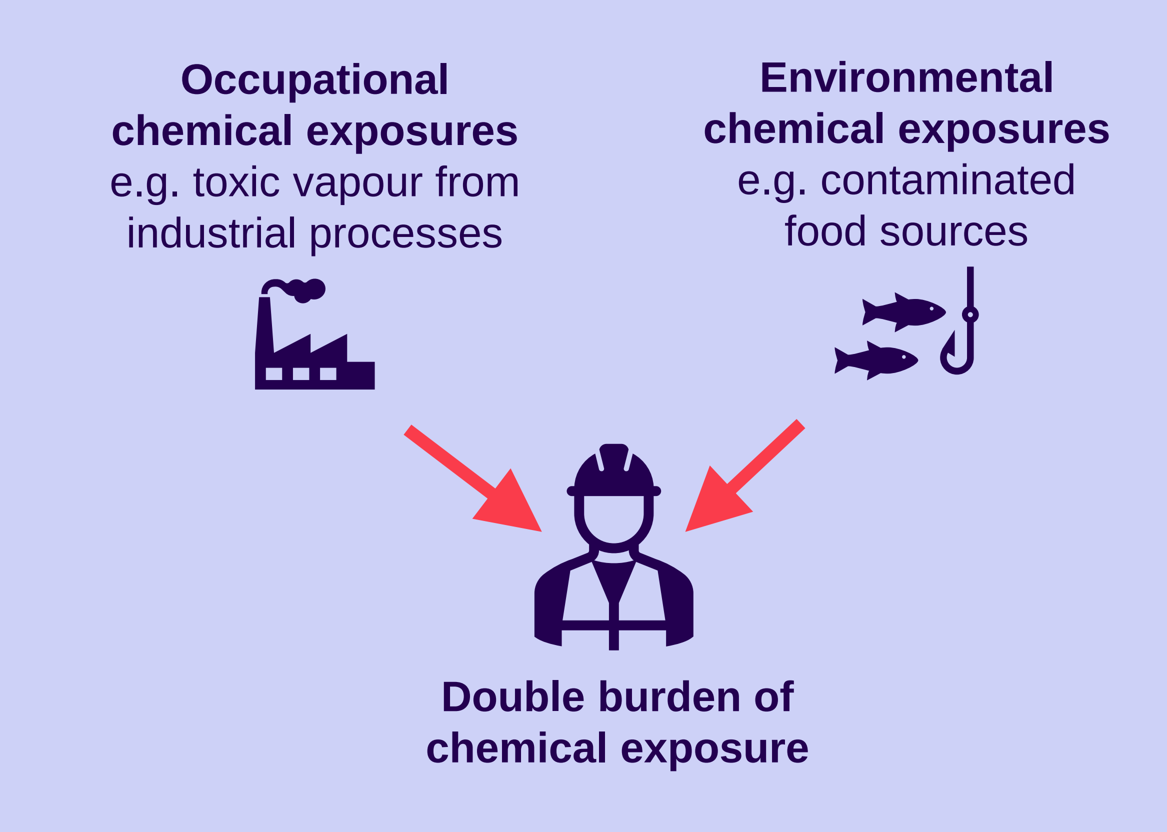
Health impacts for workers

- Health impacts may be:
  - **Acute** e.g. poisoning incidents or allergic reactions.
  - **Chronic** e.g. cancer or respiratory conditions.
- The production, use and storage of chemicals can also cause **fires and explosions**, resulting in large scale fatal and non-fatal injuries e.g. Beirut explosion.

HEALTH HAZARD

Double burden of exposure for some workers

- Some workers at may face a double burden of exposure, from **environmental exposures**, as well as **occupational exposures**.
- This may occur when workers live near their place of work. In this case food sources, such as fish and seafood, may be **contaminated by waste chemicals**.
- For example, waste mercury from factories can bioaccumulate in fish as methylmercury.



Chemicals and the environment

Global chemical industry

- Global chemical sales were valued at **€3.47 trillion** in 2017.
- The chemicals industry is the **world's second largest production sector** *(ILO 2018)*.
- Asia currently produces and consumes the largest amount of chemicals.
- Workers are exposed to chemicals across almost **all economic sectors**, including agriculture, mining, construction, manufacturing and services.
- Hazardous chemical are both classic (e.g. asbestos) or emerging (e.g. manufactured nanomaterials).

Largest global chemical sales: China (37%), European Union (16%), United States of America (13%).

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Chemical emissions into the environment

- **Release of chemical pollutants** into the environment has **accelerated considerably** in the past half-century.
- **Trillions of tonnes of chemicals** are discharged into the environment by different sectors, including **mining**, **agriculture**, **construction** and **energy** *(Naidu 2021)*.
- The Agency for Toxic Substances and Disease Registry (ATSDR) lists **275 priority chemicals** as pollutants.
- **Chemicals can migrate globally** in air and water, in human and animal vectors, in waste materials and nanoparticles, such as microplastics (*Naidu et al. 2021*).

Impact of everyday use of chemicals on the environment

- The environment has a certain capacity to **biodegrade toxic substances**.
- However, some substances are **resistant** to decomposition processes.
- Adverse effects increase with the concentration of substances and their **accumulation in food chains**.
- Chemicals released from worksites can cause **long-term environmental damage**.
- Damage highest in agricultural, chemical and energy sectors.

Special topic: Chemical pollution and biodiversity loss

Chemical pollution is one of the main drivers of biodiversity loss

- **Mercury**: Anthropogenic emissions are increasing, polluting the air, freshwater and oceans.
- **Persistent organic pollutants (POPs)**: Human-made chemicals that are persistent in the environment and are found around the globe in air, water and soil. PCBs and DDT continue to be found in biota, despite being banned in many countries.
- **Pesticides:** Threats to bees and soil ecosystems, impacting global food security. Agricultural runoff is a major source of water pollution.
- **Hazardous waste dumps**: Mismanagement of hazardous wastes in large waste dumps globally is resulting in serious impacts on biological diversity.
- **Plastics**: Production is expected to double by 2050, have demonstrated impacts on marine species and terrestrial ecosystems, including soils.

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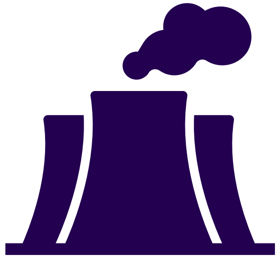
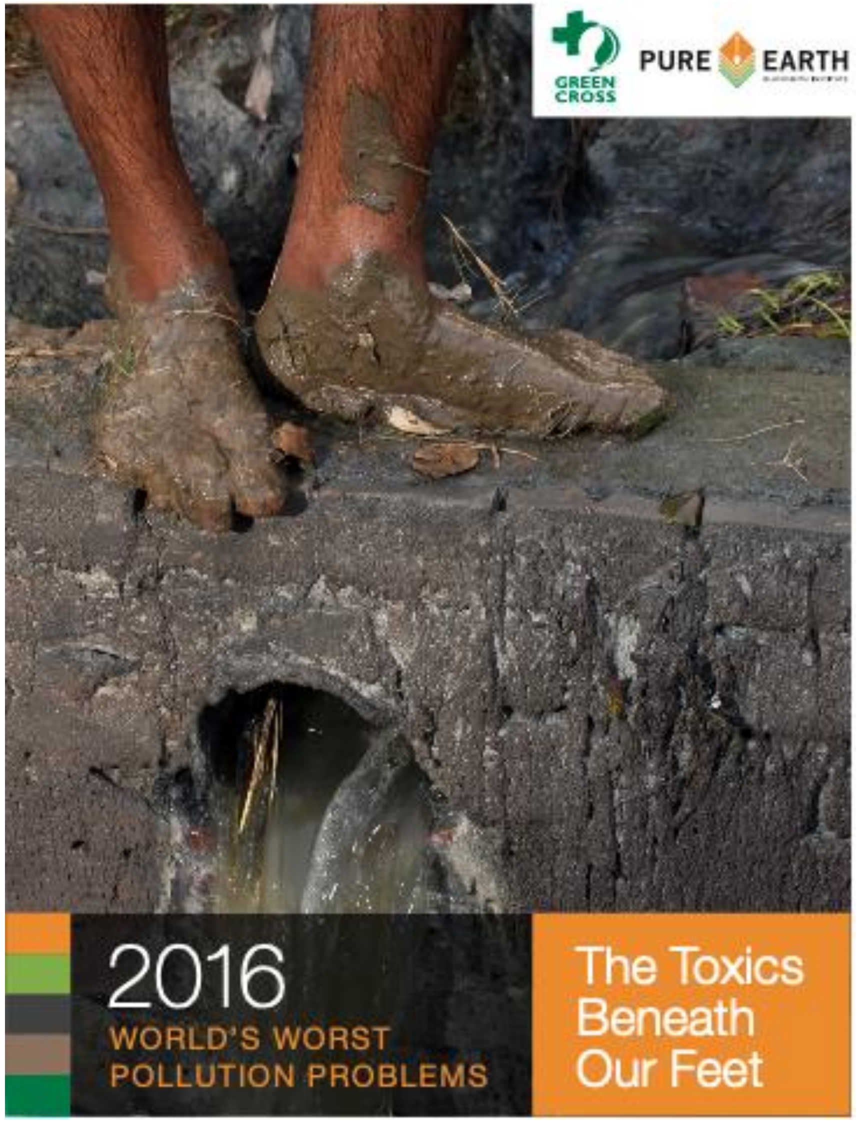
Question:

Can you guess which industries are the worst polluters?



The world's worst polluters

- 2016 report by Pure Earth and Green Cross Switzerland.
- Update on the **top ten polluting industries** globally.
- Identified that **a staggering 200 million people** in the developing work face health risks from industrial pollution.
- The top ten industries account for 7 to 17 million Disability-Adjusted Life Years (DALYs) in LMIC.



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The top ten polluting industries - Pure Earth and Green Cross Report 2016

Rank	Industries	How workers are exposed to hazardous chemicals	Examples of potential chemical pollutants
1	**Used lead acid batteries**	Chemicals are released in manual recycling processes, such as breaking batteries and smelting metallic components.	Lead
2	**Mining and ore processing**	Chemicals used in mining or processing activities and those produced as by-products.	Lead, arsenic, cadmium, mercury, hexavalent chromium
3	**Lead smelting**	Chemicals are emitted during smelting processes.	Lead, cadmium, mercury
4	**Tanneries**	Chemicals used in the tanning process are released in wastewater, leading to contaminated food and water.	Hexavalent chromium
5	**Artisanal and small-scale gold mining**	Chemicals are released during the heating of amalgam and other processes. Food sources may also be contaminated.	Mercury

The top ten polluting industries - Pure Earth and Green Cross Report 2016

Rank	Industries	How workers are exposed to hazardous chemicals	Examples of potential chemical pollutants
6	**Industrial dumpsites**	Waste-pickers and scavengers are exposed to chemicals from products in the form of leachate, dust and gases.	Lead, hexavalent chromium
7	**Industrial zones**	Exposures are industry dependent, however may be from chemical processes, waste products and dust.	Lead, hexavalent chromium
8	**Chemical manufacturing**	Workers may be exposed from emissions, accidental spills and waste products.	Pesticides, volatile organic compounds, heavy metals
9	**Product manufacturing**	Worker exposures depend on product type and chemicals used, but may be from inhalation of contaminated dust and gases, the burning of solid waste and emissions from energy sources.	Lead, mercury, hexavalent chromium, dioxins, volatile organic compounds, sulfur dioxide
10	**Dye industries**	Workers may be exposed when handling dyes and from ingestion of contaminated water and food.	Lead, mercury, cadmium, chlorine compounds

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New update report to The Lancet Commission on Pollution and Health *(Woodruff et al. 2022)*

- Pollution was responsible for **9 million deaths in 2019** (equivalent to one in six deaths worldwide).
- Increases in deaths from modern types of pollution (e.g. **ambient air** and **toxic chemical pollution**) overshadow progress made in reducing pollution deaths associated with extreme poverty (e.g. **household air** and **water pollution**).
- Pollution remains the world's **largest environmental risk factor for disease and premature death**, especially affecting **low- and middle-income countries (LMIC)**.
- **Air pollution** accounts for nearly **75% of the nine million deaths**. More than **1.8 million deaths** are caused by **toxic chemical pollution** (including lead), an **increase of 66%** since 2000.
- Excess deaths due to pollution have led to **economic losses totalling US$ 4.6 trillion** in 2019, equating to 6·2% of global economic output.
- **92% of pollution-related deaths** and the greatest burden of economic losses occur in LMIC.

Case study: Leather tanning in Hazaribagh, Bangladesh

- Chromium is widely used in under-regulated tannery sites to make leather goods more durable.
- Hazaribagh is densely populated and heavily contaminated, housing up to 95% of all tanneries in Bangladesh.
- About 85,000 tons of rawhides are processed for leather production in Bangladesh annually.
- Most tanneries in Hazaribagh do not have proper systems for treating high-volume chromium waste. More than 60% of the chromium used can be found in the resulting waste.
- Workers may be exposed when handling hazardous chemicals without PPE or other protections, from waste-water or from contaminated food and water.
- Over 8,000 workers in Hazaribagh tanneries suffer from gastrointestinal, dermatological and other diseases.

(Source: Pure Earth and Green Cross Report 2016)

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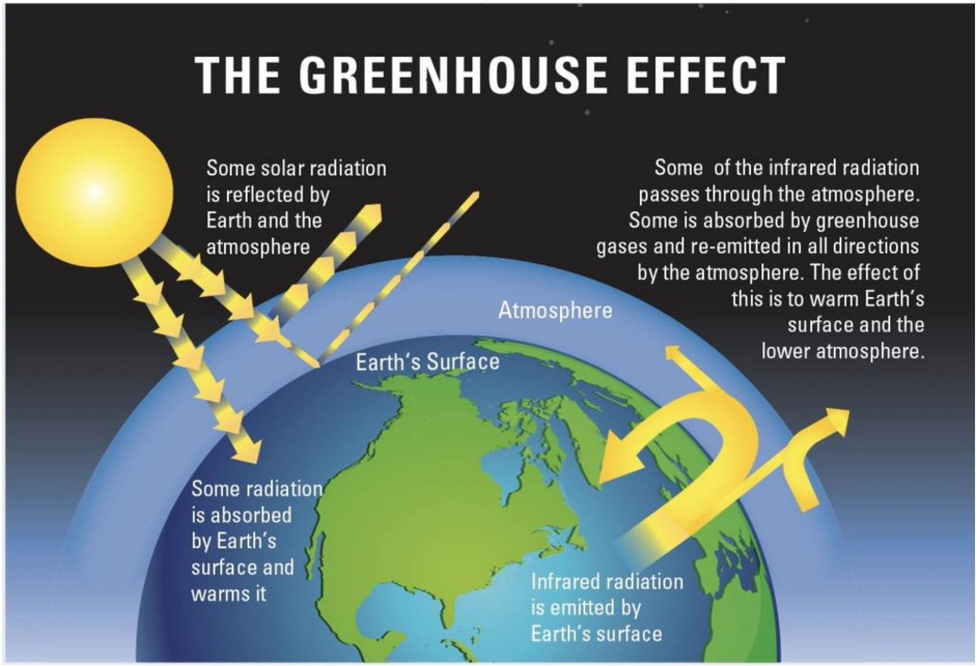
Chemicals and climate change

Greenhouse gases and global warming – A recap

- Greenhouse gases occur naturally and are essential to the human survival.
- However, **industrialization**, **deforestation** and **large-scale agriculture** have caused quantities of greenhouse gases (GHGs) in the atmosphere to rise to record levels.
- The concentration of GHGs in the earth's atmosphere is directly linked to the average global temperature on Earth.
- **The Greenhouse Effect** is the warming of the earth's surface and troposphere caused by increased concentrations of GHGs.
- The most abundant GHG, accounting for **about two-thirds of GHGs**, **carbon dioxide (CO_2)**, is largely the product of burning fossil fuels.



(Source: www.climate-change.com)

Climate change

- Climate change is defined as a **change in the statistical properties of the climate system**, when **considered over long periods of time**, regardless of cause *(ENSAA 2011; IPCC 2001)*.
- There is concordance amongst scientists that climate change encompasses **atmospheric carbon dioxide variations**, **altered worldwide temperatures** and **precipitation variation**, all directly or indirectly influencing the following *(Delcour et al. 2014)*:
  - Sea levels and salinity
  - Alterations in arable land
  - Crop yields
  - Changes in soil quality
  - Nitrogen deposition
  - Plant diversity

The impacts of climate change

- The world is **warming faster** than ever before.
- Global average temperature are now **1.1°C higher** than at the beginning of last century *(IPCC 2021)*.
- All regions of the world are impacted, with **shifting weather patterns** threatening food production and water availability and **rising sea levels** increasing the risk of catastrophic flooding *(IPCC 2021)*.
- Between 2030 and 2050, climate change is expected to cause **approximately 250,000 additional deaths per year**, from malnutrition, malaria, diarrhoea and heat stress *(WHO 2021)*.
- There is **alarming evidence** that important tipping points, leading to **irreversible damage** may already have been reached or passed *(Persson et al. 2022)*.

The global chemicals industry and greenhouse gases

- The **single biggest user of fossil fuels** and therefore an important contributor to greenhouse gas emissions and the climate crisis *(UNEP 2021)*.
- The **third largest emitter of carbon dioxide**, the primary greenhouse gas emitted through human activities *(IEA 2018)*.
- Greenhouse gases are emitted at every stage of a chemical's lifecycle, including **production**, **use** and **waste**.
- The industry's **production capacity nearly doubled** to around 2.3 billion tons between 2000 and 2017 *(Cayuela and Hagan 2019)*.
- The petrochemical industry specifically is projected as one of the main drivers of **increases in fossil fuel demand** in the next decade (IEA 2018).

Perfluorinated chemicals (PFAS), a toxic 'forever chemical', emits HCFC-22, a greenhouse gas that is 5,000 times more potent than carbon dioxide (Chem Trust 2021).

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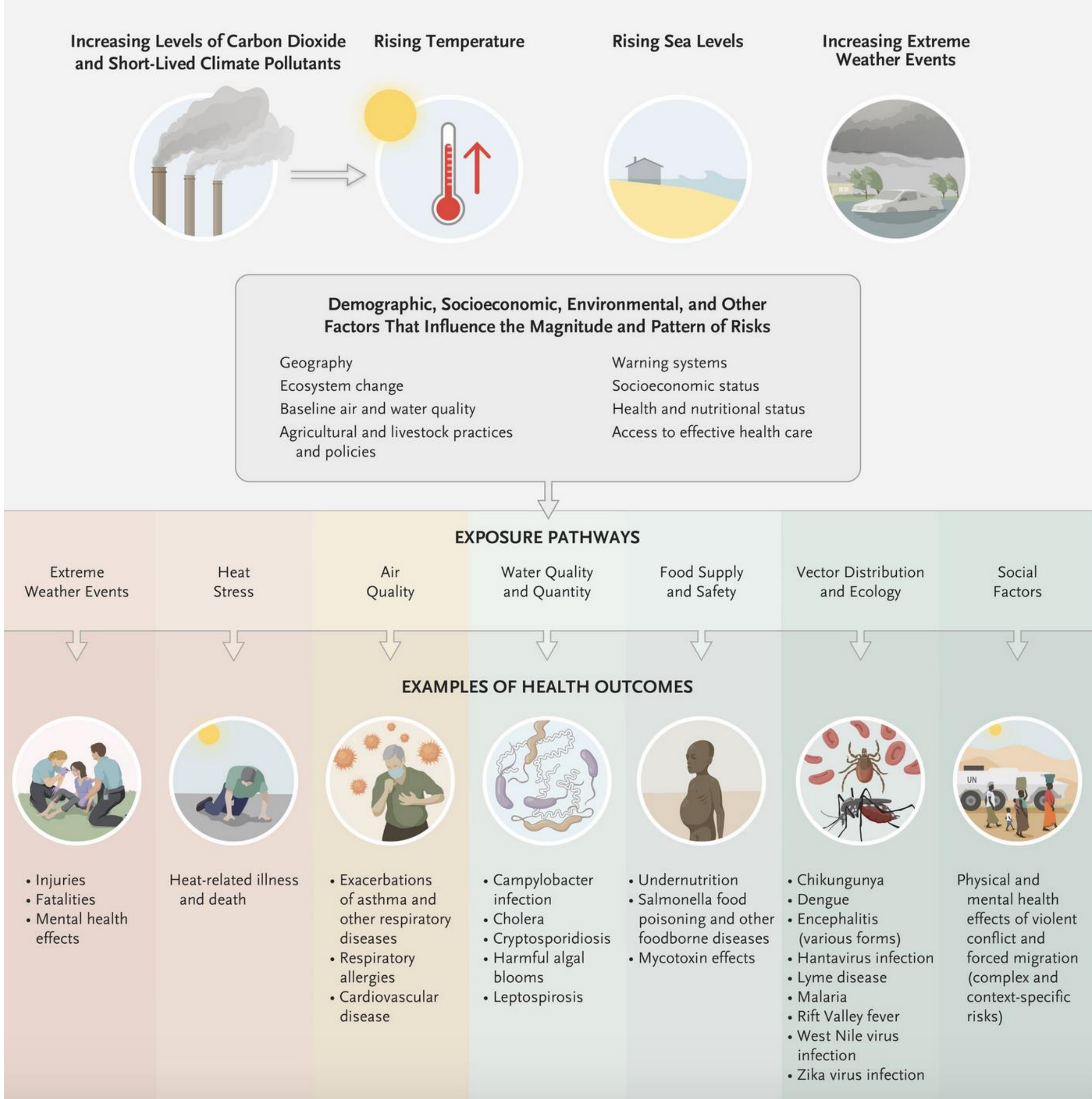
Climate change and the world of work

Climate change and health

- Major Health Risks Associated with Climate Change *(Haines and Ebi 2019)*.



Linkages between climate change and the world of work

- Today, **1.2 billion jobs** or **40% of the global labour force** are at risk because of environmental degradation *(ILO 2018a)*.
- As global warming intensifies, it will **damage infrastructure**, **disrupt business activity** and **destroy jobs**.
- The harm resulting from **unmitigated climate change** is likely to cause significant **economic and employment losses**.
- It is a **direct threat** to the growth of real **gross domestic product** (GDP), as well as to **labour productivity** and **working conditions** *(ILO 2019)*.

Between 2000 and 2015, 23 million working-life years were lost annually as a result of various environment-related hazards caused or exacerbated by human activity *(ILO 2018b)*.

The relationship between climate change and the world of work

The relationship between climate change and the world of work is influenced by three crucial aspects *(ILO 2018)*:

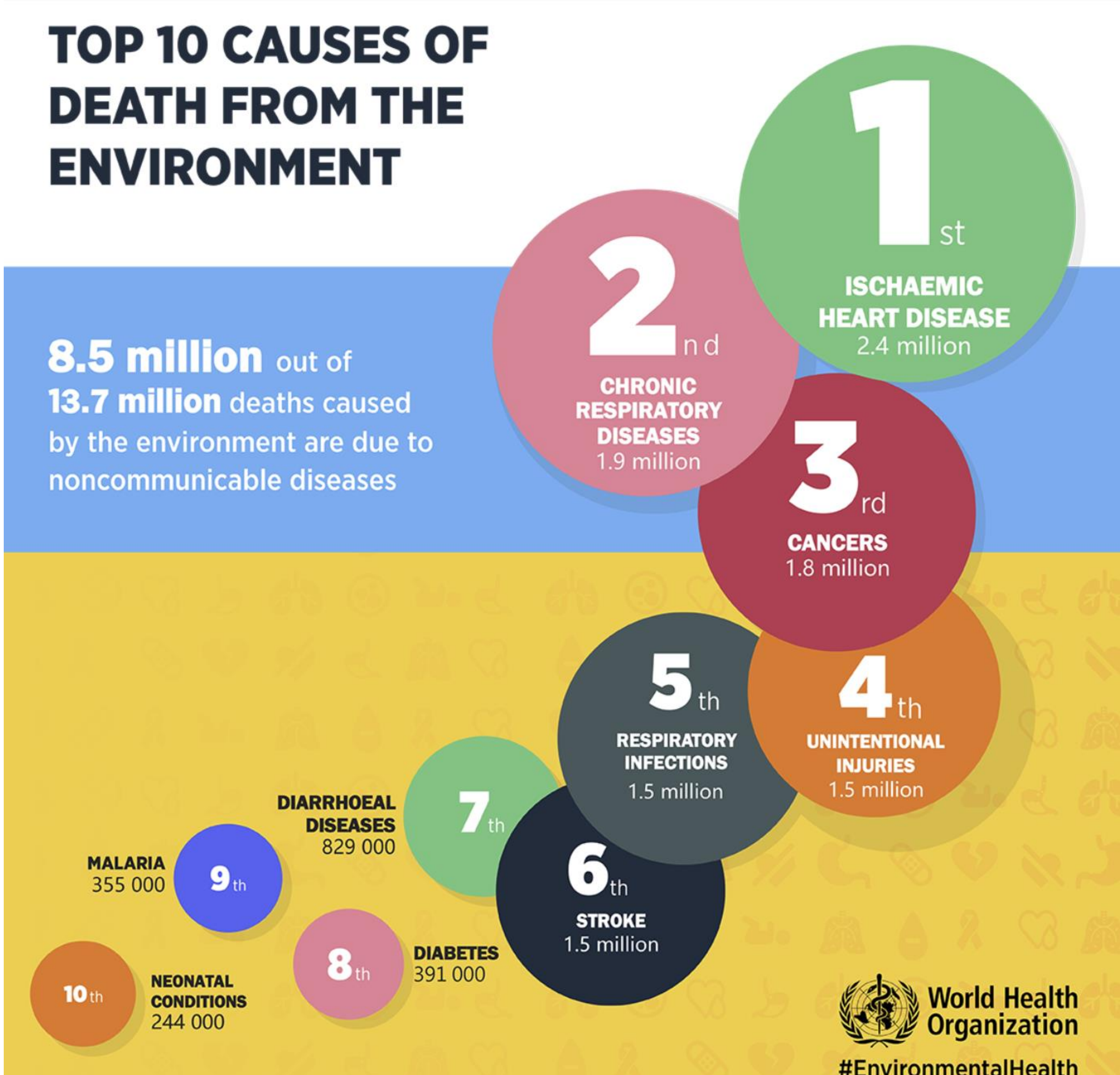
1. **Healthy ecosystems** - Jobs rely on the services ecosystems provide. Climate change threatens the provision of vital services, thus endangering jobs which depend on them.
2. **Environmental stability** - Jobs and decent working conditions depend on the absence of environmental hazards and the maintenance of environmental stability.
3. **Worker vulnerability** - The risks and hazards associated with environmental degradation will impact vulnerable workers most.

Climate change and worker health

- Climate change can impact human health both directly, and indirectly through the ecosystem.
- Increasing evidence demonstrates that climate change and environmental degradation continues to present **increased risk of occupational injury, disease and death** *(Kiefer et al. 2016)*.
- Informal sector workers in developing countries are particularly at risk, as they have **minimal OSH and social protections**. Also, those in **physically demanding jobs** e.g. construction and agriculture.

Environmental health

- 23% of global deaths are linked to modifiable environment factors. *(Prüss-Ustün et al. 2016)*.



Main occupational health risks associated with climate change *(Ansah et al. 2021)*

• Heatstroke	• Heavy sweating	• Respiratory conditions
• Cardiovascular disease	• Exhaustion	• Immune dysfunction
• Fatigue	• Headache	• Fainting
• Sleeplessness	• Chemical poisoning	• Asthma
• Skin rashes	• Zoonotic infections	• Cancer
• Digestive problems	• Injuries	• Kidney diseases

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Why are workers most at risk?

- Workers are particularly at risk because:
    1. They are often the **first to be exposed** to the effects of climate change.
    2. They may be exposed for **longer durations** and at **greater intensities**.
    3. They are often exposed to conditions that the general public can **choose to avoid** *(Kiefer et al. 2016)*.

Sectors at risk

- Sectors which are heavily dependent on natural resources, such as **agriculture** and **forestry**.
- **Fisheries** will be impacted by ocean acidification and changing ocean temperatures.
- Natural disasters will destroy critical infrastructure and take lives, disrupting sectors such as **energy** and **water providers**, **construction**, **transport** and **tourism.** They will put pressure on **emergency and rescue services**, the **health care sector** and other **public services**.
- More extreme weather events will affect **banking** and **insurance companies**.
- The **manufacturing sector** will be exposed, mainly through spill-over effects coming from the most affected sectors.

(Source: ETUC 2020)

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Key impacts of climate change on the world of work

Climate change impacts worker health AND chemical use at work

- A number of key impacts of climate change on worker health and the use of chemicals in the world of work have been identified:
  - Heat stress
  - Air pollution
  - Ozone depletion
  - Pests and pesticides
  - Infertile soil and fertilizers
  - Vector distribution and ecology
  - Major industrial accidents
  - Freshwater cycle
  - Ocean acidification

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Heat stress

Heat stress and health

- The rise in global temperatures will make ‘**heat stress**’ more common.
- Heat stress refers to **heat received in excess of that which the body can tolerate** without suffering physiological impairment.
- Heat stress during work restricts a worker’s **physical functions and capabilities**, **work capacity** and **productivity**.
- Excessive heat can increase **OSH risks and workers’ vulnerability**, impacting **physical**, as well as **mental health**.
- It can lead to heat stroke, heat exhaustion, rhabdomyolysis, heat syncope, heat cramps, heat rash and even death *(NIOSH n.d.)*.

Heat stress and productivity

- At high temperatures, worker **productivity is reduced** because it is either too hot to work or workers must work at a slower pace.
- Temperatures above 24–26°C are associated with **reduced labour productivity**.
- At 33–34°C, a worker operating at moderate work intensity **loses 50%** of his or her work capacity *(ILO 2019)*.
- It is projected that by 2030, 2.2% of total working hours worldwide will be lost to high temperatures – a productivity loss equivalent to **80 million full-time jobs** *(ILO 2019)*.
- Heat stress is projected to reduce global GDP by **USD 2.4 billion** in 2030 *(ILO 2019)*.

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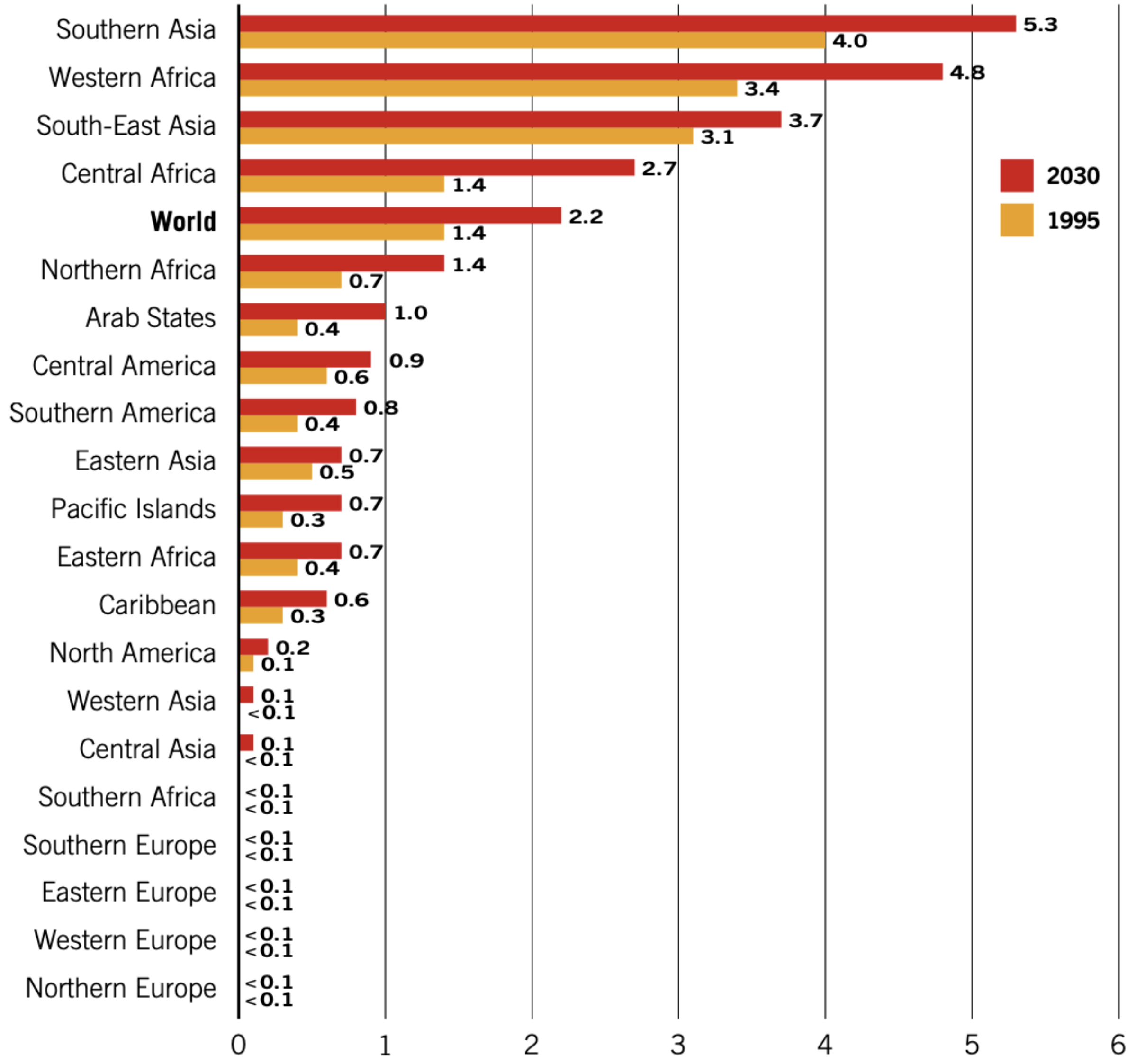
The geography of heat stress

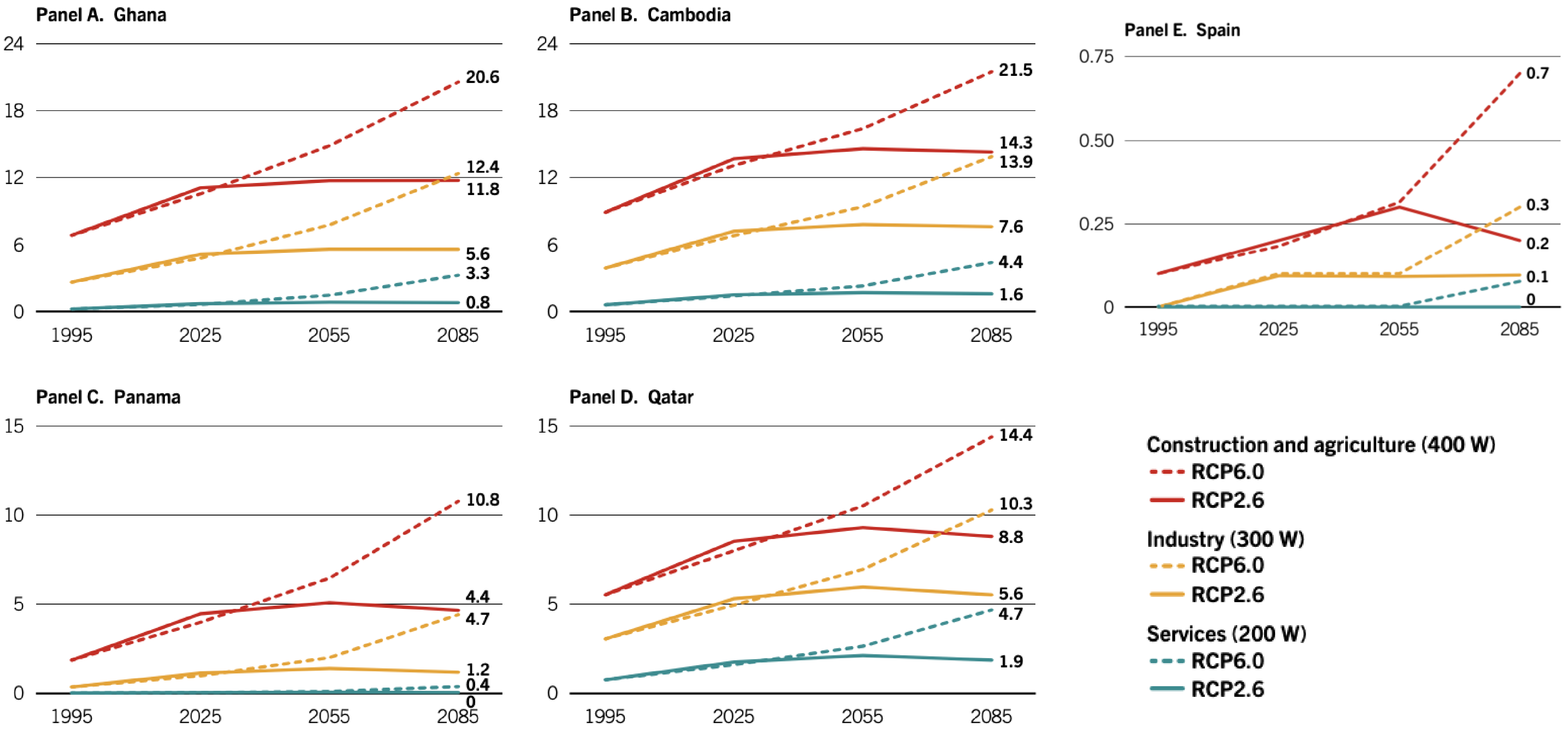
- Countries most affected by heat stress have **higher rates of working poverty**, **informal employment** and **subsistence agriculture**.
- The impact of heat stress is **unevenly distributed geographically.**
- **Southern Asia** and **Western Africa** are expected to be most affected by heat stress, with productivity losses in 2030 of 5.3% and 4.8%, corresponding to around **43 and 9 million full-time jobs**, respectively.
- **Agricultural and construction workers** will be the worst impacted. The agricultural sector alone accounts for 83% and 60% of global working hours lost to heat stress in 1995 and 2030, respectively.

Working hours lost to heat stress by subregion, 1995 and projections for 2030 (percentages)



Source: ILO estimates based on data from the ILOSTAT database and from the HadGEM2 and GFDL-ESM2M climate models (using as input the RCP2.6 climate change pathway, which envisages a global average temperature rise of 1.5°C by the end of the century).

Figure 9.1 Percentages of working hours lost to heat stress under the RCP2.6 and RCP6.0 climate change scenarios, Ghana, Cambodia, Panama, Qatar and Spain, 1995–2085 (projections)



Special topic: Heat stress may increase the number of migrant workers

- Migration is considered to be a likely response to climate change *(IOM 2017)*.
- Temperature levels have a causal effect on out-migration decisions.
- For example, if global temperature increases by 2°C by the end of the century, asylum applications to the EU are expected to double *(Missirian and Schlenker 2017)*.
- Out-migration may be linked to the country of origin's dependence on agriculture *(Cai et al. 2016)*.
- Weather shocks also affect internal population movements, including on migration to urban areas, as a study of sub-Saharan Africa has shown *(Barrios et al. 2006)*.
- Migrant workers are considered a vulnerable worker group, due to their work in informal sectors, often with limited OSH protections.
- Climate change and rising temperatures are therefore likely to lead to larger populations of vulnerable migrant workers.

Figure 8.2 Correlation between net migration and labour productivity loss

Note: Positive net migration values correspond to in-migration towards a given subregion from the rest of the world.

Source: ILO estimates based on World Bank data and the HadGEM2 and GFDL-ESM2M climate models.

Workers most at risk of heat stress

- **Outdoor workers** in physically demanding jobs e.g. agriculture, construction and refuse collection.
- **Indoor workers** inside factories and workshops, where temperature is not regulated *(ILO 2019)*.
- Workers in **heavy clothes** or protective equipment e.g. pesticide spreaders and firefighters.
- Vulnerable worker groups are at particular risk of heat stress, for example, **child labourers** and **pregnant workers**.
- Workers **of all ages** can suffer from heat stress, even younger populations *(Ansah et al 2021)*.
- **Older workers** are particularly affected, because of their reduced heat tolerance and aerobic capacity *(Lundgren et al 2013)*.

It is a serious problem for a large proportion of the world's 1 billion agricultural workers and 66 million textile workers *(ILO 2019)*.

Case study: Heat stress and heavy PPE

- A study by Havenith et al. (2011) looked at improvements to protective clothing to alleviate heat strain, whilst maintaining protection against chemicals.
- Selectively permeable membranes with low vapour resistance were compared to textile-based outer layers with similar ensemble vapour resistance and also layers with increased air permeability.
- Heat strain was shown to be significantly higher with selectively permeable membranes compared to air permeable ensembles.
- Air permeability of the textile version improved ventilation and allowed better cooling by sweat evaporation.
- This was reflected in lower values of core and skin temperatures, and heart rate.
- Based on protection requirements, it is concluded that air permeability increases can reduce heat strain levels allowing optimization of chemical protective clothing.

Chemicals and heat exposure

- **Absorption of chemicals**
  - Absorption via pulmonary and cutaneous routes can significantly increase due to the elevation in pulmonary ventilation and vasodilation *(Gordon et al. 2008; Leon 2008)*.
  - Warm wet skin also promotes the absorption of chemicals *(ETUC 2020)*.
- **Distribution of chemicals**
  - The redistribution of blood flow can have an impact on the distribution and accumulation of chemicals in the body *(Gordon 2005)*.
  - Retention of some chemicals may be increased in soft tissues, due to a reduction in urinary excretion *(Leon 2008)*.
- **Biotransformation**
  - Can lead to an increase in enzymatic activity and protein binding, two factors that can theoretically modify the toxicokinetics of chemicals *(Lenz 2011)*.

Chemicals and heat exposure

- **Excretion**
  - Renal excretion of chemicals can decrease due to dehydration and a reduction in renal blood flow *(Gordon 2005; Vanakoski and Seppäla, 1998)*.
- **Toxicity**
  - Can increase biological processes e.g. rate of enzymatic reactions, binding to receptors, lipid peroxidation, oxidative phosphorylation.
  - May lead to an increase in the intensity of the effects of chemicals *(Leon 2008)*.

Chemicals and thermoregulatory systems

Chemical agents can affect thermoregulatory mechanisms, which could reduce workers' capacity to adapt to thermal stress *(Johnson Rowsey et al. 2003)*.

- **Vasoconstricting substances**, such as lead and inorganic compounds, can hinder heat dissipation *(Vyskocil et al. 2005)*.
- **Organophosphorus compounds** and **carbamates** can cause acetylcholinesterase inhibition, which can modify responses associated with maintaining body temperature, such as skin blood flow, heart rate, respiration, and sweat secretion *(Leon 2008)*.
- Exposure to the **metal oxides** present in welding fumes can lead to a series of symptoms including fever (metal fume fever) *(Fine at al. 1997)*.
- **Pentachlorophenol (PCP)** can cause increases in metabolism, body temperature and sweating *(Gordon 2005)*.

Conditions of the outdoor environment *(Truchon et al. 2014)*

- **Solar radiation, wind and humidity** can affect the concentrations and distribution of chemicals present in the work environment.
- A high temperature promotes the dispersion of chemicals in the air.
- In higher temperatures, more **volatile substances** will tend to be present in vapour form, thus **increasing the levels of exposure** via the respiratory tract.
- Humidity and wind velocity are the most important factors related **to heat losses by evaporation**.
- Low humidity coupled with wind promotes the evaporation of perspiration from the skin surface, making this mechanism more effective. Wind can also promote **heat losses by convection**.

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- A study in Quebec, Canada, by Truchon et al. (2014) looked at the occupations most at risk from concomitant exposure to chemicals and thermal stress.
- Risks were calculated for 136 occupations.
- Lower mean ratings were linked to higher risks.
- A risk rating equal to 1 was associated with occupations for which simultaneous exposure to thermal stress and chemicals was assessed as very high risk.
- Gold casters, roofers, casters, smelter operators and forge helpers were found to be most at risk, however all occupations show here were considered high risk.

Increasing risk

Occupations	Rating				n[4]
	Mean	S.D.	Min	Max	
Gold caster[1]	2.1	1.5	1	6	11
Roofer[2]	2.2	1.1	1	4	13
Caster[1]	2.3	1.5	1	6	13
Smelter operator[1]	2.3	1.6	1	5	13
Forge helper[1]	2.4	1.0	1	5	13
Firefighter[3]	2.4	1.8	1	7	12
Metal processing labourers[1]	2.5	1.1	1	5	13
Firing kiln labourer[1]	2.5	1.3	1	5	13
Smelting furnace helper[1]	2.5	1.3	1	5	13
Foundry labourer[1]	2.5	1,3	1	5	13
Casting helper[1]	2.5	0.9	2	5	13
Moulder[1]	2.5	1.3	1	6	13
Oven operator[1]	2.5	1.6	1	6	13
Ceramic kiln operator[1]	2.6	1.4	1	5	12
Brick kiln operator[1]	2.7	1.4	1	5	12
Metal fabricating machine operator[1]	2.7	1.6	1	6	13
Furnace operator[1]	2.7	1.7	1	6	13
Steel hardener[1]	2.8	1.5	1	6	13
Extruder[1]	2.8	1.6	1	6	12
Smelting furnace operator[1]	2.9	1.6	1	6	13
Die-casting machine operator[1]	2.9	1.6	1	6	12
Boilermaker[1]	2.9	1.5	1	5	12

[1] Non-metallic mineral product manufacturing/primary metal manufacturing/fabricated metal product manufacturing sector
[2] Construction sector
[3] Utilities/Public administration sector
[4] Number of experts who assigned a rating

Case study: Chronic kidney disease (CKD) in tropical countries

- Epidemics of Chronic Kidney Disease of unknown aetiology (CKDu) are affecting large numbers of people doing heavy manual labour in hot temperatures.
- CKDu has emerged in hot, rural regions of the Americas, Africa, the Middle East and India, where abnormally high numbers of agricultural workers have begun dying from irreversible kidney failure.
- It is likely caused by a combination of factors, such as heat exposure and dehydration, chemicals (e.g. agrochemicals), poverty and malnutrition.
- Over 30 factors have been proposed as causative, including agrochemicals and heavy metals, but none has been properly tested nor proven as causative *(Wimalawansa et al. 2019)*.
- There are no published field studies that consider multiple risk factors in both Latin American and Asian regions with high CKDu prevalence *(Redmon et al. 2021)*.
- Conditions such as, having favourable climatic patterns, adequate hydration, and less poverty and malnutrition seem to prevent the disease *(Wimalawansa et al. 2019)*.

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Ozone depletion

What is ozone depletion?

- The **gradual thinning** of Earth's ozone layer in the upper atmosphere.
- Caused by the release of chemical compounds containing **gaseous chlorine** or **bromine**, from industry and other human activities.
- Thinning is most pronounced in the polar regions, especially over Antarctica.
- Major environmental problem, because it **increases the amount of ultraviolet (UV) radiation** that reaches Earth's surface, which increases prevalence of **skin cancer**, **eye cataracts**, and **genetic and immune system damage**.
- **The Montreal Protocol**, ratified in 1987, was the first of several comprehensive international agreements enacted to halt the production and use of ozone-depleting chemicals.

Ozone depletion

- The complex interaction of greenhouse gases, climate change, and stratospheric ozone depletion, results in **increased ultraviolet (UV) radiation** that can affect all people, particularly outdoor workers.
- **Outdoor construction workers**, for example, can accumulate sufficient solar UV exposure over 30-40 years of work to more than **double their risk of non-melanoma skin cancer** *(Cherrie et al. 2021)*.
- Other high-risk occupations include **lifeguards, power utility workers, gardeners, postal workers and dock workers** *(John et al. 2020)*.
- Other health conditions include **sunburn, pterygium, cataracts and melanoma** *(Wright and Norval 2021)*.

Case study: Airline pilots and UV exposure

- A few studies have demonstrated that airline pilots are at risk of adverse health effects in their eyes from exposure to UV radiation *(Schulte et al. 2016)*.
- Hammer et al. (2009) noted some evidence of increased melanoma occurrence in professional pilots.
- Chorley et al. (2011) concluded that pilots flying in daylight hours are exposed to solar radiation that is 2 or 3 times greater at cruising altitudes compared to exposures at sea level.
- Although pilots are protected by the aircraft windshield which blocks most UVB radiation, there is no standard for the optical transmission properties of the aircraft windshields *(Schulte et al. 2016)*.
- It is known that UV radiation increases by 10–12% every 1,000 meters of altitude and thereby subsequently affects pilots *(Chorley et al. 2014)*.
- Therefore, UV radiation at 10,000 m of altitude for commercial aircraft may be 2–3 times higher than at sea level.

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Air pollution

Climate change and air pollution

- Various air pollutants increase **global warming** and global warming leads to formation of various **air pollutants** *(Schulte et al 2016)*.
- The most common pollutants considered in air pollution estimates include **fine (PM2.5) and course (PM10) particulate matter**, **ozone**, **nitrogen dioxide (NO_2),** and **sulfur dioxide (SO_2)**.
- Globally, **over 1.2 billion workers** spend most of their working hours outdoors, at risk for exposure to outdoor air pollution *(WHO 2018)*.
- Indoor workers are also impacted by air pollution.

860,000 deaths a year can be attributed to occupational exposure to air pollutants, although the real magnitude is likely to be much higher *(WHO 2018)*.

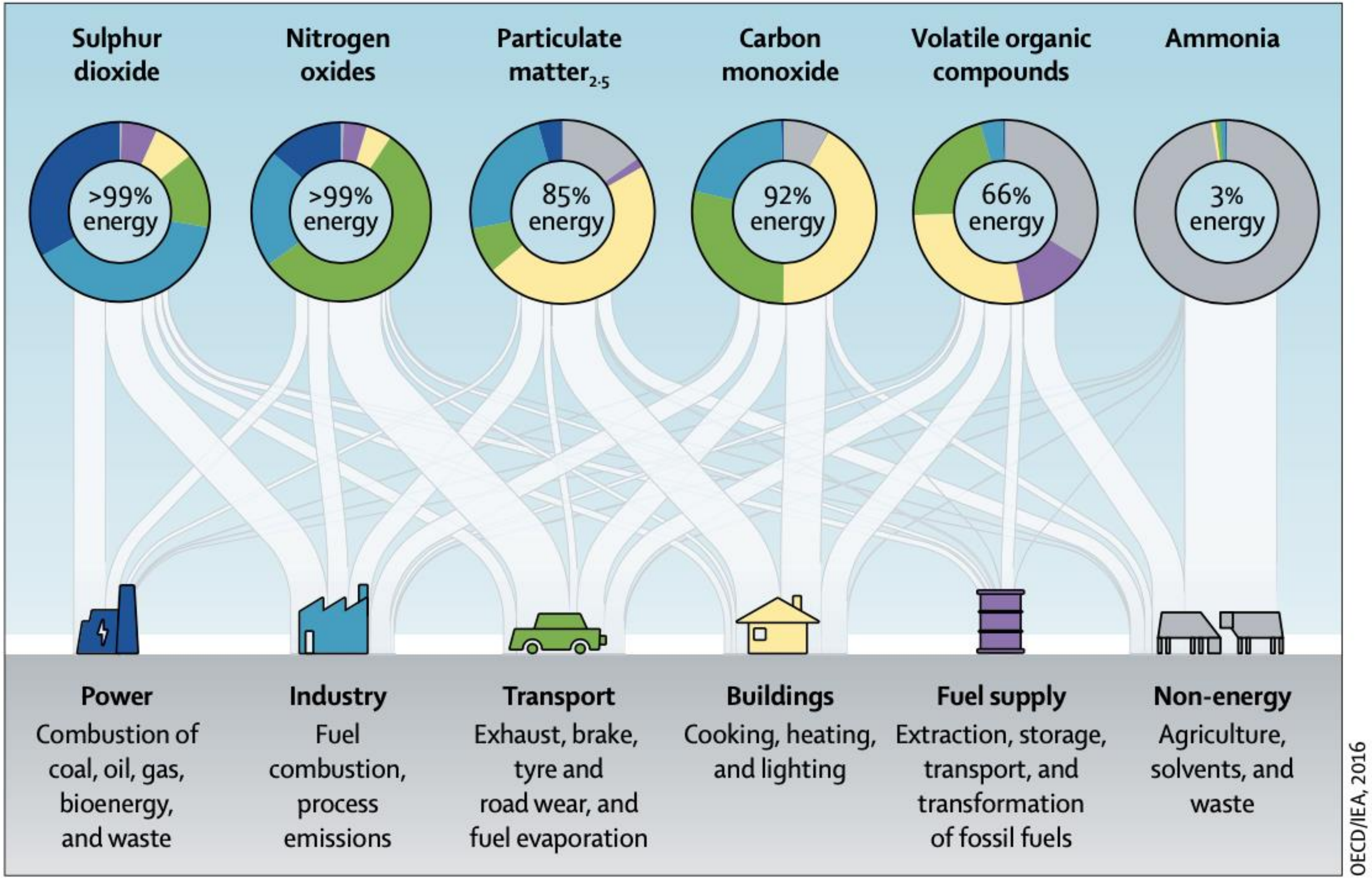


Figure: **Selected primary air pollutants and their sources**

Air pollution and health

- The 2021 ILO Global Review linked ambient air pollution to **numerous health impacts** *(ILO 2021)*.
- Air pollution has been classified by IARC as **carcinogenic** to humans (Group 1).
- According to IARC there is sufficient evidence that air pollution can cause **cancer** of the lung *(IARC 2013a)*.
- Particulate matter, a major component of outdoor air pollution, has also been classified by IARC as **carcinogenic** to humans (Group 1) *(IARC 2013a)*.
- For **lung cancer** alone, air pollution causes 223,000 deaths/year worldwide *(IARC 2013b)*.
- Air pollution has also been linked to **stroke**, **heart disease**, **lung cancer**, and both chronic and acute **respiratory diseases**, including asthma.
- Outdoor workers in hot environments have increased respiratory rates and thus may be more affected by air pollution than other members of the general population *(Schulte et al. 2016)*.

Pests and pesticides

What are pesticides?

- Chemicals with **biologically active ingredients** which **kill pests**, including insects, rodents, fungi and unwanted plants.
- Used by agricultural workers and those in vector control.
- **Toxic by design** and **all present some level of risk**.
- Most are designed to act on the **nervous system of animals**.
- Approximately **1.8 billion people are engaged in agricultural activities** worldwide and **most use pesticides** to protect food and commercial products that they produce *(Carvalho 2017)*.
- LMICs account for about **70% of worldwide Highly Hazardous Pesticides (HHP)** use, i.e. over 1.2 million tonnes in 2017 *(Public Eye 2020)*.
- Global pesticide use has continued to grow steadily to 4.1 million tonnes per year in 2017, **an increase of nearly 81% from 1990** *(FAOSTAT 2019)*.

How do pesticides contribute to climate change?

- The **manufacture, transport and application** of pesticides creates **GHG emissions** through energy use in production.
- Three main GHGs are emitted during production: **carbon dioxide, methane and nitrous oxide** *(Heimpel et al. 2013)*.
- Pesticides also cause further emissions through their effects on soils. Widely used **soil fumigants** such as chloropicrin can **increase soil nitrous oxide emissions seven-fold** *(Spokas and Wang 2003)*.

Why does climate change increase dependence on pesticides?

- Pesticide use is directly impacted by:
  - Pesticide efficacy
  - Crop characteristics
  - Pest occurrence
- All of these are influenced by climate change **(Delcour et al. 2015)**.

Pesticide efficacy

- **Pesticide transport** and **degradation** are the two main routes that affect pesticide availability and efficacy *(Delcour et al. 2015)*.
- Climate change can reduce concentrations of pesticides due to a combination of **increased volatilization** and **accelerated degradation** *(Noyes et al. 2009; Zhang et al. 2006)*.
- Increased volatilization and accelerated degradation are both strongly affected by a **high moisture content**, **elevated temperatures** and **direct exposure to sunlight** *(Johnson et al. 1995; Otieno et al. 2013)*.
- In general, a warmer climate may necessitate an increased pesticide usage *(Noyes et al. 2009; Rosenzweig et al. 2001)*.

Crop characteristics

- Pesticide adhesion and uptake into a plant is driven by plant growth and soil properties, both strongly liable to climatic influences *(Delcour et al. 2015)*.
- Most food crops are sensitive to the direct effects of **high temperature** and **precipitation extremes** or indirect effects of the climate on **soil processes**, **nutrient dynamics** and **pest organisms** *(Rosenzweig et al. 2001)*.
- **Increased temperatures** will affect **plant productivity** *(Rosenzweig et al. 2001)*, giving rise to a potential increase in volume and array of pesticides used *(Noyes et al. 2009)*.
- Precipitation is the other major determining factor of crop productivity, influencing variations in crop yields, yield quality and pests in both a positive and negative way. Intense rainfall can **damage younger plants** and be detrimental to crop productivity *(Rosenzweig et al. 2001)*.
- Climatic changes can influence the location and availability of host plants for pest species and provide a **green bridge** for pests during winter *(Delcour et al. 2015)*.

Pest occurrence

- **Pest infestations** often coincide with modifications in climatic conditions *(Rosenzweig et al. 2001).*
- **Temperature increases** and **precipitation changes** are the main pest infection determinants.
- **Insect pests**: Climate change promotes distribution and abundance due to migration and range shifts, increases pest outbreaks and alters the dissemination of vectors, all favouring insect pests compared to crops *(Delcour et al. 2015)*.
- **Plant diseases**: Plant diseases are mainly affected by temperature, rainfall, humidity, radiation and dew *(Patterson et al. 1999)*. For example, wet conditions promote the germination of spores, the spread and activity of zoospores and the proliferation of fungi and bacteria *(Roos et al. 2011; Rosenzweig et al. 2001)*.
- **Weeds**: A temperature increase appears to cause fundamentally altered weed communities and a geographic niche expansion of many species *(Jackson et al. 2011; Patterson et al. 1999).* Also, an increased atmospheric CO_2 concentration directly increases weeds' herbicide tolerance and severity *(Gutierrez et al. 2008)*.
- The challenge of pests will rise due to **increased prevalence of pests, diseases and weeds**.
- **Stronger pesticides** and **more frequent sprayings** may be necessary.

Case study: Climate warming promotes pesticide resistance through expanding overwintering range of a global pest

- Ma et al. (2021) looked at how increasing winter temperatures affect the range limits and pesticide resistance of a global pest, the diamondback moth (Plutella xylostella).
- This moth originated from South America and spread to all other continents.
- It now ranges from tropic to temperate zones, causing **economic loss as high as US$ 4–5 billion per year**, making it the **most destructive pest of cruciferous crops** around the world.
- The species is also famous for its **strong resistance to over 97 different insecticide active ingredients**.
- Importantly, it can only overwinter in warm areas, from which it quickly migrates far north during the growing season, damaging local crops.
- By analysing experimentally parameterised and field-tested models, the study showed that climate change over the past 50 years increased the overwintering range of this pest by **~2.4 million km^2 worldwide**.
- Also, **mean pesticide resistance** was **158 times higher** in overwintering sites compared to sites with only seasonal occurrence.

Pesticides: Health impacts

WHO considers HHPs as a major public health concern *(WHO 2019)* and the introduction of regulations to phase out the use of HHPs has saved uncountable lives *(WHO/FAO 2019)*.

- Health effects may be acute or chronic.
- **Acute effects** are related to **pesticide poisonings**, which occur commonly in developing economies where **pesticides are mislabelled**.
- It is estimated that **385 million cases of unintentional, acute pesticide poisoning** occur annually and **44% of farmers are poisoned** by pesticides every year *(Boedeker 2020)*.
- A range of different pesticides have been classified by IARC as **carcinogenic to humans (Group 1)** and **probably carcinogenic to humans (Group 2A)**.
- Other health impacts include **neurotoxic effects e.g. Parkinson's disease**, **Alzheimer's disease** and **endocrine disruption**.

Pesticides: IARC classification

Carcinogenic to humans (Group 1)	Probably carcinogenic to humans (Group 2A)
▶ Arsenic and arsenical compounds ▶ Pentachlorophenol (PCP) ▶ Lindane ▶ Ethylene oxide	▶ Dichlorodiphenyltrichloroethane (DDT) ▶ Organophosphates (malathion, diazinon, glyphosate) ▶ Aldrin and dieldrin captafol ▶ Ethylene dibromide formaldehyde

Infertile soil and fertilizers

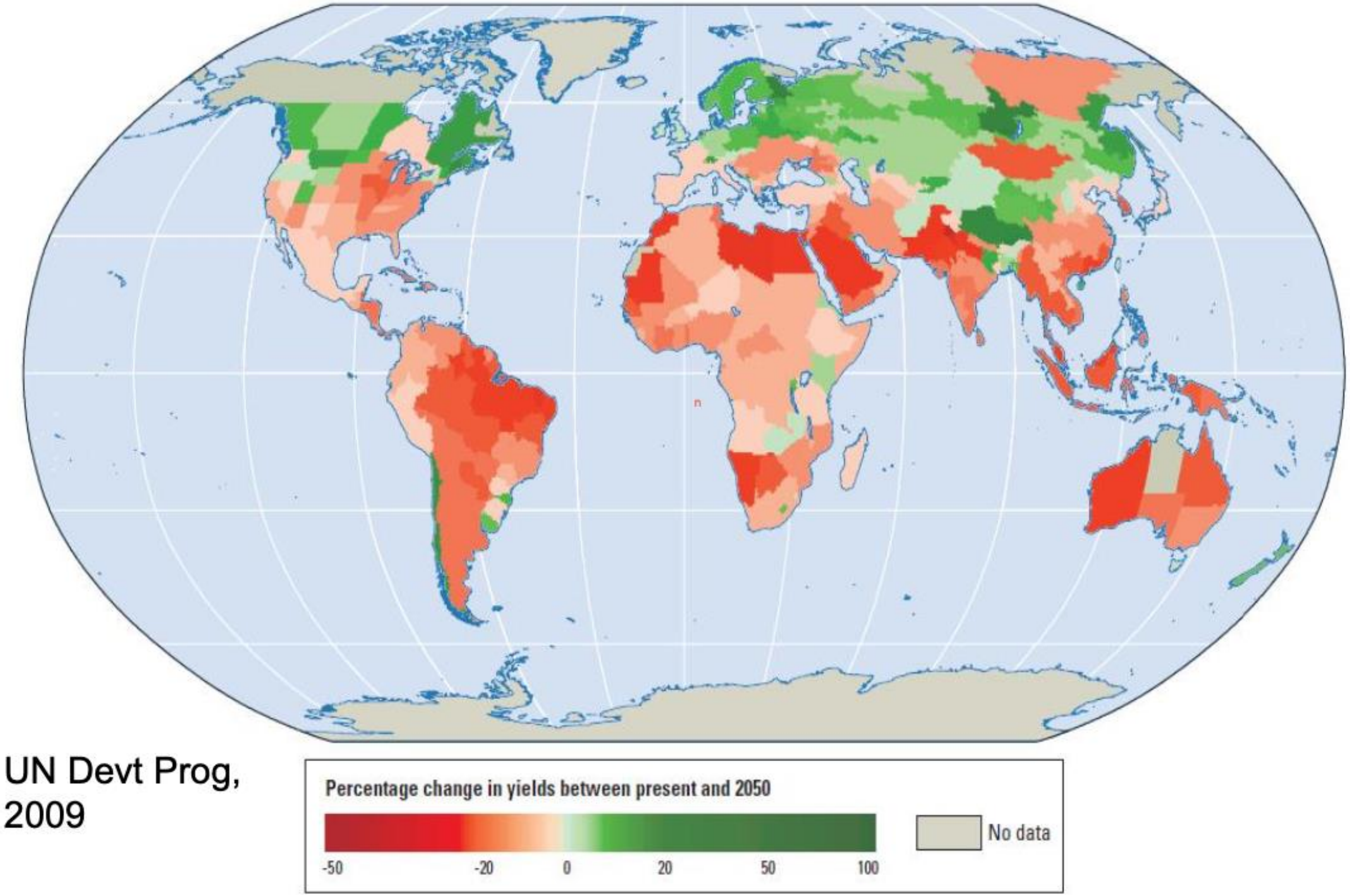
Fertilizers

- Fertilizers are **plant nutrients** and trace elements applied generally to the soil to **promote the growth of crops**.
- May be of **natural** or **synthetic** origin.
  - **Nitrogen:** Nitrogen fertilizers are made from ammonia (NH_3) produced by the Haber-Bosch process. 80% of ammonia use worldwide is for the manufacture of agricultural fertilizers (ammonium nitrate and ammonium sulphate). Boom in use: **800% increase** between 1961 and 2019.
  - **Phosphorus:** Widely used, but are of **little toxicological concern**.
  - **Potassium:** Potash is a mixture of potassium minerals used to make potassium fertilizers. Potash fertilizers are usually potassium chloride, potassium sulfate, potassium carbonate or potassium nitrate.

Fertilizers and climate change

- Fertilizer use can impact climate change, however climate change can also impact fertilizer use.
- The use of **nitrogen-based fertilizers** is driving up global emissions of nitrous oxide, a **highly potent greenhouse gas** which impacts global warming **300 times more** than carbon dioxide *(Tian et al. 2020)*.
- Increased precipitation due to climate change can cause **erosion** and thus **decrease essential soil nutrients** such as nitrogen and phosphorus, which are essential for plant growth.
- Loss of fertile soil can pressure agricultural workers to increase use of chemical fertilizers and other agrochemicals, impacting safety and health.

CLIMATE CHANGE: Poor Countries Projected to Fare Worst
MODELLED CHANGES IN CEREAL GRAIN YIELDS, **TO 2050**



UN Devt Prog, 2009

Fertilizers: Health impacts

Phosphorus

- Local effects include severe skin burns, burns to the upper airways and gastrointestinal tract and severe pulmonary inflammation,
- Systemic effects include multi-organ toxicity (hepatotoxicity, renal, gastrointestinal and cardiovascular).

Ammonia

- The toxic effects are typically limited to tissues in direct contact with ammonia.
- Exposure to high concentrations of liquid or vapour causes severe burns to the skin, eyes, upper airways and gastrointestinal tract.
- In the respiratory tract it can cause laryngeal oedema, pneumonitis and pulmonary oedema. Airway obstruction and respiratory insufficiency may be fatal.
- There may be permanent effects including visual impairment, and chronic pulmonary disease such as obstruction of small and large airways, bronchiectasis and interstitial lung disease.

Case study: Fertilizer use among chili farmers in Thailand

- Chemical fertilizer use has increased in Thailand over the past decades.
- A **cross-sectional descriptive study 76 chili farmers** was carried out by Nganchamung and Robson (2017).
- All chili farmers used both **chemical** and **organic fertilizers** in chili farms.
- 80.3% used chemical fertilizers 1-3 times monthly.
- **Improper behaviours** regarding chemical fertilizer use were found e.g. handling chemical fertilizers with **bare hands** and **no personal protective equipment**.
- About 26.3% of them reported having some symptoms within 48 hours while working with chemical fertilizers.
- Most common symptoms were **coughing** or **sneezing** (15.8%) and **skin irritation** or **itching** (14.5%).

International Labour Organization

Vector distribution and ecology

Vector-borne diseases

- Vector-borne diseases are human illnesses caused by **parasites**, **viruses** and **bacteria** that are transmitted by vectors.
- Vectors are **living organisms** that can transmit infectious pathogens between humans, or from animals to humans.
- Examples of vector-borne diseases include malaria, dengue, schistosomiasis, human African trypanosomiasis, leishmaniasis, Chagas disease, yellow fever, Japanese encephalitis and onchocerciasis.
- Vector-borne diseases account for more than **17% of all infectious diseases**, causing more than **700,000 deaths** annually *(WHO 2020)*.
- The burden of these diseases is highest in **tropical and subtropical areas**, and they **disproportionately affect the poorest populations**.
- Changed in weather patterns due to climate change can impact vector-borne disease transmission both directly and indirectly.

Vectors and the diseases they can transmit

Vector	Diseases
Mosquitoes:	
Aedes aegypti	Dengue, yellow fever, chikungunya, Zika virus
Aedes albopictus	Chikungunya, dengue, West Nile virus
Culex quinquefasciatus	Lymphatic filariasis
Anopheles (more than 60 known species can transmit diseases)	Malaria, lymphatic filariasis (in Africa)
Haemagogus	Yellow fever
Sandflies	Leishmaniasis
Triatomine bugs	Chagas disease
Ticks	Crimean-Congo haemorrhagic fever, tick-borne encephalitis, typhus, Lyme disease
Fleas	Plague, Murine typhus
Flies (various species)	Human African trypanosomiasis, onchocerciasis

(Source: WHO 2014)

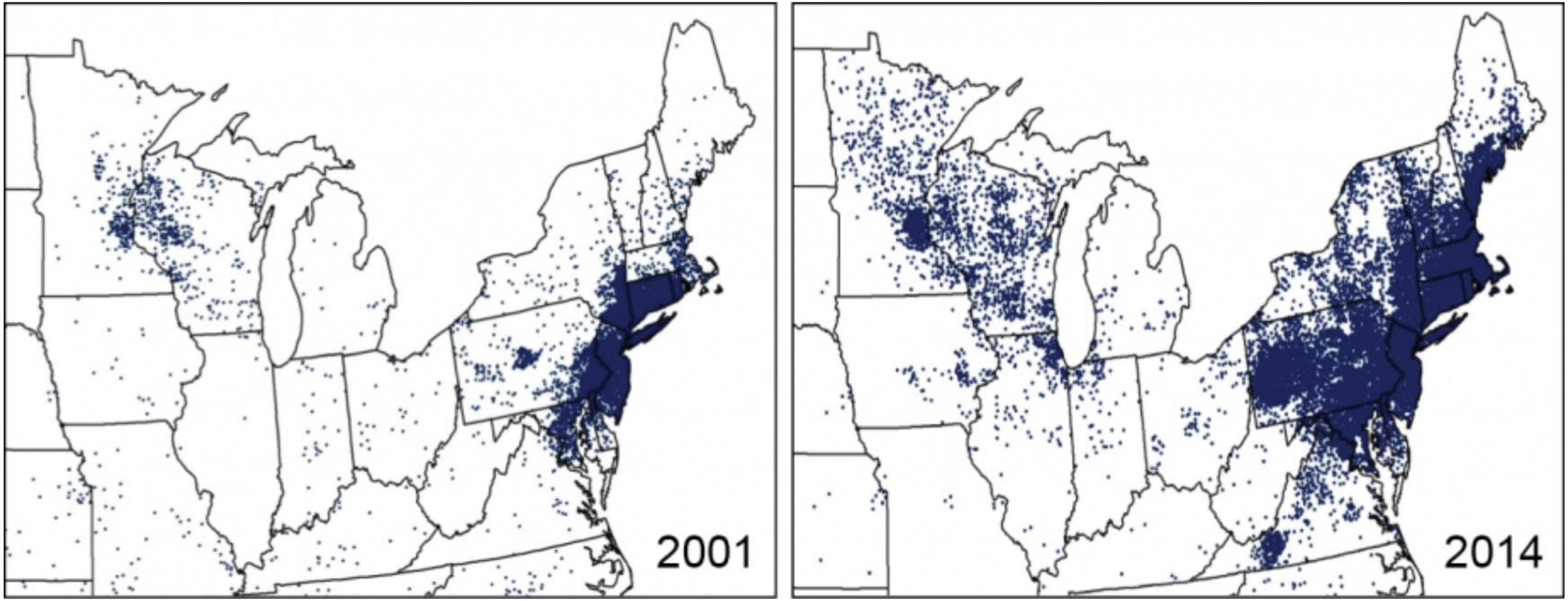
Climate change and vector-borne disease

- Changing climatic conditions, such as rainfall patterns, temperature and humidity, affect the number and survival rate of mosquitoes and some other vectors.
- The evidence that climate change has contributed to the expanded range of certain vectors is considerable *(Schulte et al. 2016)*.
- **Higher ambient temperatures** *(WHO 2006)*
  - Distribution of mosquitoes and other vectors may expand with increasing temperatures.
  - Ambient temperature determines insects reproduction rate, biting behaviour and survival.
  - The incubation period of pathogens inside vectors tends to be shorter at warmer temperatures.
- **Precipitation**
  - Important for diseases transmitted by vectors that have aquatic developmental stages (such as mosquitoes) *(Campbell-Lendrum et al. 2015)*.
- **Humidity**
  - Can influence diseases transmitted through vectors such as ticks and sandflies *(Campbell-Lendrum et al. 2015)*.

Case study: Lyme disease in the United States

- Lyme disease is a bacterial illness that can cause fever, fatigue, joint pain, and skin rash, as well as more serious joint and nervous system complications.
- Lyme disease is transmitted through the bite of certain species of infected ticks that live on deer, rodents, birds, and other host animals.
- The incidence of Lyme disease in the United States has nearly doubled since 1991, from 3.74 reported cases per 100,000 people to 7.21 reported cases per 100,000 people in 2018 *(CDC 2019)*.
- Studies show that climate change has contributed to the expanded range of ticks, increasing the potential risk of Lyme disease, even in areas where the ticks were previously unable to survive *(Beard et al. 2016)*.
- Warming temperatures associated with climate change are projected to increase the range of suitable tick habitats.
- Shorter winters could also extend the period when ticks are active each year, increasing the time that humans could be exposed to Lyme disease *(EPA 2021)*.

Figure ES6: Changes in Lyme Disease Case Report Distribution



Maps show the reported cases of Lyme disease in 2001 and 2014 for the areas of the country where Lyme disease is most common (the Northeast and Upper Midwest). Both the distribution and the numbers of cases have increased (see Ch. 5: Vector-Borne Diseases). (Figure source: adapted from CDC 2015)[7]

Indirect impacts of climate change on vector-borne diseases

- These include wider effects on the natural environment and on human systems e.g. drought may affect water-storage, land-use and irrigation practices *(Campbell-Lendrum et al. 2015)*.
- **Population movement**, in turn, can affect vector ecology, and human exposure to infection
- Previously **relatively stable geographical distributions are now changing** owing to a range of factors including: climate change, intensive farming, dams, irrigation, deforestation, population movements, rapid unplanned urbanization, and huge increases in international travel and trade *(WHO 2016)*.
- These environmental and social factors may either reinforce climate effects or counteract them.

Examples of how climate change has increased the risk of vector-borne diseases for workers

- Climate change has contributed to a >320% in the north-eastern states of the USA.
- **West Nile** and **Zika** viruses, other known vector-borne hazards to outdoor workers, may increase because of climate change *(Schulte et al. 2016)*.
- The incidence of **coccidioidomycosis**, a fungal disease endemic in the Southwest USA, has been associated with a number of outdoor occupations and has increased substantially from 1998–2011 (CDC 2015).
- Drought-ridden areas may lead to outdoor workers breathing more **windborne dusts** with various toxicities and possibly containing harmful organisms *(Schulte et al. 2016)*.
- A longer **ragweed pollen** season and expanded ranges for poisonous plants have significant implications for outdoor workers *(Smith et al. 2014)*.
- **Waterborne diarrheal disease** is sensitive to climate variability impacting workers in occupation such as fishing *(Schulte et al. 2016)*.

Vector-borne diseases and chemical use

- Outdoor workers are primarily at risk of vector-borne diseases as they have heightened exposure to vectors such as mosquitoes, ticks and fleas that can transmit parasites, viruses, or bacteria *(Schulte et al. 2016)*.
- Sectors include construction, landscaping, forestry, brush clearing, land surveying, farming, oil field and utility work, natural resources management, and wildland firefighters.
- Vector control, through the use of insecticides, plays a key role in the prevention and control of infectious diseases such as malaria, dengue and filariasis *(WHO 2006)*.
- Workers may therefore be increasingly exposed to these hazardous chemicals.
- Additionally, workers may find themselves frequently working in the presence of disinfectants, which have been linked to COPD, infertility and asthma *(ILO 2021)*.

Case study: Climate change and malaria

- Climate change can increase opportunities for malaria transmission in traditionally malarious areas, in areas where the disease is controlled and in new areas *(Fernando n.d.)*.
- An increase in temperature, rainfall, and humidity may cause a proliferation of the malaria-carrying mosquitoes at higher altitudes, resulting in an increase in transmission in non-malarious areas *(Jetten et al. 1996)*.
- At lower altitudes where malaria is already a problem, warmer temperatures will alter the growth cycle of the parasite in the mosquito enabling it to develop faster, thereby increasing transmission *(Sutherst 1998)*.
- Climate change greatly influences the El Niño cycle, that is known to be associated with increased risks of some diseases transmitted by mosquitoes, such as malaria.

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Major industrial accidents

Chemicals and major industrial accidents (MIA)

- Over the past decades, successive major accidents caused by chemicals, have caused **deaths**, **injuries**, significant **environmental pollution** and massive **economic losses**.
- There are many examples of major accidents caused by disastrous chemical accidents:
  - Leverkusen, German (2021)
  - Beirut, Lebanon (2020)
  - Rouen France(2019)
  - Bentos Rodrigues, Brazil (2015)
  - Tianjin, China (2015)
  - West,Texas,USA (2013)
  - Gumi, Korea(2013)
- Rising temperatures and other effects of climate change have the potential to **increase the occurrence and severity of MIA**.

Rising temperatures and chemical volatility

- Rising temperatures due to climate change have the potential to **increase volatility of temperature-sensitive chemicals**, which could lead to another **serious accident** *(Truchon et al. 2014)*.
- Non-insulated, single skin chemical storage containers do not provide any form of manual temperature control. Temperatures inside these containers can reach as high as 50°C, when the ambient temperature is around 30°C.
- **‘Thermal runaway’**, exponentially increased heat from a thermal reaction, can cause over-pressurisation due to violent boiling or rapid gas generation. This over-pressure may result in a plant **failing catastrophically** causing **blast or missile damage** *(HSE 2014)*.
- A release of flammable materials from the process could result in a **fire** or an **explosion**.

Rising temperatures and munitions

- More intense heat waves can also **destabilize the components of munitions**, particularly where explosives are not properly stored.
- Most munitions are designed to withstand severe heat, but only in the relatively short term. If exposed to extreme temperatures and humidity for long enough, a munition can become unstable.
- For every 5°C increase above its ideal storage temperature, the **chemical stabilizer** used to prevent self-ignition **depletes by a factor of 1.7** *(Scientific American 2019)*.

Natech

- **Natural Hazards Triggering Technological Accidents** or ‘**Natech**’ pose a serious risk for major industrial accidents and chemical exposures in the world of work.
- A Natech event is a **technological accident triggered by a natural hazard**. These can include floods, earthquakes, lightning, cyclones and extreme temperatures.
- A **technological accident** can include damage to, and release of chemicals from, fixed chemical installations, oil and gas pipelines, storage sites, transportation links, waste sites and mines.
- Many natural disasters have led to **major damages** to hazardous installations, triggering the release of **hazardous substances**, **fires** and **explosions**.
- It is likely that the risk and impact of Natech events is increasing, due to a combination of **increasing industrialization and urbanization** coupled with a predicted **increase in hydro-meteorological hazards caused by climate change** *(WHO 2018)*.

Examples of vulnerable sites for chemical release caused by Natech (WHO 2018)

Fuel storage sites, tank farms

- kerosene
- petroleum
- propane
- butane

Waste storage sites

- oil
- solvents
- polychlorinated biphenyls

Chemical factories

- alkalis
- acrolein
- methanol
- organic peroxides

Transport: railways, roads, rivers, sea

bulk chemicals e.g.:
- ammonia
- chlorine
- petroleum
- methanol

Gas and oil pipelines

- natural gas (methane)
- crude oil

Tailing dams

- toxic sludge
- mine tailings containing cyanide and arsenic

Food processing plants

- ammonia

Hospitals, laboratories, pharmacies

- reagents
- disinfectants
- medicines
- gases
- radiological material

Petroleum or petrochemical industries

- ammonia
- benzene
- crude oil
- hydrogen sulfide

Acid mine drainage (abandoned mines)

- aluminium
- arsenic
- cadmium
- lead
- manganese

Pesticide storage depots

- carbamates
- organophosphates
- organochlorines

Metallurgical industries

- toxic metals
- cyanide
- sulfuric acid
- ammonia

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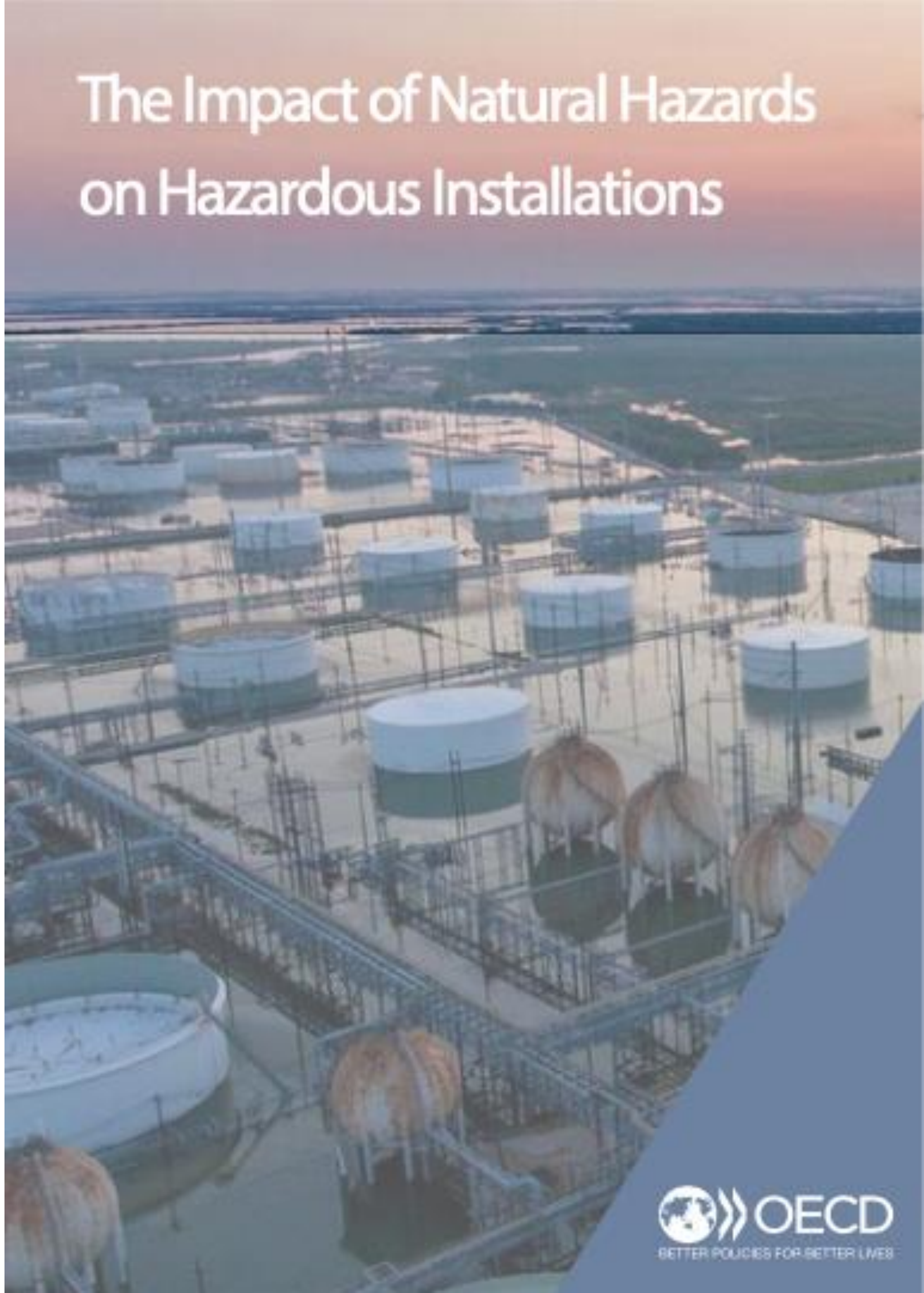
OECD report to raise awareness of natech risk, 2022

- What is Natech?
- The causes and consequences of Natech accidents.
- What makes the management of Natech risk so special?
- How are Natech risks managed?
- Natech risk management:
  examples of international support and transboundary cooperation.



Case study: A natech caused by Hurricane Harvey in Texas, USA *(CSB 2018)*

- On 24 August 2017, Hurricane Harvey, a Category 4 hurricane, hit southeast Texas.
- Over the next days, the storm produced unprecedented amounts of rainfall over southeast Texas and southwest Louisiana, causing significant flooding.
- A facility at Crosby, which handled organic peroxides, was located within the 100-year and 500-year flood plains.
- Rainfall exceeded the equipment design elevations and caused the plant to lose power, back-up power, and critical organic peroxide refrigeration systems.
- On 31 August 2017, organic peroxide products stored inside the refrigerated trailer decomposed, causing the peroxides and the trailer to burn.
- Twenty-one people sought medical attention from exposure to fumes generated by the decomposing products when the vapor travelled across a public highway adjacent to the plant.
- Over the course of three fires, in excess of 350,000 pounds of organic peroxide combusted.

Other impacts of severe weather events

- Climate projections point towards an **increase in the frequency and intensity of extreme weather events**, such as floods, drought, wildfires and hurricanes.
- These events put workers at **risk of physical injury**, **mental health conditions** and **death**.
- **First responders**, such as firefighters and healthcare workers, may be exposed to hazardous chemicals in the **immediate aftermath of extreme weather events**, for example if chemical storage facilities are damaged.
- Construction workers may also be exposed to chemicals during **clean-up operations.**
- Potential chemical exposures include numerous hazardous substances, such as lead, solvents, asbestos and industrial waste chemicals.

Case study: Construction workers and asbestos

- Intense Tropical Cyclone Idai in 2019 was one of the worst tropical cyclones on record to affect Africa and the Southern Hemisphere.
- The long-lived storm caused catastrophic damage, and a humanitarian crisis in Mozambique, Zimbabwe, and Malawi, leaving more than 1,300 people dead and many more missing.
- The Cyclone left a high exposure of hazardous waste, primarily asbestos from lusalite sheets *(ILO 2019)*.
- Construction workers were particularly exposed when clearing up older damaged buildings.
- Asbestos can cause asbestosis, a chronic lung disease, and is classified by the International Agency for Research on Cancer (IARC) as carcinogenic to humans (Group 1) *(IARC 2012)*.

Climate change and wildfires

- A wildfire is an unplanned fire that burns in a natural area such as a forest, grassland, or prairie.
- In recent years, the **widespread devastation of wildfires** has dominated headlines around the world, as millions of acres were destroyed and thousands of people left homeless.
- Fires in the western US and Australia have been among the **most deadly**.
- The risk of wildfires increases in **extreme weather conditions** (e.g. extremely dry conditions and high winds), such as those caused by climate change.
- Wildfires and volcanic activities affected **6.2 million people** between 1998-2017 with **2400 attributable deaths worldwide** from suffocation, injuries, and burns
- The size and frequency of wildfires are growing due to climate change *(WHO n.d)*.

Health risks for firefighters

- The increase in wildfires is a specific risk for firefighters as they may be exposed to **high levels of air pollution** *(Adetona et al. 2011)*.
- They will be more exposed to smoke and have a reduced firefighter recovery time between fire seasons *(Schulte et al. 2016)*.
- The base camps in which these firefighters live may contribute to their particulate matter exposures via **vehicle emissions, dust and generator use** *(McNamara et al. 2012)*.
- They may also be exposed to naturally occurring asbestos, during trail and forest road maintenance, timber stand grading, cutting fire lines, and while fighting fires *(Schulte et al. 2016)*.

Firefighters and PFAS

- Firefighters will also be increasingly exposed to hazardous chemicals contained **in firefighting foams**, for example, **perflourinated chemicals (PFAS).**
- PFAS have been linked to a variety of cancers, with PFOA classified as possibly **carcinogenic** to humans (Group 2B) by the IARC.
- They are also known to interfere with **immune function**, **endocrine function** and **breast development**.

Case study: PFAS and female firefighters

- Several studies have shown that firefighters have higher blood levels of PFAS compared to the general population.
- Exposure is from PFAS-containing firefighting foam, as well as PFAS-treated protective gear.
- Firefighting is generally a male-dominated occupation and most studies have been focused on male worker cohorts.
- However, one study found women firefighters have higher incidence and mortality rates of breast cancer compared to the general US population *(Daniels et al. 2014)*.
- Another study of Florida firefighters found that women firefighters had an increase in overall cancer risk compared to the general Florida population *(Ma et al. 2006)*.
- A recent study of an all-female cohort of firefighters showed that all the 86 female firefighters had at least four PFAS detected in their serum samples (PFHxS, PFOA, PFOS, and PFNA). Three additional PFAS were detected in 70% of the firefighters.

Freshwater cycle

Climate change and the freshwater cycle

- The freshwater cycle is strongly affected by climate change.
- The presence and availability of freshwater is indispensable for sectors like agricultural and industrial production processes *(Bunsen et al. 2021)*.
- **Over 2 billion people live in water-stressed countries**, of which **733 million live in high and critically water-stressed countries**. *(UN Water 2021)*.
- According to independent assessments, the world will face a **global water deficit of 40%** by 2030 *(UN Water 2021)*.

The freshwater cycle and chemicals

- Lack of access to clean water can the **severe consequence** for the health of workers.
- It can also **exacerbate consequences of high temperatures**, such as heat stress.
- For those using hazardous chemicals, access to water may be essential for **maintaining hygiene** and **cleaning equipment**.
- **A lack of access to cleaning facilities** may increase risk of chemical exposures for workers and their families.
- Additionally, limited access to clean water sources, may **increase worker reliance on chemicals**, such as disinfectants.

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Ocean acidification

Ocean acidification and climate change

- Ocean acidification is the ongoing decrease in the pH value of the earth's oceans primarily caused by uptake of carbon dioxide (CO_2) from the atmosphere.
- It is a direct consequence of increased human-induced CO_2 concentrations in the atmosphere.
- Ocean acidification can impact the health of workers in a number of ways.
- Food quantity and quality could be reduced, making workers less capable of carrying out physically arduous work tasks.
- Decreasing fish and seafood stocks due to ocean acidification may cause a loss of livelihood for some workers, which could impact mental health *(Falkenberg et al. 2020)*.
- Ocean acidification can cause harmful algal blooms, which could in turn trigger respiratory issues and skin irritations in some workers *(Wells et al. 2020)*.


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Climate change and vulnerable workers

Widening inequalities in the world of work

- Workers all around the world will be impacted by climate change.
- However, workers in some regions, for example **South Asia** and **Central Africa**, will be impacted most *(ILO 2019)*.
- Workers in industries like **construction** and **agriculture** will most affected, however also less likely to have access to health insurance and other social protection benefits that would help them to cope with workplace accidents and injuries resulting from heat stress.
- Climate change issues such as heat stress could entrench existing **inequalities in the world of work**, notably by worsening the working conditions of the many women working in agriculture, and of male workers on construction sites *(ILO 2019)*.
- It could be a push factor for migration, for example by prompting people to move to cities in search of better job prospects or when communities are forced to move due to rising sea levels.
- Different countries have different levels of **public, financial, institutional and technological capabilities** to deal with climate change.

Women and pregnant workers

- Women differ from men in their physiologic compensation to elevated temperatures, which may **increase their risk of heat stress** *(Sorensen et al. 2018)*.
- They are at higher risk of **cardiovascular complications** *(Chen et al. 2005)* and **impaired cognitive function** *(Kim et al. 2019)* due to air pollution.
- Pregnant workers are more susceptible to **heat exhaustion**, **heat stroke**, or **dehydration**, with heat stress linked to birth defects and other reproductive problems *(Lucas 1977)*.
- **Reproductive cycles** and **life stage** impact vulnerability of female workers to chemical exposures e.g. pregnancy, lactation and menopause.

Migrant workers

- Migrants are more exposed to climate change-related events and are more sensitive to such changes because of their **poverty** and **mobility**.
- **Heat stress** is concern, as migrant workers frequently work outside in **physically demanding jobs**.
- They may have **limited access to healthcare** and lack social protections.
- May not speak the local language, therefore are unable to understand **chemical labels**, **safe handling procedures** and **training materials**.
- Often work in informal workplaces where there is a **lack of regulation and OSH**.
- Workers have **limited information** and **education** on health hazards.
- Limited access to effective protective equipment.

Older adult workers

- Particularly vulnerable to **heat stress**, **poor air quality**, **exposure to infectious diseases**, **weather extremes** and other climate-related hazards.
- Less able to tolerate stress and are more at risk of disease due to a **lower physiological reserve capacity**, **slower metabolism** and **weaker immune system**.
- Have a **higher disease burden** and **existing chronic health conditions** may be exacerbated by climate-related risks at work *(Carnes et al. 2014)*.
- Exposures to climate change induced **vector-borne** and **waterborne pathogenic hazards** may pose a greater health risk among sensitive older adults with **compromised immune systems** *(Balbus and Malina 2009)*.

Disabled workers

- Disabled people have been shown to have generally **poorer health outcomes** *(WHO 2011)*.
- They are especially susceptible to heat-related illness and death, for reasons such as **physical vulnerabilities**, **barriers to accessing healthcare services**, **poverty**, **lower education** and **communication difficulties** *(EPA 2016)*.
- For example, a disabled workers with a **respiratory impairment** may be more at risk of adverse health impacts due to air pollution.
- They may be **more susceptible** to hazardous chemicals and face **unique risks** from chemical exposures depending on their particular disabilities.

Child labourers and youth workers

- Child labourers may be at higher risk of **heat stress** and **vector-bourne diseases** *(Arnold et al. 2020)*.
- Exposure to **increasing concentrations of air pollutants** form an additional risk for children working outside.
- Youth workers are also more vulnerable to the impacts of climate change, as they may be **still developing**, both physically and mentally.
- The adverse impact of chemical exposure on children's health is unique due to their **developing physiology, anatomy, metabolism and health behaviours**.
- Exposures to even low doses of hazardous chemicals can cause **devastating and lifelong functional impairments**.

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A final word...

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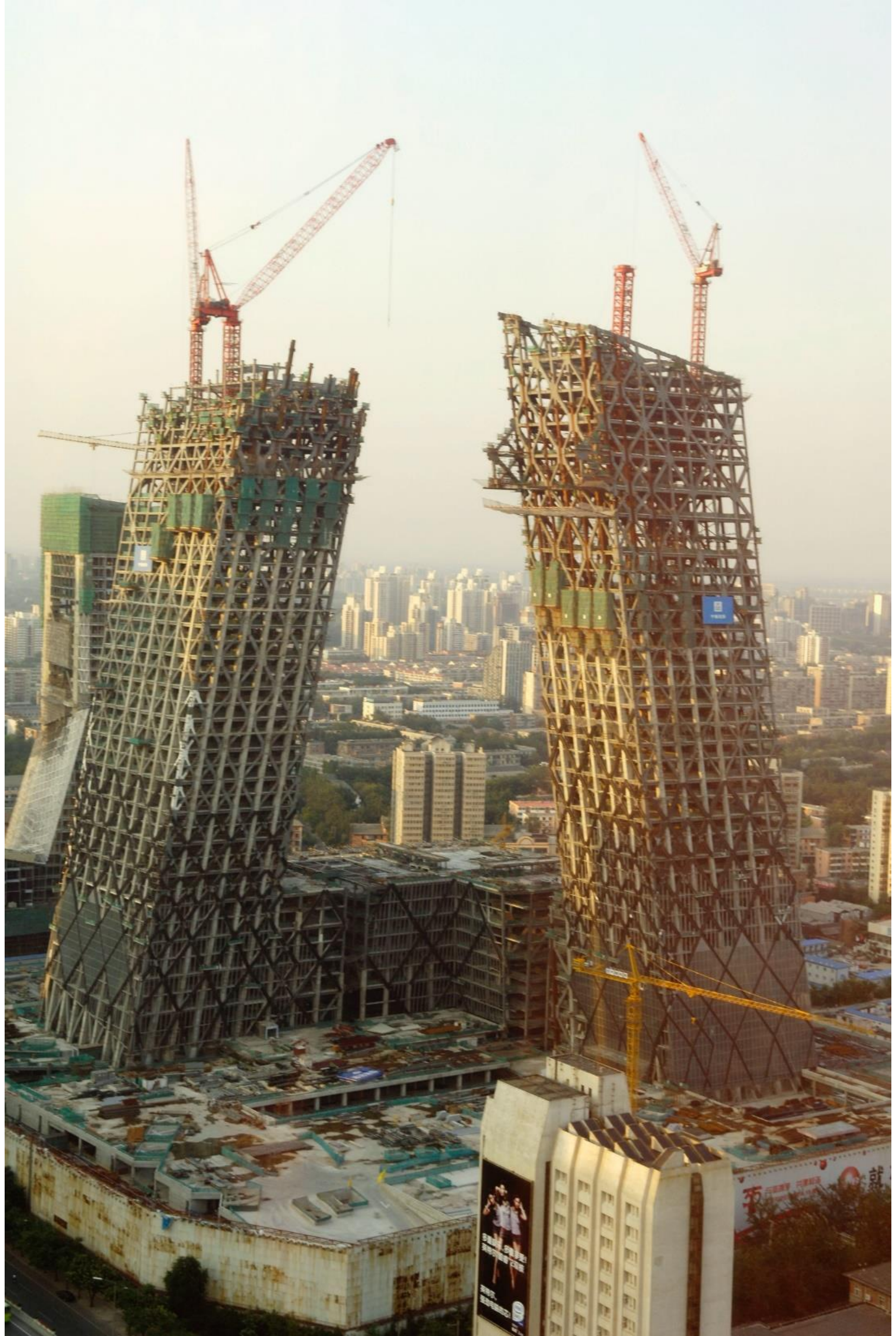
A rapidly changing world of work

- Emerging trends in the world of work will impact OSH priorities and produce new environmental challenges.
- Adaptations to issues such as climate change will themselves have environmental consequences which must be considered.
- Rapid shifts to sustainable technologies will create new industries with no infrastructure or OSH protections, impacting the health of the most vulnerable workers.



End of session activity

Quiz

Quiz

1. Name the top 5 polluting industries from the Pure Earth and Green Cross Report.
2. According to the ILO 2018, the relationship between climate change and the world of work is influenced by 3 crucial aspects. What are they?
3. What are the top 3 causes of death from the environment?
4. Discuss which sectors are at risk of climate-related changes and suggest why.
5. Which unidentified disease is affecting large numbers of workers doing heavy manual labour in hot temperatures?
6. What are the most common pollutants considered in air pollution estimates?

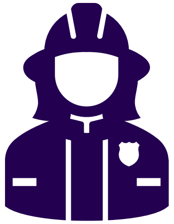
Quiz

7. Why does climate change increase dependence on pesticides?
8. Give some examples of vectors and vector-borne diseases.
9. What are ‘Natech’?
10. Can you name some vulnerable sites for chemical releases caused by Natech?
11. Identify worker groups which will be vulnerable to the impacts of climate change and discuss why they may be more at risk.
12. Give 3 examples of how climate change could cause workers to be more exposed to chemicals.

How might the health of these workers be impacted by climate change?

Construction workers

Firefighters



Agricultural workers

Can you fill in the blanks with the numbers below?

1. One worker dies every ………… seconds due to occupational chemical exposure.
2. Global chemical sales were valued at € ………… trillion in 2017.
3. Global average temperature are now ………… °C higher than at the beginning of last century
4. Between 2030 and 2050, climate change is expected to cause approximately ………… additional deaths per year, from malnutrition, malaria, diarrhoea and heat stress.
5. The chemical industry's production capacity nearly doubled to around ………… billion tons between 2000 and 2017.
6. Today, ………… billion jobs or ………… per cent of the global labour force are at risk because of environmental degradation.
7. Heat stress is projected to reduce global GDP by USD ………… billion in …………
8. It is estimated that ………… million cases of unintentional, acute pesticide poisoning occur annually

1.2	**2,400**	**30**	**2.3**	**250,000**
385	**1.1**	**40**	**2030**	**3.47**

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Key ILO resources

- Working on a warmer planet: The effect of heat stress on productivity and decent work (2019).
- Exposure to hazardous chemicals at work and resulting health impacts: A global review (2021).
- World Employment and Social Outlook: Greening with Jobs (2018).
- The employment impact of climate change adaptation: Input document for the G20 Climate Sustainability Working Group (2018).
- The Sound Management of Chemicals and Waste in the World of Work (2019).
- All You Need to Know: Convention No. 170.
- Major hazard control: A practical manual (1993).
- Prevention of major industrial accidents: code of practice (1991).
- Diagnostic and exposure criteria for occupational diseases - Guidance notes for diagnosis and prevention of the diseases in the ILO List of Occupational Diseases (revised 2010) (2022).