CHEMICALS AND CLIMATE: CHALLENGES FOR THE HEALTH SECTOR

Tracey Easthope and Megha Rath

Introduction

All natural and human-made systems are being impacted by the climate crisis. The scale of those impacts will be determined by the extent of the climate disruption, but ample evidence exists that disruptions are significant in nearly every respect, and will accelerate. The health sector is a major contributor to the climate crisis. As noted in the *Introduction* to this book, the healthcare sector's climate footprint is equivalent to 4.4% of global net emissions (HCWH, 2019). Seventy-one per cent of the healthcare sector's greenhouse gas emissions are the result of the healthcare supply chain (HCWH, 2019).

Chemicals are the fundamental building blocks of products and materials used in healthcare. The widespread manufacture, use and disposal of hazardous chemicals has created a second crisis that poses a global threat to human rights (UN, 2019), contaminates air, water and soil, poisons food chains and people, and threatens human and ecosystem health. For example, three million people are hospitalised with acute pesticide poisoning each year. The health sector contributes to this crisis, which takes a toll not only on the environment and communities, but also on healthcare workers. According to the US Center for Disease Control and Prevention, healthcare workers have the highest prevalence of asthma of all professions – higher than workers in manufacturing, agriculture and mining (Mazurek & Syamlal, 2018).

Chemical contamination can act in concert with climate change to exacerbate and accelerate ecosystem and human health impacts that threaten the basis of all life. Healthcare is also at the centre of the humanitarian response to many challenges as the climate and chemical crises accelerate. The health sector will be required to do more under difficult circumstances, as public health is increasingly threatened by extreme weather, population dislocation and pandemics (Box 20.1). This chapter will help readers to:

1. Recognise the breadth and severity of human and ecosystem threats from the interconnected crises of chemical pollution and climate change.

Box 20.1 Case study**Coronavirus, chemicals and climate**

The coronavirus pandemic highlighted the interconnected crises of climate and hazardous chemicals in healthcare. The frequency of pandemics is expected to increase as changes in climate collide with changes in people's settlement patterns. Areas with high rates of particulate air pollution have been shown to have higher death rates from COVID-19 (Wu *et al.*, 2020). Healthcare organizations are at the centre of the response to pandemics, being required to serve all who are sick, while protecting healthcare workers. With a novel infectious agent, personal protective equipment and disinfection chemicals were reportedly used in enormous quantities in an attempt to provide safe care. The increased volume of disinfectants resulted in a significant increase in calls to poison control centres (Chang *et al.*, 2020). Impacts include risks to wildlife (Nabi *et al.*, 2020), during both manufacture and disposal. In addition, every month, the world used 89 million medical masks, 76 million gloves and 1.6 million goggles (WHO, 2020a). This level of production means an increased volume of chemicals used in production.

The COVID-19 pandemic led to an “abrupt collapse of waste management chains... Wuhan, the COVID-19 epicentre of China, experienced a massive increase of medical waste from between 40 and 50 tons/day before the outbreak to about 247 tons on 1 March.... With fewer options available, traditional waste management practices such as landfills and incineration are replacing more sustainable measures such as recycling, with adverse effects on the environment” (Siming *et al.*, 2020). Cities across the world experienced similar challenges, including those in India. The increased incineration of PPE releases chemicals and particulate air pollutants that both exacerbate climate change and threaten public health including impairing lung capacity. Methane gas and CO₂ are generated by waste decomposition in landfills, contributing to climate impacts.

2. Realise the unique challenges faced by the health sector when confronting the climate and chemical crises.
3. Understand how the manufacture, use and disposal of the large volume of chemicals and materials used in healthcare can impact both the climate and human health.
4. Identify the products used in healthcare that have a significant impact on the climate.
5. Learn about solutions that reduce the need for health services, the use of chemicals of concern and the release of GHGs.

The chemical industry in the healthcare supply chain

Seventy one per cent of the healthcare sector's greenhouse gas emissions are the result of the healthcare supply chain including the production, transport and disposal of goods and services, such as pharmaceuticals, cleaners and disinfectants, disposables and plastics, food and agricultural products, packaging, medical devices, hospital equipment and instruments (HCWH and Arup, 2019). Manufacturing all of these products also results in the release of chemicals of concern.

The size of the global chemical industry was \$5 trillion in 2017 and is projected to double by 2030, and approximately 62 per cent of the 345 million tons of chemicals consumed in the EU in 2016 were hazardous to health (UNEP, 2019). 35% of the volume of chemicals used in the EU are reported to be toxic to ecosystems, according to the report. This chemical pollution threatens the critical systems that contribute to ecosystem stability and support ecosystem services including biodiversity. In addition, the WHO estimated the global burden of disease from selected chemicals to be 1.6 million lives in 2016. This is likely to be an underestimate (UNEP, 2019).

The global healthcare market is expected to grow at a compound annual growth rate of 8.9% to nearly \$11,908.9 billion by 2022 (BusinessWire, 2019), increasing the chemical and climate footprint of the sector. In addition, climate change is adding to the conditions that make health-related social conditions worse, increasing the demands on, and threatening the stability of, the health sector. Those increased demands for services in turn increase the chemical and GHG footprint of the sector.

In the last several decades, the health sector's reliance on single-use plastics has increased dramatically resulting in significant climate and chemical impacts. 25% of the waste generated by a hospital is plastic. A single surgery can produce up to 20 pounds of waste, most of which is plastic. Polymers and plastics, especially polyethylene, polypropylene, polyvinyl chloride, polyethylene terephthalate, polystyrene and polycarbonate comprise about 80% of the industry's output worldwide. Building materials and packaging make up a significant percentage of this output. Plastics manufacturing and its associated energy consumption account for 7–8% of total oil and gas consumption globally. In 2019 alone, the production and incineration of all plastic added more than 850 million metric tons of greenhouse gases to the atmosphere—equal to the pollution from 189 new 500-megawatt coal-fired power plants, according to a report (CIEL, 2019). Half of all plastics ever manufactured have been made in the last 15 years, overwhelming the world's ability to manage them. Possibly the largest contributor of any material to the toxic chemical economy, five of the most commonly used polymers use chemicals of high concern at every step of manufacturing. Most plastic also contains toxic chemicals, which can be released to the environment as they degrade (CPA 2014). Workers are

particularly vulnerable to toxic exposures during plastic manufacturing. Plastics, particularly PVC, can also leach toxic chemicals like plasticisers into vulnerable patients, which can threaten health (Schettler, 2020). The subject of plastics in healthcare is dealt with in greater detail in the chapter titled *The Paradox of Plastics in Healthcare and Health*.

Pharmaceuticals make up a significant fraction of products manufactured by the chemical sector, and pharmaceuticals generate a high percentage of waste per product. In 2019, patients received an estimated 1.8 trillion days of therapy, an average of 234 per person globally. By 2024, the global pharmaceuticals market should reach USD 1,550 billion and grow at a pace of 4.4% per year, 1.8% above the forecast worldwide economic growth. The U.K's National Health Service found that medical equipment and pharmaceuticals alone generated 30% of their system's GHG emissions (NHS 2020).

Pharmaceuticals are also biologically active and can threaten health during manufacture, use and disposal. More than six hundred pharmaceuticals or their transformation products including antibiotics, analgesics, lipid-lowering drugs and oestrogens have been detected in the environment of 71 countries, threatening aquatic life, contributing to antimicrobial resistance and threatening human health (aus der Beek *et al.*, 2016). The Swedish Government has classified pharmaceuticals based on their environmental impact.

Many healthcare institutions have large foodservice operations. Agriculture contributes an estimated 21–37% of total net anthropogenic GHG emissions mainly due to the use of chemical fertilisers, pesticides and animal wastes (IPCC, 2019). This will increase with food demand. Agriculture is also contributing to the chemical contamination crisis. A 2020 study estimated that 385 million cases of unintentional, acute pesticide poisoning occur annually world-wide including around 11,000 fatalities (BMC, 2020).

All of the disposable plastics, PPE, IV bags, gloves and other materials generated by the healthcare sector must go somewhere. The disposal of healthcare waste contributes significantly to the climate and chemical crises. High levels of methane gas and CO₂ are generated by waste decomposition typical of landfills. Leachate from landfills contaminates water sources. As noted above, the incineration of plastic will add significantly to GHG emissions.

The vast scale of the chemical and climate crises require solutions on the same scale. These solutions should increase resilience and promote health for all, and address the disproportionate public health and safety risks to vulnerable populations. Solutions must address the following:

Focus on prevention

A health promotion model that addresses the social determinants of health such as economic and housing security, and access to food, safe water and other basic necessities, and that emphasises public health interventions is the most important way to reduce healthcare demand. Preventive approaches that address population health such as vaccination and screening are

cost-effective and can help build resilience and promote healthy behaviours (WHO, 2014). They can also contribute to wider sustainability, with economic, social and environmental benefits.

Eliminate unnecessary care

Eliminating unnecessary care and avoiding the use of products where they are not needed is an effective way to reduce the release of GHGs and chemicals of concern. Evidence of widespread overuse is accumulating from many countries including low- and middle-income countries (LMICs), although the problem predominates in high-income countries (Brownlee *et al.*, 2017). Overuse can coexist with unmet health needs. Avoiding re-hospitalisation by adhering to strict infection control is also critical to reducing the need for care, and consequently, the release of GHG's and chemicals of concern (WHO, 2016).

Detoxify and decarbonise the supply chain

A comprehensive global framework is needed, with ambitious goals and indicators to address the chemical sector. The energy intensity of the chemical sector could be reduced by up to 25% compared to the current level through wide-scale upgrading, replacement and deployment of best available technologies, particularly in countries and industries where this has not yet happened. The sector could also dramatically reduce the toxicity of its output by a major investment in green chemistry innovations. Demand from the healthcare sector must help drive this change. Healthcare can take steps to detoxify and decarbonise its supply chain (HCWH, 2019) by: ending the purchase and use of single-use, disposable plastic where possible; fostering the transition to zero-waste healthcare; requiring extended producer responsibility as a critical component of circular economies; adopting and enforcing targets to eliminate chemicals of concern in products where possible; reducing pharmaceutical waste through regulations; instituting take-back programmes; adopting and enforcing ambitious targets to reduce GHGs emissions from all supply chain sectors; driving innovation in bio-based feedstocks and advances in green chemistry, among other solutions. Several papers have detailed these opportunities including a report from Health Care Without Harm: *Health Care's Climate Footprint: How the health sector contributes to the global climate crisis and opportunities for action* (HCWH, 2019).

Integrate product design, recycling and waste management

Products must be designed with life cycle management in mind in order to address the full range of chemical and climate threats. Designing products for end-of-life reusability and recyclability, reduction of GHG's and

elimination of waste is critical. Designing products without hazardous chemicals will also facilitate reuse and recycling in a circular economy.

The sector already has years of experience in evaluating and making purchasing decisions based on the toxicity of products and services throughout their life cycle. Critical work is still needed to understand the energy intensity of products, and to make the chemical and climate impacts of products more transparent in order to allow demand to drive change through the supply chain. It is essential to expand advocacy to accelerate this work and to drive markets toward less toxic, less climate threatening and less waste-producing products. The UNDP- HCWH Sustainable Health in Procurement project offers a model of detoxifying and decarbonising the supply chain.

The impact of chemicals on climate change

Some products used in healthcare can have direct climate impacts. These agents have high global warming potential (GWP). They include the use of climate-altering chemicals like anaesthetic gases, air conditioning and cooling agents and fumigants.

Anaesthesia gases are potent greenhouse gases. Commonly used anaesthetics include nitrous oxide and the fluorinated gases sevoflurane, isoflurane and desflurane. At present, the majority of these gases are not captured, and enter the atmosphere. Research by the National Health Service (NHS) Sustainable Development Unit indicates that the United Kingdom's anaesthetic gas footprint is 1.7% of the total and the majority can be attributed to nitrous oxide use (CSH, 2019). Medical nitrous oxide use for UNFCCC Annex 1 nations contributed an additional 0.4% to the global healthcare footprint, and an additional 2.5% to the global Scope 1 footprint (HCWH, 2019). Together, UNFCCC nations accounted for 57% of the global GDP, and 73% of global health expenditure in 2014, so the full impact of nitrous oxide use in anaesthesia can be expected to be substantially greater than the figures for Annex 1 nations alone (HCWH, 2019). For fluorinated gases used in anaesthesia, global emissions to the atmosphere in 2014 were estimated to be an additional 0.2% of the global healthcare footprint (HCWH, 2019). Due to increasing uptake of fluorinated gases, increasingly preferred to nitrous oxide, the footprint from anaesthetic gases can be expected to increase. Anaesthetic gases currently contribute at least 0.6% of healthcare's global climate impact (HCWH, 2019). Wider adoption of waste anaesthetic capture systems has the potential to be a high impact healthcare-specific climate mitigation measure (Box 20.2).

Air conditioning and cooling agents have a direct impact on the climate. There have been various multilateral environmental agreements such as the Montreal Protocol and Kigali Amendment that are adapting better standards and safer chemicals to minimise these impacts within the health sector. WHO's Project Optimize introduced solar direct drive refrigerators for the vaccine supply chain, and introduced the requirement of procuring

Box 20.2 Case study**Nitrous oxide**

For many individual health facilities and systems, the proportion of the contribution of both nitrous oxide and fluorinated anaesthetic gases to their climate footprint can be very high. For instance, Albert Einstein Hospital in Sao Paulo, Brazil found that GHG emissions from nitrous oxide contributed 75% of their Scope 1 GHG emissions and nearly 35% of their total reported GHG emissions in 2013. Meanwhile, a study of operating theatres in three health systems in the United States, United Kingdom and Canada found that preferential use of desflurane resulted in a ten-fold higher quantity of anaesthetic-related GHG emissions across hospitals in the study (Bouley *et al.*, 2017).

chlorofluorocarbon (CFC) free refrigerators within the pre-qualification standard for refrigerators procured by the WHO (2013).

Fumigants are among the most hazardous and greenhouse gas-producing pesticides. Fumigant use has been shown to contribute to nitrous oxide, a greenhouse gas 300 times more potent than carbon dioxide.

Sustainable procurement criteria to avoid these products is the most important intervention to reduce Scope 1 emissions from the sector.

The interlinkages between chemicals and climate change

Global climate change is already directly responsible for 150,000 deaths annually (WHO, 2020b). From 2030 to 2050 it is expected to cause 250,000 additional deaths per year, from malnutrition, malaria, diarrhoea and heat stress. Toxic pollution is already conservatively estimated to be the single largest source of premature death in the world (UN, 2019). The interaction of these two crises will multiply the risks to humans and ecosystems.

1. Extreme weather events associated with climate change will increase exposure to toxic chemicals

Drought can threaten water quality because of toxic chemical loading in the environment. Regions subject to decreases in precipitation may experience enhanced volatilisation of POPs and pesticides to the atmosphere (Noyes *et al.*, 2009). Regions subject to increased precipitation will experience enhanced surface deposition of airborne POPs and increased run-off of pesticides and other contaminants to water sources. Hurricanes and extreme rainfall often result in flooding and costly damage to facilities or homes that store, make or use toxic chemicals (Reible *et al.*, 2006). Healthcare can become a source of chemical

contamination because of the volatile and toxic substances on site. All of these releases can further threaten health and lead to greater demands on the healthcare system.

2. Warmer temperatures will worsen air pollution

Reduced precipitation will increase air pollution in urbanised regions. 4.2 million premature deaths annually are already due to the effects of outdoor air pollution (WHO Factsheet n.d.). Stagnation events when warm air traps pollution in the lower atmosphere are becoming more prevalent leading to increased ground-level ozone formation. Ozone is particularly dangerous for children, the elderly, people with cardiovascular or lung diseases and for those who work outside. Low levels of ozone exposure can be hazardous for anyone spending time outdoors. Air pollution can lead to more hospital and emergency room visits and long-term health risks. Climate change may also increase particulate pollution, which can travel deep into the lungs and cause or aggravate heart and lung diseases (Hong *et al.*, 2019). Healthcare contributes to air pollution both directly through energy consumption and indirectly through the supply chain.

3. Climate change will likely increase the vulnerability of biological systems to the effects of chemicals

Scientists expect warmer weather to increase the amount of chemicals that organisms take in, store, break down and eliminate. Warmer temperatures weaken the ability of humans and animals to cope with chemical toxicity (Noyes *et al.*, 2009). Suppressed immune systems as a result of chemical exposures are less capable of withstanding climate change threats (Erickson, 2019). Climate change can also make organisms more sensitive to chemical stressors (Hooper *et al.*, 2013).

These are just a few examples that underline an urgent need to reduce the volume and toxicity of chemicals used in order to reduce the threats posed by the converging threats of climate and chemical contamination.

Key takeaways

- The health sector is a major contributor to both the crises of climate change and widespread chemical contamination, and is at the centre of our humanitarian response to these crises.
- The breadth and severity of human and ecosystem threats from the interlocking crises of chemical pollution and climate change cannot be overstated.
- These threats are in large part the result of the healthcare supply chain including the manufacture, use and disposal of chemicals and materials used in the sector, and the energy required to produce them.
- The healthcare sector is uniquely vulnerable to climate and chemical challenges, and that vulnerability can threaten the stability of the sector.

- Healthcare must urgently redesign, decarbonise and detoxify the supply chain.
- Healthcare must support broader systemic changes that address prevention in order to reduce demand for healthcare services.
- There are solutions that can be implemented now to help reduce the sector's carbon footprint and dramatically reduce the toxicity and volume of chemicals and materials used in healthcare.

References

- aus der Beek, T., Weber, F., Bergmann, A., Grüttner, G., & Carius, A. (2016). *Pharmaceuticals in the environment: Global occurrence and potential cooperative action under the Strategic Approach to International Chemicals Management (SAICM)*. Umweltbundesamt.
- BMC. (2020). *The global distribution of acute unintentional pesticide poisoning: Estimations based on a systematic review*. <https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-020-09939-0>.
- Bouley, T., Roschnik, S., Karliner, J., Wilburn, S., Slotterback, S., Guenther, R., Orris, P. Kasper, T., Platzer, B. L., & Torgeson, K. (2017). *Climate-smart healthcare: Low-carbon and resilience strategies for the health sector (English)*. Investing in climate change and health series. World Bank Group. <https://documents.worldbank.org/en/publication/documents-reports/documentdetail/322251495434571418/climate-smart-healthcare-low-carbon-and-resilience-strategies-for-the-health-sector>
- Brownlee, S., Chalkidou, K., Doust, J., Elshaug, A. G., Glasziou, P., Heath, I., Nagpal, S., Saini, V., Srivastava, D., Chalmers, K., & Korenstein, D. (2017). Evidence for overuse of medical services around the world. *The Lancet*, 390(10090), 156–168. doi: 10.1016/S0140-6736(16)32585-5
- BusinessWire. (2019). *The \$11.9 trillion global healthcare market: Key opportunities & strategies (2014–2022)*. <https://www.businesswire.com/news/home/20190625005862/en/The-11.9-Trillion-Global-Healthcare-Market-Key-Opportunities-Strategies-2014-2022---ResearchAndMarkets.com>
- Center for International Environmental Law. (2019). Plastic and climate: The hidden costs of a plastic planet. CIEL. www.ciel.org/plasticandclimate
- Chang, A., Schnall, A. H., Law, R. *et al.*, (2020). Cleaning and disinfectant chemical exposures and temporal associations with COVID-19 — National Poison Data System, United States. January 1, 2020 -March 31, 2020. *Morbidity and Mortality Weekly Report*. 69, 496 -498. doi: 10.15585/mmwr.mm6916e1
- CSH. 2019. *Anaesthetics. Centre for Sustainable Healthcare*. <https://sustainablehealthcare.org.uk/what-we-do/sustainable-specialties/anaesthetics>
- Erickson, B. E. (2019). Linking pollution and infectious disease: Chemicals and pathogens interact to weaken the immune system, reduce vaccine efficacy, and increase pathogen virulence. *Chemical and Engineering News*, March 18, appeared in 97(11). <https://cen.acs.org/environment/persistent-pollutants/Linking-pollution-infectious-disease/97/i11>
- Health Care Without Harm. (2019). *Health care's climate footprint: How the health sector contributes to the global climate crisis and opportunities for action*. HWCH. https://noharm-global.org/sites/default/files/documents-files/5961/HealthCaresClimateFootprint_092319.pdf

- Hong, C., Zhang, Q., Zhang, Y., Davis, S. J., Tong, D., Zheng, Y., Liu, Z., Guan, D., He, K., & Schellnhuber, H. J. (2019). Impacts of climate change on future air quality and human health in China. *Proceedings of the National Academy of Sciences*, 116(35), 17193–17200. doi:10.1073/pnas.1812881116.
- Hooper, M. J., Ankley, G. T., Cristol, D. A., Maryoung, L. A., Noyes, P. D., & Pinkerton, K. E. (2013). Interactions between chemical and climate stressors: A role for mechanistic toxicology in assessing climate change risks. *Environmental Toxicology and Chemistry*, 32(1), 32–48. <https://doi.org/10.1002/etc.2043>
- IPCC. (2019). Land: An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystem. IPCC.
- Mazurek, J. M., & Syamlal, G. (2018). Prevalence of asthma, Asthma attacks, and emergency department visits for asthma among working adults — National Health Interview Survey, 2011–2016. *Morbidity and Mortality Weekly Report*, 67, 377–386. doi: 10.15585/mmwr.mm6713a1
- Nabi, G., Wang, Y., Hao, Y., Khan, S., Wu, Y., & Li, D. (2020). Massive use of disinfectants against COVID-19 poses potential risks to urban wildlife. *Environmental Research*, 188, 109916. doi: 10.1016/j.envres.2020.109916
- NHS. (2020). *Delivering a net zero national health service*. <https://www.england.nhs.uk/greenernhs/wp-content/uploads/sites/51/2020/10/delivering-a-net-zero-national-health-service.pdf>
- Noyes, P., McElwee, M., Miller, H. K., Clark, B. W., Van T., Lindsey, A., Walcott, K. C., Erwin, K. N., & Levin, E. D. (2009). The toxicology of climate change: Environmental contaminants in a warming world. *Environment International*, 35(6), 971–986. <https://www.sciencedirect.com/science/article/pii/S0160412009000543>
- Reible, D. D., Haas, C. N., Pardue, J. H., & Walsh, W. J. (2006). Toxic and contaminant concerns generated by Hurricane Katrina. *National Academy of Engineering*, 36, (1), The Aftermath of Katrina, March 1, 2006. <https://www.nae.edu/7623/ToxicandContaminantConcernsGeneratedbyHurricaneKatrina#:~:text=When%20Hurricane%20Katrina%20flooded%20the,in%20its%20wake%20was%20contamination.&text=Adding%20to%20the%20potential%20sources,creosote%2C%20pentachlorophenol%2C%20and%20arsenic>
- Rossi, M., & Blake, A. (2014). Plastics scorecard: Evaluating the chemical footprint of plastics. *Clean Production Action*. https://www.bizngo.org/images/ee_images/uploads/resources/plastics_scorecard_2015_2_25e.pdf
- Schettler, T. (2020). Polyvinyl chloride in health care: A rationale for choosing alternatives. *Health Care Without Harm*. <https://noharmuscanada.org/sites/default/files/documents-files/6222/Polyvinyl%20chloride%20in%20health%20care%20-%20A%20rationale%20for%20choosing%20alternatives%20-%201-31--2020.pdf>
- Siming, Y., Christian, S., & Yong, S. O. (2020). COVID-19's unsustainable waste management. *Science*, 368(6498), 1438. doi: 10.1126/science.abc7778. <https://science.sciencemag.org/content/368/6498/1438.1>
- United Nations Environment Programme. (2019). *Global chemicals outlook II: From legacies to innovative solutions, implementing the 2030 Agenda for sustainable development*. UNEP. https://wedocs.unep.org/bitstream/handle/20.500.11822/28187/GCO-II_Intro.pdf?sequence=1&isAllowed=y

- United Nations Human Rights Office of the High Commissioner. (2019, October 24). *Toxic pollution: Another extinction crisis looms, warns UN expert [press release]*. <https://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=25201&LangID=E>
- WHO Factsheet. *Air pollution*. https://www.who.int/health-topics/air-pollution#tab=tab_2
- World Health Organization. (2013). *Stimulating innovation in the vaccine cold chain equipment industry*. WHO and PATH. https://www.who.int/immunization/programmes_systems/supply_chain/optimize/TS_opt_stim_innovation_overview.pdf?ua=1
- World Health Organization. (2014). The Case for Investing in Public Health: The strengthening public health services and capacity. A public health summary report for EPHO 8. WHO. https://www.euro.who.int/__data/assets/pdf_file/0009/278073/Case-Investing-Public-Health.pdf
- World Health Organization. (2016). *Health care without avoidable infections: The critical role of infection prevention and control*. Infection Prevention and Control Global Unit Service Delivery and Safety. <https://apps.who.int/iris/bitstream/handle/10665/246235/WHO-HIS-SDS-2016.10-eng.pdf;jsessionid=73F5807D1FC29A2309ADF77F4F12F327?sequence=1>
- World Health Organization. (2020a, March). *Shortage of personal protective equipment endangering healthcare workers worldwide*. WHO News Release. <https://www.who.int/news/item/03-03-2020-shortage-of-personal-protective-equipment-endangering-health-workers-worldwide>
- World Health Organization. (2020b, August). *Climate change*. The Health and Environment Linkages Program. <https://www.who.int/heli/risks/climate/climate-change/en/>
- Wu, X., Nethery, R. C., Sabath, B. M., Braun, D., & Dominici, F. (2020). Exposure to air pollution and COVID-19 mortality in the United States. *medRxiv* April 05 20054502. doi: 10.1101/2020.04.05.20054502