September 2022
A CONVERSATION STARTER

Air Pollution, Human Health, Weather Events, and Anticipatory Action

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About the Academic Alliance for Anticipatory Action's Conversation Starter Series

As the Academic Alliance for Anticipatory Action (4As) works to develop an evidence base on anticipatory action, we regularly uncover questions that we need to explore. Through the Conversation Starter series, we share what we are learning about these questions and invite others to join us as we grapple with these questions.

If these questions resonate with you, contact us to start a conversation: Leah B. Poole, Leah.Poole@tufts.edu.

The questions we asked

As the second-leading risk factor for disease burden and death globally, air pollution is an important public health concern. Due to the connection between air pollution and climate change, it is critical to consider how the impact of air pollution can be addressed through anticipatory action. This pressing concern led us to the following questions:

- How is air pollution forecasted?
- What types of air pollution events should cause humanitarians to act?
- What early actions could humanitarians take for air pollution?
- Where else should efforts be focused?
- Is there a precedent humanitarians can learn from?

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Summary of findings

Air pollution affects human health and weather in all countries. There is evidence linking air quality to weather events, specifically seasonal shifts, heat waves, and wildfires. It is possible that these weather events can be forecasted and combined with high-quality data on trends in air quality to create a window of opportunity for early action related to air pollution. As we learn more about the relationship between air pollution, health, and weather, it is important to consider, at least in the context of humanitarian assistance, what effective actions beyond advocacy and awareness could make sense to protect vulnerable populations. These actions range from campaigns for limited car use to cash assistance to encourage staying indoors for those who rely on outdoor work.

How we went about answering the questions

We started with a simple search for air quality indices to better understand where and how air pollution is tracked and quantified. We then reviewed the methodologies of these indices reports about the most comprehensive air quality tracking databases to determine the current status and feasibility of forecasting air pollution. We also reviewed literature about health, weather, and air pollution from a variety of sources, including scholarly journals, government websites, and humanitarian reports.

Background on air pollution

Air pollution is contamination of the air people breathe, indoors or outdoors. Common pollutants include particulate matter, ozone, carbon monoxide, nitrogen dioxide, and sulfur dioxide, which cause respiratory and other diseases that lead to morbidity and mortality.[1] The major causes of air pollution are burning of fossil fuels, vehicle emissions, wildfires, and volcanoes. Burning of fossil fuels is also the major driver of climate change.

Air pollution affects human health and weather in all countries. It is usually concentrated around cities and highly industrial areas, but the wind can carry it from source areas to other areas. Air pollution is widening equity gaps, as individuals in low- and middle-income countries are most exposed to poor air quality (see Figure 1 below), while the air pollution from high-income countries continues to worsen outcomes in less-resourced areas.

The World Health Organization (WHO) estimates that 12% of deaths globally can be attributed to air pollution, making it one of the leading risk factors for death.[2] Pollutants such as particulate matter can penetrate deep into the respiratory tract and cause death from respiratory infections and diseases, lung cancer, and cardiovascular diseases.[3] Additionally, air pollution can negatively affect people's quality of life and their perceptions of their well-being. For example, a study on Mongolian adults living in Ulaanbaatar found that increased use of coal during the cold season negatively affected respiratory function, and that the choice between poor respiratory health and warmth was an uncomfortable one that significantly impacted perceived individual well-being.[4]

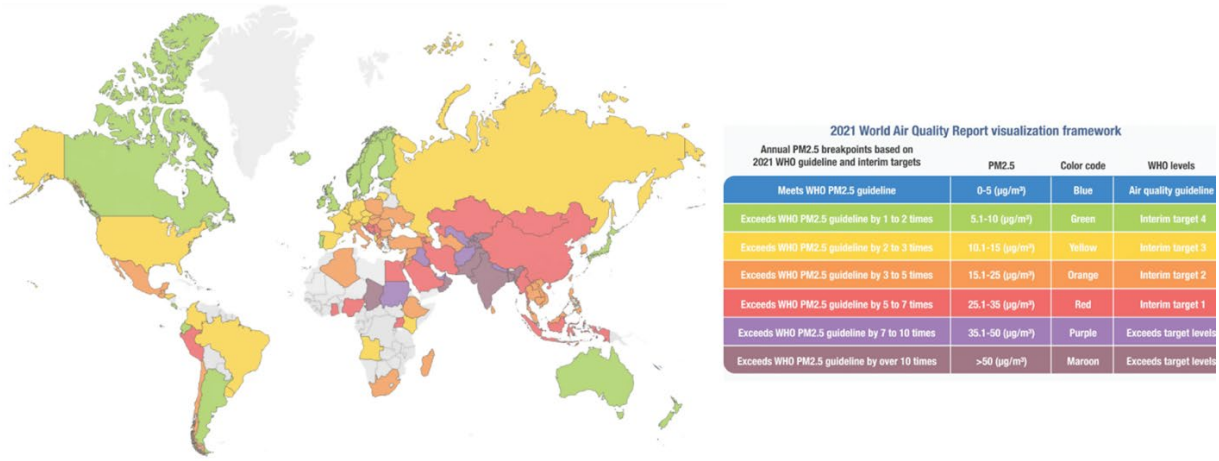

Figure 1. Countries that exceed WHO air quality guidelines.

Note: The map above, created by IQAir, displays PM2.5 measurements obtained by ground-level monitoring stations from 6,475 locations in 117 countries, territories, and regions. PM2.5 is particulate matter consisting of fine aerosol particles measuring 2.5 microns or smaller in diameter and is commonly accepted as the most harmful air pollutant to human health due to its prevalence in the environment and its broad range of health effects. The map uses colored bands to display the multiple by which countries exceed the WHO's air quality guidelines. For example, a country represented in blue meets air quality guidelines while a country represented in yellow exceeded the guideline by two to three times the recommended limit in 2021.

Further, air pollution affects the weather both where the pollution is created and, due to the interconnectedness of the environment, in places far from where the pollution begins. There is evidence linking air quality to weather events, specifically seasonal shifts, heat waves, and wildfires. It is possible that these weather events can be forecasted and combined with high-quality data on trends in air quality to create a window of opportunity for early action related to air pollution. Using this evidence, humanitarians have the opportunity to act in advance of seasonal shifts that would exacerbate air pollution and as soon as heat waves are forecasted, or wildfires become probable.

What we learned

How is air pollution forecasted?

Similar to forecasting weather, there are models to predict levels of air pollution and air quality. Air quality is predicted using local and distant pollutant concentrations and emissions, movements and possible transformations of pollutants, and prevailing winds. A combination of statistical methods, 3-D models, and climatology have been used to create pollution forecasting techniques that are continually improving in accuracy.[5]

What types of air pollution events should cause humanitarians to act?

Seasonal shifts

Warm, rising air near the ground can have the ability to lift pollution away, but in some seasons, a layer of warm air acts as a lid keeping cold air at the surface, creating a phenomenon known as thermal inversion whereby warm air traps pollution close to the ground.[6] Studies have shown thermal inversions peak in winter, and the lowest levels of particulate matter are found in transitional seasons (spring and fall).[7] Thermal inversions are more common above cities where cold, dense air gets trapped in mountain basins or valleys.

For example, in Mexico City, one of the world's largest megacities, thermal inversions have been a major environmental concern. They have been recognized and attributed to air pollution since the 1980s. The Mexican government and citizens of Mexico City have responded by improving fuel sources, increasing the frequency of vehicle inspections, implementing "no driving day" (a rule that takes private vehicles out of circulation for one day a week), and incentivizing fleet turnover by exempting low-emitting vehicles from "no driving day." As a result of these regulatory actions combined with technology advances, air pollution in Mexico City has been decreasing over the past decade despite continued increase in population and economic activity.[8]

Heat waves and wildfires

High levels of ozone often occur during heat waves because sunlight and high temperatures tend to accelerate reactions between organic compounds and nitrogen oxides, two of the six air pollutants consistently measured by WHO due to their impact on human health. It is estimated that climate change may increase summer ozone levels, creating an additional public health concern.[9]

While heat waves have their own negative impacts on human health, when they are coupled with decreased rain, the risk of wildfires increases. Wildfires are the most common natural source of air pollutants.[10] For example, the summer of 2021 record-breaking heat in southern Europe and central Russia generated immense wildfires. Countries from Spain to Türkiye were affected. At one point, the citizens of Athens, Greece were told to remain indoors due to health concerns related to high levels of air pollutants.[11]

The impact of an increase in heat, wildfires, and/or air pollution stretch beyond human health to affect food supply chains, infrastructure, businesses, and more. See Figure 2.

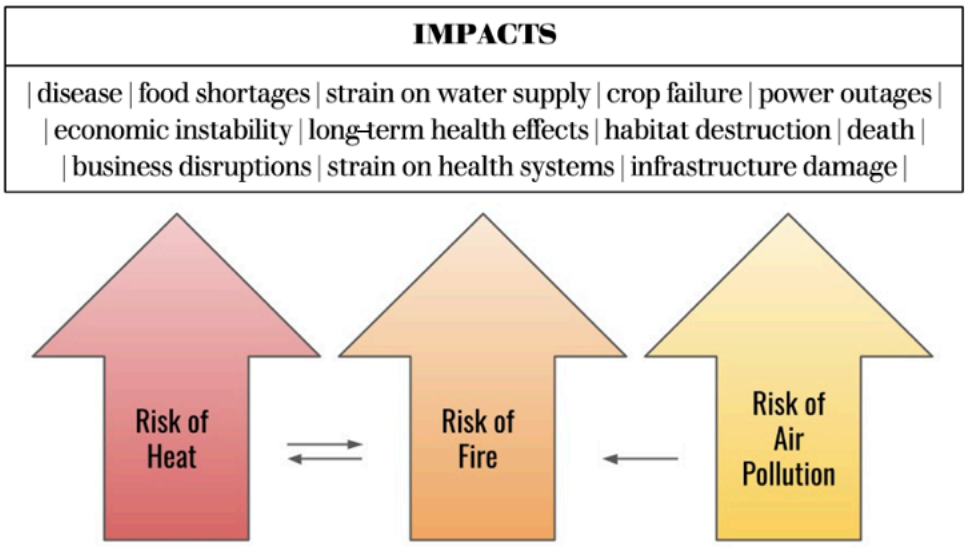

Figure 2. The interaction between risks of heat, wildfires, and air pollution and the impacts these disasters have on society.

What early actions could humanitarians take for air pollution?

As we learn more about the relationship between air pollution, health, and weather, it is important to consider, at least in the context of humanitarian assistance, what effective actions beyond advocacy and awareness could make sense to protect vulnerable populations. Table 1 below outlines recommendations and barriers for potential anticipatory response to predicted periods of poor air quality. Some of these actions can be taken to protect vulnerable individuals at the onset of anticipated or forecasted periods of exceedingly poor air quality. Other actions can be taken in the long term around the world. These are critical because we know that if we can decrease pollution levels in one country, that decrease can cause improved weather on another continent.[12]

Table 1: Potential early actions that could be facilitated by humanitarians when periods of high levels of air pollution are forecasted

Action	Barriers	Implementation level
Campaign for limited car use	Access to other methods of transportation	Municipality
Provide low- or no-cost public transportation options	Budget constraints, capacity to service increased users	Municipality
Invest in advocacy and awareness campaigns	Social acceptance and implementation of campaign suggestions	Regional
Improve access to personal protection equipment (PPE) such as face masks	Knowledge of how and when to use PPE, distribution constraints, funding	National

Advocate for staying indoors during periods of high pollution	Willingness and ability to remain indoors	National
Provide cash assistance for those who rely on outdoor work to compensate for missed work	Funding, ensuring these individuals remain employed despite missing work	Regional
Provide clean air spaces: accessible indoor spaces that are cool enough for windows and doors to be sealed off	Space acquisition, available air purification equipment, budget	Municipality

Where else should efforts be focused?

The most basic solution to air pollution is to replace fossil fuels with alternative energy sources, such as solar, wind, or geothermal. These actions require high initial capital and influence over social and regulatory barriers.[13] However, investment in advocacy and awareness campaigns can help individuals gain the knowledge they need to protect themselves from poor air quality. For example, people can protect themselves if they have access to personal protection equipment (PPE) such as face masks and know when and how to utilize this equipment. Investment in air quality tracking and monitoring and improved accessibility of this information to the public can aid in awareness raising. Investment in research can help to identify clear pathways of assistance for those who are vulnerable to poor air quality.

According to the U.S. Environmental Protection Agency (EPA), the value of clean air far exceeds the costs of reducing pollution. In a retrospective study evaluating clean air legislation, the EPA found that a $65 billion investment in air pollution regulation and technology resulted in roughly $2 trillion worth of benefits, exceeding the cost factor by 30 to 1 while improving health outcomes and preventing pollution-related death.[14]

Is there a precedent humanitarians can learn from?

In September 2020, the Ecuadorian Red Cross activated its Early Action Protocol for volcanic ash in response to an anticipated increase in eruptive activity of the Sangay volcano.[15] Volcanic ash is an irritant to eyes and lungs and has the potential to contaminate water supplies and lead to crop failure, making it a public health concern.[16] Some early actions taken in the case of the Sangay volcano include the distribution of health, livelihood, and household protection kits as well as cash-based assistance. Additionally, action was taken to provide safe water sources and to support livelihoods reliant on agricultural production.[15]

Air pollution has similar attributes to volcanic ash but is not yet included as a trigger in any early action protocol, despite the precedent that airborne particles call for early action. This precedent, combined with the disproportionate effect that air pollution has on the global south and the ability to forecast for circumstances in which particulate matter may be increased, means there is sufficient rationale for including air pollution in early action protocols. Air pollution should be considered a humanitarian priority.

References

1. World Health Organization (WHO). n.d. Air pollution. WHO website. https://www.who.int/health-topics/air-pollution (accessed August 15, 2022).

2. Ritchie, H., and M. Roser. 2017 (April 17). Air pollution. Our world in data. https://ourworldindata.org/air-pollution (accessed March 26, 2022).

3. WHO. n.d. Modelled exposure of PM air pollution exposure. WHO website. https://www.who.int/data/gho/data/themes/air-pollution/modelled-exposure-of-pm-air-pollution-exposure (accessed May 28, 2022).

4. Nakao, M., K. Yamauchi, Y. Ishihara, H. Omori, D. Ichinnorov, and B. Solongo. 2017. Effects of air pollution and seasons on health-related quality of life of Mongolian adults living in Ulaanbaatar: Cross-sectional studies. *BMC Public Health* 17 (1): 594. doi:10.1186/s12889-017-4507-1.

5. IQAir. 2022. Can air pollution be predicted? IQAir website. https://www.iqair.com/blog/air-quality/can-air-pollution-be-predicted (accessed September 9, 2022).

6. Bodor, Z., K. Bodor, Á. Keresztesi, and R. Szép. 2020. Major air pollutants seasonal variation analysis and long-range transport of PM10 in an urban environment with specific climate condition in Transylvania (Romania). *Environmental Science and Pollution Research* 27 (30): 38181–38199. doi:10.1007/s11356-020-09838-2.

7. Chen, R., R. D. Peng, X. Meng, Z. Zhou, B. Chen, and H. Kan. 2013. Seasonal variation in the acute effect of particulate air pollution on mortality in the China Air Pollution and Health Effects Study (CAPES). *Science of The Total Environment* 450–451:259–265.

8. World Meteorological Organization. 2009. Air quality, weather and climate in Mexico City. https://public.wmo.int/en/bulletin/air-quality-weather-and-climate-mexico-city (accessed September 7, 2022).

9. Vicedo-Cabrera, A. M., N. Scovronick, F. Sera et al. 2021. The burden of heat-related mortality attributable to recent human-induced climate change. *Nature Climate Change* 11 (6): 492–500. doi:10.1038/s41558-021-01058-x.

10. van Donkelaar, A., R. V. Martin, M. Brauer et al. 2016. Global estimates of fine particulate matter using a combined geophysical-statistical method with information from satellites, models, and monitors. *Environmental Science & Technology* 50 (7): 3762–3772. doi:10.1021/acs.est.5b05833.

11. European Environment Agency. (2022, June 15). Air pollution: How it affects our health. https://www.eea.europa.eu/themes/air/health-impacts-of-air-pollution (accessed August 2, 2022).

12. ScienceDaily. (2017, May 23). Reduced US air pollution will boost rainfall in Africa's Sahel, says study: New research highlights wider benefits of clean air policies. https://www.sciencedaily.com/releases/2017/05/170523081632.htm (accessed March 26, 2022).

13. Seetharaman, M. K., N. Patwa, Saravanan, and Y. Gupta. 2019. Breaking barriers in deployment of renewable energy. *Heliyon* 5 (1): e01166. doi:10.1016/j.heliyon.2019.e01166.

14. United States Environmental Protection Agency (U.S. EPA). 2015 (July 10). Clean Air Act overview. Benefits and costs of the Clean Air Act 1990-2020. Report documents and graphics. https://www.epa.gov/clean-air-act-overview/benefits-and-costs-clean-air-act-1990-2020-report-documents-and-graphics (accessed June 8, 2022).

15. ReliefWeb. (2021, March 16). Ecuador: Volcanic ashfall early action final report on early action phase (EAP2019EC01). https://reliefweb.int/report/ecuador/ecuador-volcanic-ashfall-early-action-final-report-early-action-phase-eap2019ec01 (accessed June 8, 2022).

16. National Weather Service. n.d. Volcanic ash and ashfall. https://www.weather.gov/safety/airquality-volcanic-ash (accessed June 8, 2022).

About the Academic Alliance for Anticipatory Action (4As)

The 4As is a consortium of researchers from seven universities working to increase the knowledge base on anticipatory action. 4As is led by Tufts University in the U.S., partnering with Bangladesh University of Engineering and Technology, Eduardo Mondlane University in Mozambique, Makerere University in Uganda, University of Namibia, National University of Lesotho, and University of the Philippines.

This publication was made possible through support provided by the Office of Acquisition and Assistance, Bureau for Management, United States Agency for International Development (USAID), under the terms of Cooperative Agreement No. 720BHA21CA00044. The opinions expressed herein are those of the authors and do not necessarily reflect the views of USAID.