

India's vital efforts to tackle air pollution could worsen warming

Aerosols in the atmosphere scatter sunlight and have a cooling effect — yet they also exact a heavy toll on human well-being

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Thermal power plants generate roughly 70% of India's electricity by burning coal, which also releases some sulphur that can go on to form highly reflective sulphate aerosols. | Photo Credit: Altaf Qadri

Rapidly reducing aerosol emissions, which are part of air pollution, without concurrently reducing greenhouse gas emissions could expose a large fraction of the world's most vulnerable people to a sudden acceleration of warming and extreme heat in highly polluted regions like India. Researchers warned as much in a **study** published in November 2024 in *Geophysical Research Letters*.

The analysis found regions that cleaned their air in the late 20th century have experienced a greater increase in warming trends over time while more populated urban areas with low human development indices have experienced lower levels of warming — due to the masking effect of pollution.

According to Aditya Sengupta, a graduate researcher at the University of Melbourne and first author of the study, abruptly halting the emission of aerosols can also increase the rate of warming on shorter time scales.

The study is particularly relevant for India, which is currently struggling to improve air quality on one hand while trying to stave off the worst of climate change on the other.

Greenhouse gases v. aerosols

Global warming is caused by the build-up of greenhouse gases in the atmosphere, and has been known to intensify temperature and rainfall extremes. Aerosols can counteract the impact of greenhouse gases to some extent.

This is because, while greenhouse gases trap heat and warm the earth's surface, aerosols such as sulphates and nitrates scatter solar radiation, preventing it from reaching the ground and rendering a cooling effect. Aerosols also affect the water cycle.

Greenhouse gases are also well mixed in the atmosphere. As a result, their effects, including knock-on ones on the climate, can be felt around the planet. On the other hand the concentration of aerosols in the atmosphere varies by location and time. Greenhouse gases are also more long-lived — carbon dioxide can persist in the atmosphere without breaking down for centuries — whereas aerosols live for a few days to weeks at a time.

The consequences of changes in the atmosphere's aerosol load can thus be felt almost immediately.

Thermal power

According to Govindasamy Bala, professor at the Centre for Atmospheric and Oceanic Sciences at the Indian Institute of Science, Bengaluru, growing economies and industrialisation go hand in hand with aerosol and fossil-fuel emissions.

In India, thermal power plants generate roughly 70% of the country's electricity by burning coal, which contains some amount of sulphur. "So before the flue gas [exhaust gas from the combustion process] is released to the atmosphere, you have to take out sulphur dioxide at the source to reduce air pollution," Bala explained.

Sulphate aerosols, which form through the oxidation of sulphur dioxide, are highly reflective and make up nearly 50-60% of the overall aerosol composition in India, in addition to black carbon, dust, and other pollutants, according to Bala.

Invisible offset

"[O]ur numbers show, if it were not for aerosols, we would experience much greater warming over India," Krishna AchutaRao, dean and professor at the Centre for Atmospheric Sciences, IIT-Delhi, said.

According to him, India warmed by about 0.54° C between 1906 and 2005, with the estimated warming due to greenhouse gases being about 2° C and the cooling offset from other anthropogenic factors about 1.5° C. While most of the cooling is likely from aerosols released by human industrial activity, some cooling is also likely from irrigation, AchutaRao added.

According to the first-ever **assessment of climate change over India** published by the Ministry of Earth Sciences in 2020, the country's average temperature rose by around 0.7° C between 1901 and 2018, largely due to greenhouse gas-induced warming, but was partially offset by anthropogenic aerosols and changes in land use.

To compare, overall long-term global warming is currently about 1.3° C above pre-industrial times.

Aerosols and rain

Aerosols' effects on rainfall are another matter: "In general, the temperature effect is fairly straightforward: remove aerosols, and it gets warmer," AchutaRao said. "With precipitation, things are further complicated."

According to Bala, the global mean cooling is about 0.6° C in the industrial period due to

aerosols. But he said citing a recent Intergovernmental Panel of Climate Change (IPCC) report that “this cooling is unevenly distributed — in the northern hemisphere, it is 0.9° and in the southern hemisphere it is about 0.3° C. Because of this larger cooling in the northern hemisphere, the actual aerosol effect is a slight reduction in Indian monsoon rainfall.”

Many people would like to understand what aerosols emitted by India are doing to India, but the remote effects of aerosols are also important to consider, he added. For example, a **May 2024 study** published in *Proceedings of the National Academy of Sciences* reported that when China cut its aerosol emissions, extreme heat wave events in the Pacific Ocean, along the west coast of North America, got worse.

Likewise, according to Bala's ongoing research, any substantial increase in aerosols over India could negatively affect the hydrological cycle and reduce the amount of monsoon rainfall. Understanding this process is an active area of study worldwide.

Net-zero not the end

Both aerosol pollution and greenhouse gas-related climate pollution are mainly due to large-scale industrial activity. While greenhouse gas-induced warming can increase the risk of extreme heat, aerosols can lead to respiratory ailments, creating a compounding effect on vulnerable populations, Sengupta said.

The study has found that cutting both will also require policies to support already at-risk populations that will be affected by the sudden rise in warming in the short term.

“Achieving net-zero carbon emissions would not be the end of the story, and policymakers should focus on long-term adaptation policies for the vulnerable parts of India, particularly people residing in the Indo-Gangetic plains, where the highest aerosol loading is found,” Sengupta added.

But because aerosol distribution is highly regional, it's hard to exactly predict how specific places in India will be affected when (and if) we clean up aerosols, AchutaRao said.

Experts suggested the surest step would be to develop better heat action plans. Delhi-based research organisation Sustainable Futures Collaborative **recently reported** that few

of the heat action plans of nine cities — Delhi, Mumbai, Bengaluru, Faridabad, Gwalior, Kota, Ludhiana, Meerut, and Surat — included long-term action and that even those were poorly targeted. If and when aerosols are removed from the atmosphere, the heat stress in these cities could worsen.

“While cleaning the air might accelerate ongoing warming by unmasking the greenhouse gas-induced warming, it could be beneficial in terms of increased rainfall over India. These trade-offs should be considered when assessing the effects of aerosols on our complex climate system,” Bala added.

This said, all the experts agreed the immediate benefits to human health from reducing air pollution far outweighed any adverse consequences due to higher heat or disrupted rainfall.

Neelima Vallangi is an independent journalist and filmmaker covering climate change in the Himalayan region and South Asia.

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