Extreme nighttime pollution in New Delhi air explained by new study

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In a major joint project with top Indian scientists, PSI researchers have determined why smog forms at night in the Indian capital New Delhi, contrary to all the rules of atmospheric chemistry. Their results have now

been published in the journal *Nature Geoscience*.

For the past three years, New Delhi has been ranked the world's most polluted capital. Its high levels of air pollution are responsible for a large number of premature deaths. In winter, the particulate matter levels exceed 500 micrograms per cubic meter of air. To get some idea of this magnitude, compare this value with the Chinese capital Beijing. In that smog-plagued metropolis, one cubic meter of air contains "only" 70 micrograms of particulates; whereas in Zurich the figure is just 10 micrograms per cubic meter.

Where do these extremely high particulate levels come from in nighttime New Delhi in winter? A team of researchers from the Laboratory for Atmospheric Chemistry at PSI has been investigating this question together with local scientists, including members of the Indian Institute of Technology Kanpur.

They found an extraordinary explanation. "The chemical processes that take place in the air at night are unique to the Indian capital and have not been observed anywhere else in the world," says Imad El-Haddad, an atmospheric chemist at PSI and one of the corresponding authors of the study. In their study, the team found that the trigger for the high levels of particulate matter is the fumes emitted when wood is burnt.

Wood burning is common practice for around 400 million people living in the Indo-Gangetic Plain, who use wood for cooking and heating. In the absence of strict regulations, materials other than wood are also burnt, sometimes including plastic and other waste materials.

Harmful mixture of gases

Such fires produce a mixture of gases containing countless chemical compounds, such as cresol, which our noses associate with the typical

smell of fire, as well as sugar-like molecules from the burnt cellulose in the wood. These molecules cannot be seen in the air with the naked eye, even in high concentrations. However, as night falls the temperature in New Delhi drops so rapidly that some of the gas molecules condense and within a few hours clump together to form particles up to 200 nanometers across, which can be seen as a gray haze.

"Condensation from gas to particulate phase resembles the way in which water droplets form on kitchen surfaces when one is cooking. Particles in the atmosphere act as large surfaces on which gases can condense," says Lubna Dada an atmospheric scientist at PSI and one of the authors of the study.

This process is very different from that in other places. Beijing, for example, is probably the best-studied megacity in the world in terms of its air pollution. However, in the atmosphere of the Chinese capital, particle formation follow different chemical pathways. In China, the gases from emissions such as traffic and wood burning react in the atmosphere during the day when they are exposed to light resulting in the formation of less volatile fumes capable of forming particles during the haze.

Such a pathway was also expected in New Delhi, however the opposite happens. Haze formation from the condensation of directly emitted fumes occurs at night, without photooxidation, driven by increased emissions together with a sharp decrease in temperatures. "We have shown for the first time that semi-volatile gases can form such particles at night, contributing to the haze," adds Imad El Haddad.

Where does the smog come from?

The measurements were carried out in January and February 2019. For this purpose, the researchers from India, Sweden and Switzerland set up

a station in the center of New Delhi with measuring equipment that included instruments to determine the number and size of the particles, as well as their chemical composition.

The mass spectrometers deployed are very sensitive and can detect thousands of different molecules in the air of New Delhi, whereby the particle concentrations sometimes reached hundreds of thousands of particles within the volume of air corresponding to a sugar cube. Some of the instruments came from PSI, others from partners such as the Indian Institute of Technology Kanpur and the University of Stockholm.

A second measuring station was also set up in the city with scaled-down equipment to verify that the formation of particulates is indeed a regional phenomenon. Switzerland's contribution was financed by the Swiss Agency for Development and Cooperation.

It took four years of data analysis and peer review before the results were ready to be published in *Nature Geoscience*. During this time, four groups from the Laboratory of Atmospheric Chemistry at PSI, each with a particular area of expertise, led by Imad El Haddad, André Prévôt, Claudia Mohr and Kaspar Dällenbach contributed to bringing everything together.

"More extensive measurements are currently being carried out, collecting samples at ten locations for a full year, five of them in New Delhi itself and five others in the surrounding region, which will later be analyzed at our lab," says André Prévôt, the principal investigator of the study. Long-term changes in air quality at different locations allow conclusions to be drawn about the wider sources of air pollution.

"My dream is to drive around the streets of India with our mobile laboratory to characterize local sources of pollution that are caused by different kinds of solid fuel burning, industrial and other emissions, at a

very high spatial resolution," adds Prévôt.

Awareness of the severity of air pollution in India has certainly increased and an ambitious Clean Air Program has been initiated. "In this project, financed by the Swiss Agency for Development and Cooperation, PSI scientists have teamed up with local researchers sharing their knowledge with one another to identify the sources of pollution. However, there is still a long way to go to improve the air quality, because that entails social changes and general public awareness," El Haddad concludes.

More information: Suneeti Mishra et al, Rapid night-time nanoparticle growth in Delhi driven by biomass-burning emissions, *Nature Geoscience* (2023). DOI: 10.1038/s41561-023-01138-x

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