Editorial

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Night-time clues to pollution

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Night-time chemistry has an important contribution to air pollution over China and India. Understanding the chemical evolution of pollution in the atmosphere at night is needed for effective solutions to improve air quality.

Air pollution in China and India together caused about 4.5 million deaths in 2019[1]. In the wake of some of the deadliest pollution events, China and India launched their first country-level clean air plans in 2013 and 2019, respectively. Ten years on, despite greatly improved national air quality levels, China is now finding further air pollution reductions challenging due to the trade-off between controlling $PM_{2.5}$ – inhalable particulate matter with a diameter of less than 2.5 micrometres – and ozone pollution[2], two pollutants with great health impacts. The situation in India is more concerning. The country's air quality continued to worsen after the launch of its clean air program, with a growing number of cities suffering from deadly smoke[3]. Previous research aimed at identifying pollution sources and understanding pollution chemistry is mostly about what happens during the day. In this issue, two Articles shed light on the dark side of air pollution and highlight the necessity of fully considering night-time atmospheric chemistry in efforts to tackle the air pollution challenges.

With emptier streets and quieter factories, air quality at night is easily perceived as being better than during the day. However, air quality is often at its worst in the early evening hours, with $PM_{2.5}$ levels peaking between 21:00 and 23:00 globally[4]. Unfavourable meteorological conditions are an important contributor. As the sun sets, the land surface cools, which in turn cools the overlying air. This leads to the formation of a stable atmosphere layer that suppresses vertical mixing and inhibits pollutant dispersion.

Chemistry is also at play. Chemistry of air pollution during the day and night is very different. Photochemistry – chemical reactions

facilitated by solar radiation – is the dominant pathway for the production of deadly ozone and $PM_{2.5}$ during the day, whereas radical chemistry takes over when the sun goes down. Among all the radicals, nitrate radicals produced by nitrogen oxides and ozone are especially important[5], as they are heavily involved in night-time atmospheric chemistry and greatly affect the composition of the atmosphere for air pollution the next day. An Article by Lu and co-authors report that between 2014 and 2019, the production rate of nitrate radicals in regions across China increased. This suggests the increasing contribution of night-time chemistry to China's air pollution.

In India, night-time atmospheric chemistry can set the conditions for severe wintertime haze events. An Article by Tripathi and co-authors examines the evolution of physical and chemical properties of new particles formed during winter haze events in Delhi. The authors find that driven by the physical condensation of fresh organic vapours from biomass burning, nanoparticles formed and grew rapidly at night, with sizes growing quickly into those relevant to the haze formation.

The rapid development of new particles and their contribution to severe haze pollution have also been observed in other cities, such as Beijing. What makes these events in Delhi unique is that they happened at night without photochemistry – it turns out that the nanoparticle growth rates reported in Tripathi et al. are even times higher than those observed during similar events in Beijing that normally happen during the day. The key difference appears to be that the emissions derive from biomass burning in Delhi, whereas the daytime growth of nanoparticles in other cities is instead driven by secondary aerosols formed from a mix of pollution sources[6]. The severe haze events triggered by night-time pollution chemistry highlights the urgent need of reducing emissions from biomass burning to improve air quality in India.

Night-time air pollution may hold clues to addressing some of the big challenges in pollution control. For example, nitrogen radical chemistry that dominates at night, is involved in the combustion and generation of $PM_{2.5}$ and ozone as well as their associated primary precursors, and feeds back into daytime atmospheric chemistry. Developing a framework that simulates the chemistry of nitrate radicals at night may help to find clues to mitigating the trade-off between $PM_{2.5}$ and ozone. However, night-time air pollution is currently much less understood than pollution in the day. Developing our understanding of night-time air pollution across the world is essential to get a better picture of air pollution and act to improve air quality.

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