AIR POLLUTION

Clearing smog's particulate problem

Chloride-rich particulate matter has been identified as a major contributor to air-quality deterioration in cities across India. Identification and reduction of chloride emissions could therefore improve visibility and human health across the region.

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Most of Northern India experiences poor air quality during the winter. Dense smog over the capital, Delhi, negatively affects the lives of millions[1,2] and causes transport and other disruptions, which result in heavy economic losses[3]. Particulate matter is recognized as a major contributing pollutant, and over the last decade understanding of its sources, seasonal variability[1], chemical composition, and interaction with meteorology has improved[2,4,5]. But some important questions remained unanswered. For example, it is unclear what precise role particulate matter plays in visibility reduction given that Delhi experiences far greater visibility reduction than other polluted cities in Asia. Writing in *Nature Geoscience*, Gunthe et al.[6] reveal that locally emitted hydrochloric acid from plastic-contained waste burning and industrial sources accounts for some 50% of the visibility reduction over the Indian capital under suitable meteorological conditions.

Air pollution results from complex chemical and physical interactions between atmospheric gases and aerosols that have reached harmful levels in the air. It is a global problem that has regional variations. The World Health Organization estimates that exposure to particulate matter of less than 2.5 micrometres in diameter led to the premature deaths of 4.2 million people in 2016[7]. As well as devastating health impacts, air pollution negatively impacts economies due to the costs of care, lost work hours, and disruption of services during low-visibility smog events. Unfortunately, the regional differences are stark: low- and middle-income countries account for more than 90% of the estimated premature deaths[7]. Furthermore, there are also local differences in the type and source of pollutants as well as their chemical and physical interactions. The pollution that can swamp Delhi (Fig. 1) is different from that of Beijing or the Great Smog of 1950s London. Only by understanding the regional differences can targeted and effective mitigation policies be put in place.

Fig. 1 | India Gate shrouded in smog during winter 2019. Dense smog over Delhi has negatively impacted the lives of millions and been a major reason for travel and other disruptions, causing heavy economic losses. Gunthe et al.[6] show that it is the emission of hydrochloric acid gas from industry and plastic-contained waste burning in Delhi that is responsible for nearly half of the reduced visibility experienced in India's capital during air-pollution events. Credit: Ruhani Kaur/Bloomberg via Getty Images

Particulate matter is composed of organic and inorganic matter. It can come directly from primary sources or it can form via complex processes where volatile organic compounds are converted into particulate matter. The chemical composition of the particulate matter plays an important role in determining its ability to take up water, a crucial step that causes the growth of the particles and ultimately the formation of haze and smog. As a general rule, high organic content reduces the ability of particulate matter to take up water, which reduces the likelihood of smog formation[8]. Cities such as Beijing, which suffer with poor air quality, seem to follow this rule, with only half of the particulate matter being organic and the rest an inorganic portion dominated by sulfate. But this made Delhi a bit of a mystery because incredibly dense smog forms in the city even when the overall particulate mass burden is lower than Beijing and more than 65% organic[9], which should limit the uptake of water and therefore smog formation. These findings in Delhi of smog-forming particulate matter that is counter-intuitively dominated by organic components have puzzled the atmospheric science community.

Gunthe and colleagues measure particulate matter in Delhi and Chennai, another city in India that is comparatively cleaner than Delhi, and combine these measurements with thermodynamic modelling to better understand the sources of particulate matter. In particular, they seek to explain the importance of recent observations of high particulate chloride in Delhi[8]. They find that unlike Beijing, which is dominated by large-scale industries and

fossil fuel combustion, Delhi experiences direct emission of atmospheric hydrochloric acid (HCl) from small-scale industries such as metal-, e-waste-, and plastic-processing as well as biomass- and plastic-contained waste burning. This HCl then reacts with excess ammonia in the atmosphere to form particulate ammonium chloride (NH_4Cl), which explains the high particulate chloride in Delhi's air. In addition, HCl gas also partitions into the aqueous particle phase. Thus, gas-to-particle-phase partitioning of HCl and NH_4Cl and co-condensation exponentially increase the ability of the aerosol particles to take up water. Therefore, under the favourably low-temperature and high-relative-humidity conditions of Delhi's winter, the particles have enhanced ability to take up water and grow, which ultimately leads to smog formation. Importantly, in the absence of HCl the same particles would not take up as much water or grow so large, lessening the chances of smog formation.

In order to create the science-backed policies that are so badly needed to systematically deal with air pollution in India and elsewhere, Gunthe and colleagues have shown that we must enhance our understanding of the chemical characteristics and complexity of particulate matter. This will allow high-resolution air-quality models to consider speciated emissions based on chemical compositions for a given environment. But those models must be informed by composition-based parameterization and long-term measurements of particulate matter and other pollutants.

Gunthe et al. have shown that the direct emissions of gas-phase hydrochloric acid from industry and plastic-contained waste burning is responsible for nearly half of the reduced visibility experienced by Delhi during air-pollution events. Although air pollution is a global problem, we need specific local knowledge to fight it. ❐

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Competing interests

The author declares no competing interests.