Fireworks, megacities and particulate pollution

Megacities, cities with populations exceeding 10 million, are often plagued with pollution problems. Recently, there has been great concern about the role of particulates in urban smog and air pollution and their impact on human health. Professor Jianmin Chen at the Department of Environmental Science and Engineering at Fudan University has been identifying potential sources of the most dangerous types of fine particulate matter and showing which measures can be taken to reduce their polluting effects.

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Particulates and air pollution have been the subject of many recent news headlines. With recent studies showing that these microscopic particles can be found in every organ of the body at non-negligible concentrations, resulting in organic damage, the president of the World Health Organization (WHO) has described air pollution as the 'silent public health emergency.'

Over 90% of the world's population is exposed to levels of air pollution that exceed the WHO's recommended safe limits. Many of the world's most polluted cities are in India, with regions in China and Africa also being badly affected. Of the cities with the highest pollution levels, a large proportion are megacities, with populations exceeding 10 million, such as Delhi, Bombay and Shanghai.

Restriction on firework use had been an effective measure at removing one of the contributions to air pollution

Air pollution is often measured by looking at the concentrations of one microscopic particle, $PM_{2.5}$. $PM_{2.5}$ is a solid particle that takes its name from its tiny size – it measures 2.5 micrometres in aerodynamic diameter, making it nearly thirty times smaller than a single human hair.

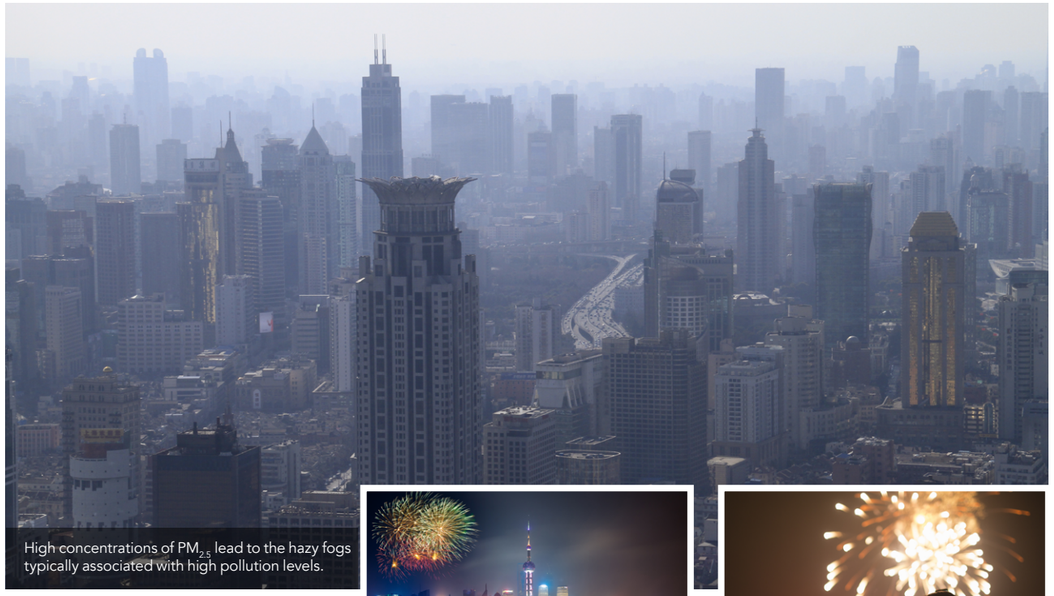
$PM_{2.5}$ levels are a good proxy for air quality as high concentrations of $PM_{2.5}$ is what leads to the hazy fogs typically associated with high pollution levels. What is more concerning about $PM_{2.5}$, however, is that its small size means it can easily be inhaled and pass into various tissues, like the heart and lungs, where it can wreak poorly understood levels of damage.

Professor Jianmin Chen, the Director of Shanghai Key Laboratory of Atmospheric Particulate Pollution Prevention, is an expert in tracking long-term $PM_{2.5}$ concentrations, though it is not an easy task. He uses a combination of analytical chemistry and spectroscopy techniques to detect not just $PM_{2.5}$ levels but also their chemical composition. Knowing what chemicals the $PM_{2.5}$ particles are made of is an important step in identifying their formation mechanisms and sources, and Professor Chen has been able to use this information to form a scientific basis for pollution control in Shanghai, China.

PARTICULATE PROBLEMS

Particulate matter, like $PM_{2.5}$, is composed of a mixture of solid particles and liquid droplets that can be found suspended in air. The mechanisms for particle formation are complex and very active areas of research, but typically larger particles, sometimes called coarse particles, are made from the breakup of big, solid lumps like dust, soil or what is released from unburnt material from fossil fuel consumption. Soot is an example of a coarse particulate.

Fine particles such as $PM_{2.5}$ are generally formed from gases. Fossil fuel consumption, such as burning petrol in cars, can still produce fine as well as coarse particles, but the production methods and composition of the particles are different. Fine particles arise from the condensation of materials that are vaporised during the combustion process and are usually made of sulfate, nitrate, ammonium and organic matter.



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High concentrations of $PM_{2.5}$ lead to the hazy fogs typically associated with high pollution levels.

What Professor Chen and his group at the Shanghai Key Laboratory have found is that, when it comes to working out the potential health impact of air pollution from $PM_{2.5}$, knowing the chemical composition is as important as the particle size. Around the area they studied in Shanghai between 2013 and 2017, they found that some of the elements the $PM_{2.5}$ particles were composed of were a little unusual.

Apart from the usual particulate substances, such as polyaromatic hydrocarbons, that come from combustion processes, nitrate, sulfate and ammonium ions, Professor Chen and his group were finding particularly high levels of potassium ions.

SEASONAL SMOG

Shanghai often experiences its worst haze episodes during the winter season, where changes in the weather result in increased concentration of aerosols, allowing for more particulate forming events. What Professor Chen noticed though was, alongside the extreme haze events in winter, there were also many 'explosive growth' events occurring not just in winter, but in early spring as well.

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Fireworks are a major part of the Chinese Spring Festival celebrations.

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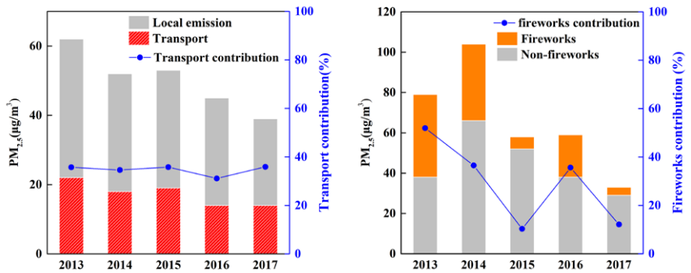
Fireworks were contributing to increases in poor air quality.

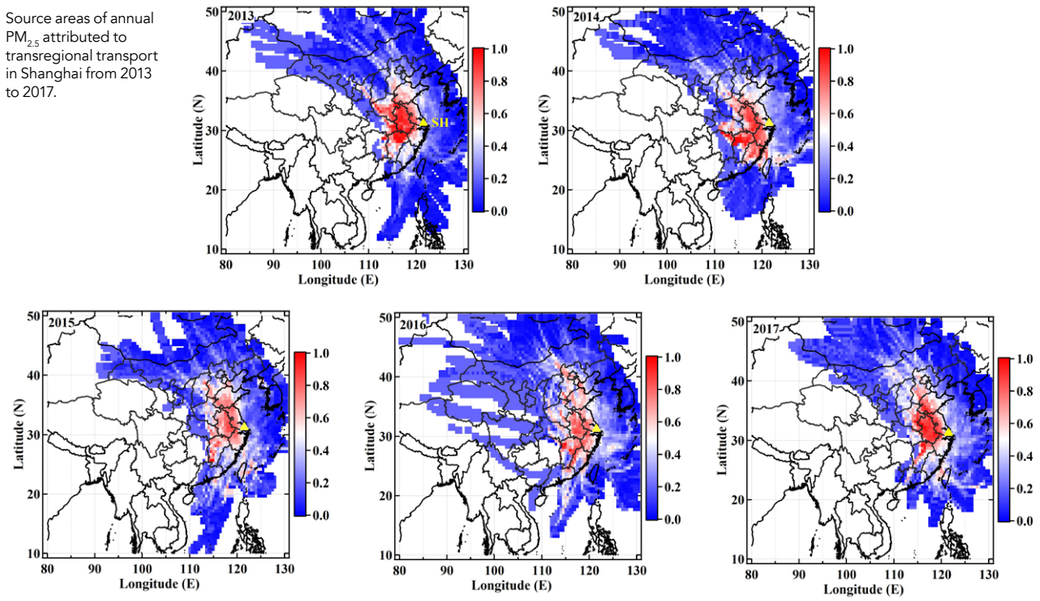
An explosive growth event is where the $PM_{2.5}$ concentration increases rapidly (by more than 100 μgm^{-3} in three hours) over a sustained period of nine hours. Explosive growth events can be triggered by a variety of sources, such as stagnant wind conditions which give higher local particulate concentrations, fuelling further particulate growth. However, the high potassium ion concentrations in the $PM_{2.5}$ being tested suggested another factor was at play.

Early spring in China is a time for the Spring Festival. Firework displays are a traditional way to celebrate the major event. However, fireworks can have a harmful impact on the environment and human health. As a result, policies on fireworks management have been implemented to improve air quality. Since 2008, the central areas of most



The contributions to $PM_{2.5}$ levels from transport pollutants going up (left) and firework displays going down (right).

Source areas of annual $PM_{2.5}$ attributed to transregional transport in Shanghai from 2013 to 2017.



Local emission (e.g. vehicles) is the dominant source causing extreme haze despite transregional transport contribution.

cities nationwide have restricted or totally banned the use and display of fireworks.

These fireworks were also the source of the potassium ions that Professor Chen and his team were detecting in their measurements. Elements such as strontium and potassium are used in fireworks to give them their brilliant colours when they burn but were also contributing to explosive growth events of $PM_{2.5}$.

Over the period of the study, from 2013 to 2017, Professor Chen saw continually decreasing levels of potassium ions, used as a proxy for the number of fireworks, over the years. On the main day of the Festival in 2013, fireworks contributed 51.9% to the overall $PM_{2.5}$ production of the day but by 2017, this was as low as 4.5%, showing that the restriction on firework use had been an effective measure at removing one of the contributors to air pollution.

Professor Chen's work focused on air quality in megacities like Shanghai.

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POLLUTION SOURCES

Professor Chen has found that one of the main contributors to air pollution in Shanghai is from transregional transport, particularly in terms of nitrate and sulfate production in $PM_{2.5}$. Elevated transport use during the winter period is also part of what contributes to the worsening hazes in that season. Given that he estimates that 5.3–8.2‰ of deaths in Shanghai between 2013 to 2017 can be directly attributed to the production of $PM_{2.5}$ specifically from transregional transportation sources alone, this represents a significant and urgent health issue.

While awareness of the health impact of particulates and air pollution is growing, there is still a great deal of work to tackle different sources of increased $PM_{2.5}$ production, particularly in megacities such as Shanghai where large amounts of transportation contribute significantly to particulate production. However, as has been shown in the case of firework restrictions, policies can have a relatively immediate effect on pollution levels, and ultimately human health.

Behind the Research

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Research Objectives

Professor Chen's work explores the mechanism of extreme haze episodes caused by particulate matter in Shanghai.

Detail

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Bio

Professor Jianmin Chen is the Director of Shanghai Key Laboratory of Atmospheric Particulate Pollution Prevention. He is specialized in atmospheric chemistry and air pollution control. His publications include over 240 papers which have attracted over 7100 citations and led to an H-index of 44 according to the Web of Science.

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Personal Response

What other pollution sources do you think will be most effective to target to reduce $PM_{2.5}$ concentrations?

" Industrial or residential coal combustion, vehicles emissions, dust and open field or household biomass burning are the main pollution sources which should be targeted to reduce $PM_{2}5$ concentrations. Rural areas account for 94% of the total land area of China. In rural areas, burning wood and coal is the traditional method of cooking and heating, and the heating season in North China usually starts in November and ends in March. Burning crop residues has been strictly controlled in the past few years and air quality improved during harvest season, which proved that controlling biomass burning was an effective way to reduce $PM_{2.5}$. "