

Taking care of the air

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Andy Extance discovers how urban air pollution monitoring is changing to protect our health

When Prashant Kumar found out an invisible enemy was harming him, he didn't start questioning his sanity – he made a career out of fighting that foe. Studying at the Indian Institute of Technology Delhi, he learned there were grains of 'particulate material' floating in the air around him, too tiny to see. 'At that time I was not very aware that these things you can't see can have a huge impact on your health,' says Prashant. He now runs the Global Centre for Clean Air Research at the University of Surrey in Guildford, UK.

While the threat remains largely invisible, pollution's effects in Delhi have become ever more obvious. On 5 December, 2017, the city's pollution caused players to vomit during a cricket match between India and Sri Lanka, stopping play. In winter, Delhi's problem is literally a burning issue. Outside the city, farmers burn waste straw. Inside, people burn wood and cow dung to keep warm and cook. And of course, more fossil fuel-burning cars are polluting the air year round, as they are everywhere in the world.

In the UK too, air pollution has become a big issue, with London often breaking legal limits set by England's Air Quality Standards Regulations 2010. In April 2017, a group of MPs from different parties called UK air pollution a 'public health emergency'. The European Environment Agency estimates that air pollution is responsible for more than 400,000 premature deaths annually in Europe. How could this happen? Have those we entrust with our health overlooked chemicals in the air around us?

Priorities up in the air

Over recent decades, there has been a steady shift in which pollutants are in the air, and which ones we pay attention to, Prashant explains. 'If you look back there was a time when sulfur dioxide was a big issue, from burning sulfur-containing coal,' Prashant underlines. As well as dissolving to create acid rain that can damage trees and buildings, sulfur dioxide reacts to help create smog. In the early 1950s a five-day Great Smog was directly linked to the deaths of over 4000 Londoners. Driven by this, the UK passed the Clean Air Act in 1956, tackling smoke and sulfur dioxide, from which point the country's air pollution has diminished.

Since then, as sulfur dioxide levels fell, other pollutant foes have become more obvious. One key type is particulate matter, or PM, usually written with a number indicating the particles' size. PM₁₀ particles are below 10µm in diameter. PM_{2.5} are those below 2.5µm in diameter. For comparison, a human hair is typically 50–70 µm wide.

PM is a complex mixture of substances that get lodged in peoples' lungs, and are linked to heart and lung diseases, Prashant explains. It is mainly produced in three ways. Some particles are released during burning, including in car engines. Others come from dusty materials found on surfaces like roads, like worn fragments of tyre. Finally, some are made in reactions between chemicals in the air, including sulfur dioxide and nitrogen oxides (NO_x), and volatile organic chemicals.

Like the UK, India has clean air standards to tackle air pollution, Prashant adds. Delhi has problems with PM partly because it is an inland city without the benefit of coastal winds, with lots of pollution sources. Delhi's problems are also partly due to how it deals with pollution, he explains. 'In London you see a lot of activity not only from the government side, but also from environmental and professional groups that feed into the policies, highlighting issues and solutions.' Governments in countries like India are less receptive to this kind of feedback, he adds.

In the UK, PM_{2.5} levels have fallen less steadily than sulfur dioxide and PM₁₀. Together with NO_x pollution, PM_{2.5} levels started rising again in the early 1990s, before control efforts succeeded in reducing them to their current all-time-low overall levels. Yet that success has recently faced a setback. In September 2015, German carmaker Volkswagen Group admitted that it temporarily, artificially lowered PM_{2.5} and NO_x emissions while diesel cars were tested for compliance with environment laws. When tested in normal use, their NO_x emissions are four times the European limit, and 11 million cars sold between 2008 and 2015 are affected. Researchers found that [the 2.6 million affected cars in Germany alone could cause 1200 early deaths in Europe](#).

Driving into the wild blue yonder

Yet the story that study told about the impact of NO_x is complex, as is almost everything about these gases. Usually, nitrogen is too stable to react with oxygen. But at high temperatures, like those in car engines, they can combine to produce a variety of molecules, including NO and NO₂. On sunny days NO₂ in particular breaks down in a photochemical reaction. This leads to a mazy network of reactions that form other substances, including ozone. Like PM, ozone can cause lung and heart damage if inhaled. However, NO also reacts with and removes ozone from the air, and NO accounts for more than four-fifths of NO_x emissions from diesel vehicles. Therefore, the scientists looking at the Volkswagen scandal's effects found that, thanks to NO removing ozone, increased NO_x emissions actually reduced the harm caused by increased PM_{2.5} emissions.

The Volkswagen scandal may have harmed official efforts to deal with pollutants such as PM_{2.5} and NO_x originating from cars, says Prashant. Scientists produce computer models to help governments with their plans. 'But when Volkswagen was cheating on their emissions, these predictions will be off,' he explains. The scandal undermined scientists' work to protect people.

To enable people to take steps to protect themselves, Prashant's team has [studied exposure to pollution while driving](#). 'We found that when you're at traffic lights or in a congested environment you get the highest exposure, but exposure is also driven by the choices you make,' he explains. 'If you keep your windows open at a traffic light you can expect a lot more emissions coming into your car. Or, if your windows are closed but you're sucking fresh air from outside at those congested places, you're sucking fumes inside. If you circulate air rather than taking the fresh inlet, and keep windows closed, that can reduce your exposure.'

Everyone is affected by exposure to high levels of pollutants, and long-term exposure, stresses Vivien Bright, who works on air quality at the Met Office in Exeter, UK. She notes that healthy people don't normally feel any instant effect from moderate air pollution. However, it can cause problems for the elderly and younger people with medical conditions, especially lung and heart problems. That includes asthma, which Vivien has.

NO₂-toriously dirty

Although London air sometimes breaches legal NO₂ limits, Vivien emphasises this only happens in a few unusual places. For example, measurements made in shopping hotspot [Oxford Street in 2013 apparently showed the highest NO₂ levels in the world](#). 'A significant amount of buses and taxis go through Oxford Street,' Vivien explains, traditionally powered by notoriously dirty diesel engines. The tall buildings on either side of this street also make it a 'street canyon'. 'It's poorly ventilated and pollutants can build up,' Vivien says. Some studies have shown that the city's efforts to replace polluting diesel-powered buses and taxis with cleaner electric models have cut NO₂ levels in the worst streets, she adds.

By contrast, Vivien says, Delhi's general PM problems dwarf London's. In November 2017, PM_{2.5} levels in Delhi reached 700µg/m³, and in January 2018, when Vivien spoke to *Education in Chemistry*, at one site they were still 400µg/m³. Vivien compares this to the UK Daily Air Quality Index (DAQI), the pollution forecast that the Met Office provides daily forecasts for. The most polluted level the DAQI reaches, 'Very high', starts at 71µg/m³, just one-tenth Delhi's November 2017 level. 'We rarely see very high levels in the UK,' Vivien comments. 'If we did, they'd be isolated. I had a quick look at central London this morning, and there's not much pollution around – currently 12.5µg/m³ for PM_{2.5}.'

The wet, windy conditions in the UK that morning helped keep pollution down, mixing the atmosphere and stopping pollutants from reaching high levels. Rain also dissolves and otherwise washes gases and PM out. And because the wind was coming from the west, over the Atlantic Ocean, the air is much cleaner than when the UK gets winds from the east, blowing in pollution from Europe. 'If you have air coming down from the Arctic, that's again very clean,' Vivien says. 'Sometimes high winds import pollutants from further afield,' she adds, as well as natural dust from the Sahara Desert, and recently smoke from wildfires in Portugal.

The place in the UK with the worst air quality on that morning was the Shetland Islands, to the north of Scotland. Its ozone levels had reached the moderate rating of 101–120 $\mu\text{g}/\text{m}^3$. Surprisingly, there is often more ozone in the air in rural areas as there is less NO for it to react with than in urban areas.

The Shetlands' ozone shows up strikingly as a lone yellow marker on the [interactive UK-AIR map](#) produced by the UK's Department for the Environment, Food and Rural Affairs (Defra). Vivien's team combines that data with the Met Office's weather models to produce [daily pollution forecasts](#). She stresses that the UK has collected air quality data since the 1960s, with the substances monitored expanding in line with the shifts in focus Prashant emphasises. And now, one scientist argues that we need a further expansion.

Soaring into the unknown

Parisa Ariya, from McGill University in Montreal, Canada, says we should start specifically tracking nanometre-size particles in the air. She bases that both on measurements of the air and evidence from the snow that often falls near her lab. 'Snow is a snapshot of atmospheric processes,' she explains. The falling snow captures substances in the air, and so [testing fresh snowfall with techniques including mass spectrometry provides an easy way to study the atmosphere](#).

The McGill team has found many different types of nanoparticle, some from natural sources. Others, however, were manmade materials, ranging from those that are usually fairly harmless, such as titanium oxide, to the toxic metal cadmium. She is especially worried about toxic nanoparticles from electronic waste that is supposedly sent to be recycled, but which may not be.

We're not yet certain about the health threat these nanoparticles pose, Parisa explains, but they're likely to cause damage through chemical reactivity when they get into our systems. 'Because little particles have a greater surface to volume ratio, that provides a huge possibility for different types of chemistry, lots of weird things happen,' she says. 'That's actually one reason we use them as catalysts.'

Nanoparticles count as PM, because they're smaller – by a factor of 1000 or more – than the micron-scale size limits used to define this pollution. Parisa points out that while there are more nanoparticles than larger particles, because they are so much smaller they account for less of the overall weight of PM. Yet current regulations aim to reduce the total concentration of pollutants, a measure that divides the weight emitted by the volume substances are spread over. They therefore prioritise eliminating larger particles. As such, nanoparticle emissions are effectively unregulated, she warns, although Canada, Europe and China have started talking about what to do.

Many countries have largely dealt with problems caused by sulfur dioxide, and are getting to grips with NO_x and PM, with more or less success. Now, to understand the nanoparticle problem and deal with it, international collaboration will be needed. That's because nanoparticles' size makes it easy for the wind to carry them long distances. 'They can be transported across the sea and have a potential impact regionally and globally,' Parisa says. And this underlines just how connected we all are, she adds. 'We all have one planet, we have one environment – and the atmosphere allows pollution to become really international.'