Imperial College London

CUTTING THROUGH THE SMOKE

Air quality research at Imperial College London

BY LINDA GEDDES

Air pollution is recognised as one of the greatest environmental threats we face in our modern world. It is also an important public health issue, associated with some 7 million deaths globally each year. Yet although we know that the gases and particulate matter produced by burning fuel are harmful, there is still a great deal we don't know about how individual pollutants contribute and combine to affect human health over the short and longer term.

The challenges of combatting air pollution aren't only scientific: "People are very attached to their cars, and policymakers tend to want to just continue as usual, so we also need to find new ways to engage members of the public, stakeholders and decision-makers to make them want to do more about air pollution to improve human health," says Dr Audrey de Nazelle, a lecturer in air pollution management in the Centre for Environmental Policy at Imperial College London.

Solving these complex and important issues requires a multidisciplinary approach, so Dr de Nazelle has established a Network of Excellence in Air Quality, drawing expertise from across the faculties of Natural Sciences, Engineering, Medicine and the Business School to try and address these challenges.

"Air pollution is a huge field with lots of different components relating to various areas of research that are present at Imperial," says Dr de Nazelle, who leads the Network. "It made sense to try and coalesce those forces, both to improve our own research and help us collaborate better, but also to improve our connection with decision-makers and the public and have a greater impact in the outside world."

These external connections are particularly important, she says, because tackling air pollution could have other positive implications for society, which should be considered from the outset.

Dr Audrey de Nazelle

"We tend to think about air pollution as a technological problem requiring better fuel efficiency or emissions control, but the types of policy that you put in place can have broader co-benefits," says Dr de Nazelle. "For example, if we encourage decision-makers to create cities that are more walking and bicycle-friendly, and friendlier to public transport users, then not only are we improving air pollution but we're also getting people to be physically active or creating environments where people can talk to each other. To me, the air quality network is a way to think a bit beyond air pollution."

So far, the Network has identified five key areas, which it is seeking to address through its research: air pollution science, new tools for monitoring and modelling air quality, control and prevention, co-benefits, and policy. It is seeking input from industrial and government stakeholders, policy-makers and members of the public.

"By understanding the actual needs on the ground – both from an industrial and a policy perspective – and having a better understanding of how the system works, we believe that we can have a greater impact by ensuring that our research is useful and is used," says Dr de Nazelle.

THE FINE MATTER

Air pollution is often referred to as an invisible killer, because unlike cigarette smoke, it is less obvious when you are breathing it in. "People often think of air pollution as affecting others, but not themselves," says Dr Laure de Preux, Assistant Professor of Economics at Imperial College Business School. "They may think that where they live is safe when actually it might be highly polluted, or that pollution is terrible in London, but not for them directly."

Dr Laure de Preux

Globally, more than 80% of people living in urban areas are exposed to pollution levels that exceed World Health Organisation limits. It's not only big cities like London that are affected – even small, and relatively leafy, green places like Oxford have been found to have dangerously high levels of pollutants like nitrogen dioxide.

Although it is less visible than cigarette smoke, the pollutants emitted from burning fuels like wood, coal or petrol are similar. "When you smoke a cigarette, you are inhaling lots of gases and particles that are produced through the combustion process of tobacco being burned in air," says Dr Marc Stettler, director of Imperial's Transport and Environment Laboratory. We find some of these pollutants in ambient air, and while they may be at lower concentrations than if we inhale a cigarette, and the type of particles differs slightly, "in a broad sense, they are both particulate matter – particles that we breathe in and which get deposited in our lungs – and we know that on a population level, inhaling particulate matter isn't good for our health," explains Dr Stettler.

Across the European Union, air pollution is estimated to contribute to around 467,000 premature deaths each year – 40,000 of them in the UK. Lung cancer, chronic obstructive pulmonary disease and asthma have all been associated with higher levels of airborne particulate matter in the environment. But the lungs aren't the only body part affected: spikes in the concentrations of fine particulate matter and nitrogen oxides are also associated with increased hospital admissions for heart attacks, heart failure, heart rhythm disturbances and stroke.

There's even evidence that tiny airborne particles can enter the brain: some studies suggest that people living close to very busy roads are at increased risk of dementia, while others suggest that school children can have their cognitive development impaired. The precise mechanisms by which air pollution contributes to these very different diseases are still unclear, but they are all thought to have one thing in common: "As the particles you inhale get smaller, they can penetrate deeper and deeper into your respiratory system and into your lungs, where they trigger inflammation," says Dr Daniela Fecht, a research fellow at Imperial's School of Public Health.

Even so, our understanding of how airborne pollutants interact to affect individuals' health remains limited. "There's a lot still to be done in terms of understanding where the pollution is coming from, what the pollution is, and how it affects health," says Dr Stettler.

Most studies have focused on the health impact of air pollutants at a population level, rather than tracking individuals' exposure patterns and correlating these with health outcomes. These have shown us, for example, that children attending schools near busy roads experience more asthma attacks, but they don't tell us much about the risks to an individual child.

This is now beginning to change, thanks to the development of cheaper wearable sensors that can monitor exactly what someone is being exposed to as they go about their daily lives. "They are giving us a much more detailed and personalized picture of how air pollution is affecting individuals," says Dr Stettler.

However, to effectively tackle air pollution, researchers first need to know precisely what they are dealing with and where it's coming from. Particulate matter can refer to anything that floats in the air, including particles generated by human activities such as burning fuel, but also those from more natural sources such as pollen and sea spray. "We still don't have a firm idea as to which particles in this complex mixture are most responsible for the health effects of air pollution," says Dr Fecht.

To try and disentangle the effects of these different components on our health, researchers in Imperial's Faculty of Medicine are using a relatively new technique called metabolomics. When we are exposed to various substances in our environment, including air pollutants, these trigger characteristic molecular signatures which can be detected in our blood and body tissues. By combining measurements of people's exposures to pollutants from personal sensors with these biological measurements, Imperial researchers hope to gain a better understanding of their effects on the body and how they might contribute to long-term disease risk.

They are also studying people's genes to better understand how their patterns of expression change in response to poor air quality. Not only could this provide new insights into why some people are more susceptible to the effects of air pollution than others, it may also help determine whether air pollution is the source of any symptoms reported by individual patients.

CLEANER VEHICLES

To date, much of the focus in terms of trying to reduce air pollution has been on measuring and reducing the emissions from vehicles. Since the 1970s, European Union regulations have meant that new cars have to meet certain fuel-pipe emissions standards to try and cut air pollution. Similar standards exist in many other countries as well. Yet, as the recent "Dieselgate" scandal surrounding the car manufacturer Volkswagen showed, such standards are vulnerable to manipulation: Volkswagen's engineers intentionally programmed some of their diesel engines to activate emissions controls only during laboratory testing, but when the cars were driven in the real world their nitrogen dioxide emissions were many times higher.

Attempting to overcome this problem, Dr Stettler and his colleagues have been testing a real-time vehicle emissions

monitoring system in diesel, gasoline and hybrid cars to try and gain a clearer picture of their real-world emissions.

In 2018, they published a detailed analysis of the carbon dioxide and nitrogen dioxide emitted by 149 different passenger car models – accounting for 56% of all passenger cars sold in Europe during 2016. "In general, we found that diesel cars are worse for nitrogen oxides but better than petrol cars in terms of carbon dioxide emissions," Dr Stettler says. "It potentially leads to a trade-off that we have to face about what's more important to us: is it air quality, or is it climate change?"

Someday, such technology could even be used to implement varying road charges based on the actual emissions a vehicle is spewing out, rather than the current flat rate car tax system that operates in the UK and elsewhere.

Imperial researchers are now trying to use real-time emissions monitoring to generate a more detailed picture of where these

Dr Marc Stettler

real-world emissions are occurring. We know, for example, that tail-pipe emissions are higher when vehicles accelerate, and that high concentrations of air pollutants tend to be found near traffic lights, where such acceleration events occur frequently – but real-time monitoring might reveal other air pollution hotspots in our towns and cities as well. For instance, although people often focus on the pollutants coming out of car tailpipes, another source is brake pads: the friction generated when they press against the wheels releases tiny metallic particles, which have been less well studied, but are potentially more toxic.

In the short term, such knowledge could be used to help reduce people's exposure to vehicle emissions. "If we have a more detailed idea of where the pollution is, then we can do things like directing people to the other side of the road, or via a different route," says Dr Stettler. It would be possible to try and reduce the amount of air pollution pedestrians are exposed to through smarter phasing of traffic light crossing timings with vehicle movements.

Longer-term, drivers could potentially be provided with real-time feedback on their vehicles' emissions to encourage them to drive in a less polluting way. For instance, some studies have suggested that aggressive driving that involves a lot of sharp acceleration and braking can as much as double the amount of nitrogen oxides emitted by vehicles; it also increases fuel consumption, potentially costing the driver money. "Getting the driver involved is something that has so far been largely overlooked in terms of improving air quality in cities," says Dr Stettler. "Having that sort of information provided to them would I think incentivize smoother driving with more gentle acceleration."

SMARTER CITIES

Imperial's researchers aren't only trying to monitor the real-time emissions from vehicle tail-pipes. The Intel Collaborative Research Institute (ICRI) – an industry/academic partnership involving Intel Laboratories, Imperial College London and University College London – has been working across several London boroughs to develop and deploy a network of air quality sensors attached to trees and lamp-posts, as well as systems that process the data they generate to enable real-time analysis of air pollution levels on a street-by-street basis.

"Right now, air quality is a very expensive thing to measure accurately," says Mr Greg Jackson, Research Assistant and PhD student in Imperial's Adaptive Emergent System Engineering Labs. For instance, the traditional air quality measurement system used across London consists of around 150 sensors that each cost between £10,000 and £100,000 and require regular maintenance. "If we could deploy a larger number of more geographically granular air quality sensors we could potentially accrue more information about micro-changes in air quality – so things that will be driven by traffic movements or weather patterns," says Mr Jackson.

The sensors that ICRI has developed are smaller and less accurate than the gold-standard ones that are in widespread use, but they are cheaper and easier to deploy, and don't need regular maintenance to continue to operate. ICRI researchers have also developed software that will help enable useful data to be recovered from the sensor networks.

The hope is that such sensors could provide local authorities with more detailed data about pollution hotspots, enabling them to produce more accurate air quality reports, and even rapidly identify areas of slow-moving traffic. This real-time information could also be fed back to drivers, providing further encouragement to e.g. turn off idling engines or adopt other behaviours to improve air quality.

A PRICE TAG ON POLLUTION

Trying to change the behaviour of individual motorists is one thing, but to significantly improve the quality of the air we breathe, action is also needed at a national and international level.

This isn't only a health issue, but also one of social equality. "If you look at air pollution levels in deprived areas compared to the most affluent areas, they are very different," says Fecht.

"You can move away into a clean area if you have the financial power to do so, but otherwise you, as an individual person, can't change much about your environment, so it is more of a government responsibility to make sure that everyone has clean air to breathe."

Despite the number of deaths attributed to air pollution, many local and national governments have been slow to act. "We know air pollution kills, and directly represents a burden for our health care system and society, so you wonder why it is still so cheap to pick up your car and drive a few streets in a city like London," says Dr de Preux.

Taking action against air pollution costs money, which governments and large business are often reluctant to part with – unless they can see a quantifiable benefit. "We know that if we significantly reduce the number of cars in London then some jobs will be lost, which has an economic cost that is often used to support the status quo. Regrettably, this number is not compared to the health benefits as they are harder to quantify in monetary units," says Dr de Preux. "If we can't quantify the health benefits associated with an intervention, or convert them into monetary units, then they are simply ignored from any of economic evaluation. Reducing traffic then represents then a huge monetary cost, with little financial saving."

Until recently, no-one had put a price on local health savings that might be made by addressing air pollution. However, Imperial researchers, including Dr Fecht and Dr de Preux, in collaboration with the UK Health Forum, were recently commissioned by Public Health England to calculate the health and social care costs of exposure to fine particulate matter and nitrogen dioxide. The figure they came up with for 2017 was £157 million – based on data for diseases with a well-established connection to air pollution.

Assuming levels of these pollutants remain the same, the researchers estimate that the total cost of air pollution to the NHS and social care between 2017 and 2035 could be as high as £18.6 billion – arising from 2.5 million new cases of coronary heart disease, stroke, lung cancer, and many other diseases.

"Compared to other exposures, such as smoking, that's a fairly small number, but we didn't include the wider economic costs, such as if you have a disease you might have lots of days off work," says Dr Fecht.

Neither does this analysis consider the broader co-benefits of tackling air pollution, such as reducing the damage to buildings or ecosystems, encouraging more people to cycle to work and therefore get more exercise, or helping to meet climate change targets.

Dr Daniela Fecht

INVESTING IN THE RIGHT PLACES

Even so, when funding is limited, it is important to make sure that it is spent in the most effective way: Encouraging more people to walk or cycle to work instead of driving may sound like a great way of improving people's fitness as well as reducing air pollution – but only if exercising in polluted areas doesn't undermine their health in other ways. It is therefore essential that such policies are grounded in evidence.

Researchers from universities including Imperial recently compared the health effects of a walk in London's Hyde Park against one along Oxford Street, and discovered that, for people over 60 at least, high levels of air pollution on the busy shopping street cancelled out some of the physical benefits they got from walking.

However, in separate studies that assessed the health impact of cycling in cities with air pollution levels typical of those in Europe or North America, Dr de Nazelle and her colleagues discovered that for most people, the benefits of exercising outweigh the risks: "People can cycle as much as they want and it is still going to be beneficial in terms of long-term mortality impact," she says.

Such studies are essential if we are to ensure that given policies aimed at improving air quality are the most effective at improving health. However, quantifying the co-benefits of air pollution could also help decision-makers make better choices when several different policies are on the table.

"If we try to deal with air pollution in isolation, it is a huge missed opportunity," says Dr de Nazelle. "We can get much more bang for our buck if we create a holistic framework that also considers the co-benefits for climate change, energy conservation, physical activity, noise, and green space."

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