Fire and the crazy world of air around us

Written by **Peter Knapp,** *Imperial College*

Wouldn't a nice crackling fire in your home be lovely through the winter? Maybe some scented candles or incense to relax with, too. You might be looking forward to a good fry-up on a Saturday morning. I am willing to place a bet with you that you will think differently about these by the time you finish this article...

The 2019 coronavirus has made us all a lot more aware of what is in the air and, just like the rich zoo of subatomic particles or plankton, the air contains all sorts of things floating around that we can't see, like bacteria, fungi, pollen, plastic fibres, exhaust particles, brake dust, tyre fragments, heavy metals, droplets from the lungs and mouth, cooking oils, cleaning products, construction dust... and the list goes on. These are all types of 'aerosols', defined as a solid or liquid suspended in the air. Gases like sulphur dioxide and nitrogen dioxide also add to the mix.

You may be wondering how much of this stuff is in the air, where they come from, and what they might be doing to your body and to the rest of nature.

I wrote an article for Catalyst in issue 31 while I was working on an antimatter experiment at CERN. Things have changed for me a bit since then; now I'm doing a PhD with Imperial College London on Indoor Air Quality. I am also an active member of a scientific group who raises awareness of the climate and ecological emergency and who campaigns for political action. This is what I love about working in science: that you can change what you're doing to suit your interests, even when they might drastically change.

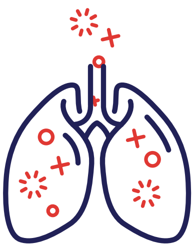
My work at CERN actually helps my research into air quality, as the electric charges are important in the dynamics of both antimatter particles and aerosols. Aerosols can pick up or lose electrons, giving them an electric charge that can affect how easily they might pass into cells, or help to track where pollen from a criminal's clothing came from, and they even affect the weather. Perhaps the charge of breath droplets containing viruses affects how they disperse or settle. This is quite a new area of research, so there is a lot to investigate.

Before my aerosol research I had a teaching job in Beijing, where the enormous blanket of smog hugged the city and reduced the lifespan of millions of people. The children at the school wore masks, like we do during the current pandemic, to protect themselves from the air pollution that they could never really escape. How could this be ok? And why did it appear that nobody really talked about it or tried to solve it? I wanted to help fix this problem.

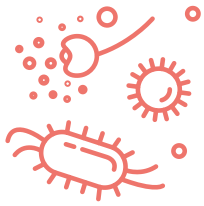
In Beijing, we had official air quality readings to tell us what the air was like outside and it was routinely 'unhealthy' and sometimes 'hazardous', and as we generally spend over 90% of our time indoors I started to tape up the windows to protect myself from the pollution outside. I started to wonder if indoor air really was 'better' than air outside, so I bought some air quality monitors for my home and realised that cooking, candles, incense, or anything that burned made the air in my home up to 100 times more polluted than one of the most polluted cities in the world! The air quality indoors also became much worse when it got bad outside. The World Health Organisation (WHO) provides indoor and outdoor safe limits, but many cities are rarely within them, including London where I now campaign for cleaner air in schools and neighbourhoods.

What was this invisible and odourless poison floating around? And how could I get it out of my air!?

I started to read about it and found the term 'PM2.5', which means any 'particulate matter' that is less than 2.5 microns in diameter – so small you can't see it. Line up 400 of the largest particles in that range and it would be 1mm long. This doesn't include atoms or molecules, but anything roughly between the size a virus up to a sixth of a pollen grain. It turns out that this size is important because they can penetrate deep into the lungs and irritate the alveolar wall (the part where your blood gets oxygen).



The air contains things floating around that we can't see, like bacteria, fungi and pollen.



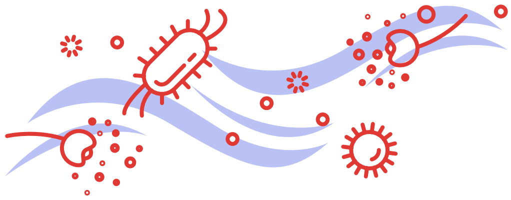
Particles less than 0.1 microns, called PM0.1, get into the blood and can reach the brain, liver, kidneys, and so on. As a rule of thumb: the smaller the particles are, the worse they are for your health, although what they are made of is also important.

Short periods of high pollution kills people. The Netflix series The Crown shows the horrible 5 days in 1952 where smog built up in London, predominantly from coal burning, and killed around 12,000 people[1]. There is no memorial for them, but 4 years later the Clean Air Act reduced coal-burning and made chimneys a little cleaner. Long-term exposure to air pollution also kills people, however. Over years of exposure to moderate levels of PM0.1 (or even just a few hours with high-dose activities like welding), there is evidence to show that this causes diseases of the heart and blood vessels that feed all the body's organs, including the brain[2]. Strokes account for 40% of deaths in the UK[3]! Air pollution is shown to be a possible cause of pneumonia, type 1 and type 2 diabetes, cancer, and dementia, and may also cause asthma and allergies like hayfever[4]. Children growing up in London's 'clean' LEZ (low emissions zones) lose a lung volume equivalent to two large chicken eggs due to air pollution[5]. Nitrogen dioxide (NO_2) from industry and road traffic drifts into nature reserves and damages plant leaves, and appears to be a factor in rapid decline in biomass of insects and birds that eat the damaged plants[6].

There is a lot of focus on outdoor or 'public' air. But with so many of us spending time indoors, sources of indoor pollution are becoming even more important. I took a sensor into some shops along a Bristol high street between 2-3pm to find out how they compared to the outdoor air.

The measurements are in µg/m3, which means how many micrograms of PM2.5 are in 1 cubic metre of air. Breathing in any amount of PM2.5 is not good for your health, but the WHO has a somewhat arbitrary 'safe limit' of outdoor exposure as an annual mean of 10 µg/m3, and a maximum mean of 25 µg/m3 over 1 day. There isn't yet any such regulation of indoor air quality, and as you'll see this would be a good idea to put into action! The outdoor air was measured at a safe 3 µg/m3, but these were the readings in the shops and pubs:

Small particles in the air can get into our lungs and blood.



Venue	PM2.5 reading (µg/m3)	Possible source
Outdoor air on a clean day	3	
Sandwich shop	53	Small oven
Kebab shop	83	Meat on spit and hot plate
Body Shop	3	Scents containing limonene and pinene
Fried Chicken takeaway	107	Deep fat fryer
Pub	1833	Open fireplace

This was astounding. The people working in the pub were breathing in around 25 times the WHO guideline for 24-hour exposure, which was polluting their lungs, blood, and their organs. But open fireplaces aren't the worst culprits… incense burning is, which produces around 4.5 times more particulate matter than a cigarette[7]. The Body Shop was curious; and, after some reading, I found that personal care products like perfumes and spray deodorants are a significant source of outdoor smog as they react with gases in the air such as ozone (O_3)[8]. Ozone is good in the upper atmosphere as it shields us from the Sun's harmful ultraviolet rays, but ozone around roads and houses isn't very good for us at all as it aggressively reacts with cells in your lungs and can worsen bronchitis, emphysema and asthma.

Amazingly, cooking can generate so much PM2.5 that it can seep outside and affect the air quality outdoors too! It was measured that cooking certain foods could be equivalent to having 10 cars idling in your kitchen[9]. Frying or grilling high-fat meats such as burgers, sausages and bacon appear to be the worst polluters from the commonly cooked foods and, in terms of number of particles, smoky cooking produces mostly PM0.1 – the really bad stuff[10]. Unfortunately, we can't measure PM0.1 very cheaply at the moment because it's so small… maybe you can help to develop a device that can accurately read these tiny particles in the future?

In the meantime, here are some suggestions that can help to make your home an oasis of clean air:

- find alternatives to spray products where possible;
- fry with the hood fan on and use the back rings as the hood sucks up more from there, and reduce the amount of meat you cook as it produces a lot of harmful aerosol;
- dry your clothes outside if you can, as air-drying indoors can lead to mould spores building up that can produce allergic reactions and asthma attacks;
- avoid burning candles, incense, and fireplaces, and also plug-in air fresheners, which are very strong polluters;
- open windows when using cleaning products and vacuum carpets frequently to prevent dust building up;
- open the windows every day, even for a short time to reduce build-up of things like the carcinogen (cancer causing substance) formaldehyde that is found in furnishings made of MDF or chipboard;
- making or buying a PM2.5 sensor helps you to know when to open windows, here are some instructions on how to make your own[11];
- and make your own cheap air purifier by strapping a HEPA filter to a fan – it really works[12]!

Air quality around the world is affected by our decisions in the UK, too. The food we eat and the products we buy make a difference to the health of people and survival of species in the countries that produce them. Animals reared for meat are frequently fed soya beans, which contributes largely to deforestation and burning of rainforests. But what about all the soya in tofu and other vegetarian foods? Surely, they contribute more to deforestation… Well, deforestation results from high demand. According to Greenpeace, "most of the world's soya is grown for the meat industry. Only 6% of the soya grown globally is eaten by humans. 90% of all soya is fed to chickens, pigs and cows. The rest is used for things like pet food and biofuels"[13]. Even pigs from a local farm in the UK could be fed soya from the Amazon. Therefore, if you don't know how the animal has been fed, you might be contributing to deforestation by eating it. For many reasons, it is a good idea to reduce meat and dairy consumption to a maximum of once per week.

Half of Borneo's rainforests are gone as demand for palm oil, another murky ingredient, has risen. According to the WWF "it's in close to 50% of the packaged products we find in supermarkets, everything from pizza, doughnuts and chocolate, to deodorant, shampoo, toothpaste and lipstick"[14]. Sustainable palm oil can be found, where the aim is to stop further deforestation, but reforestation should be the real aim. Personally, I have cut meat and palm oil out altogether and I buy food grown locally where possible to reduce transport emissions. Transport of exotic foods brought to the UK by boat or plane contributes to polluting the air, so it's a good idea to eat locally grown food.

Speaking of transport: cars, buses, and taxis are like little indoor environments that suck in fumes from the vehicles in front, which then get trapped in the vehicle and accumulate. The deep London Underground stations can be toxic, too. Hampstead – the deepest London Underground station – was measured to have 658 μg/m3 of PM2.5 perhaps from brake dust, rail abrasion and motor brushes[15]. Trains that travel above the ground tend to be much cleaner and cycling or walking is associated with lower risk of mortality[16].

Now here is where we need your help. So many questions about aerosols still need to be answered like: how do viruses get around in places like restaurants or cinemas; what particles do we find floating in rooms like classrooms or bathrooms, and how do they affect our health; what are 'good' aerosols and 'bad' aerosols, and how might they cause asthma or hay fever; how do volcanic eruptions affect planes and the climate; should the government regulate our indoor air quality; and can forests talk to each other with aerosols that they produce? Maybe you could help to answer one of these questions. For something that looks quite empty, the air is an important and invisible mix of mysteries just waiting to be explored.

Glossary

HEPA filter - High Efficiency Particulate Air filter

μg/m3 - Micrograms per cubic metre

PM2.5 - Particulate matter that is under 2.5 microns in diameter

About the author

My life so far in 50 words: comprehensive school; applied for Medicine but I studied Maths with Astronomy instead; 4-year music career; taught Maths in China and Switzerland; Masters in Antimatter Physics at CERN; wrote a book about North Korea; started a PhD in Aerosol Science at Imperial College London!

STEM LEARNING

Article links

[1] https://doi.org/10.1289/ehp.6539

[2] https://www.nature.com/articles/s12276-020-0403-3

[3] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/304668/COMEAP_cardiovascular_disease_and_air_pollution.pdf

[4] https://doi.org/10.1016/j.rmed.2015.05.017

[5] https://doi.org/10.1016/S2468-2667(18)30202-0

[6] http://dx.doi.org/10.1088/1748-9326/aa8051

[7] https://dx.doi.org/10.1186%2F1476-7961-6-3

[8] https://dx.doi.org/10.1126/science.aaq0524

[9] https://dx.doi.org/10.1289%2Fehp.5518

[10] https://doi.org/10.1016/j.atmosenv.2013.01.061

[11] https://sensor.community/en/sensors/airrohr/

[12] https://smartairfilters.com/en/blog/diy-vs-blue-air/?rel=1

[13] https://www.greenpeace.org.uk/news/soya-meat-vegetarian-vegan/

[14] https://www.wwf.org.uk/updates/8-things-know-about-palm-oil

[15] https://doi.org/10.1016/j.envint.2019.105188

[16] https://doi.org/10.1136/bmj.j1456