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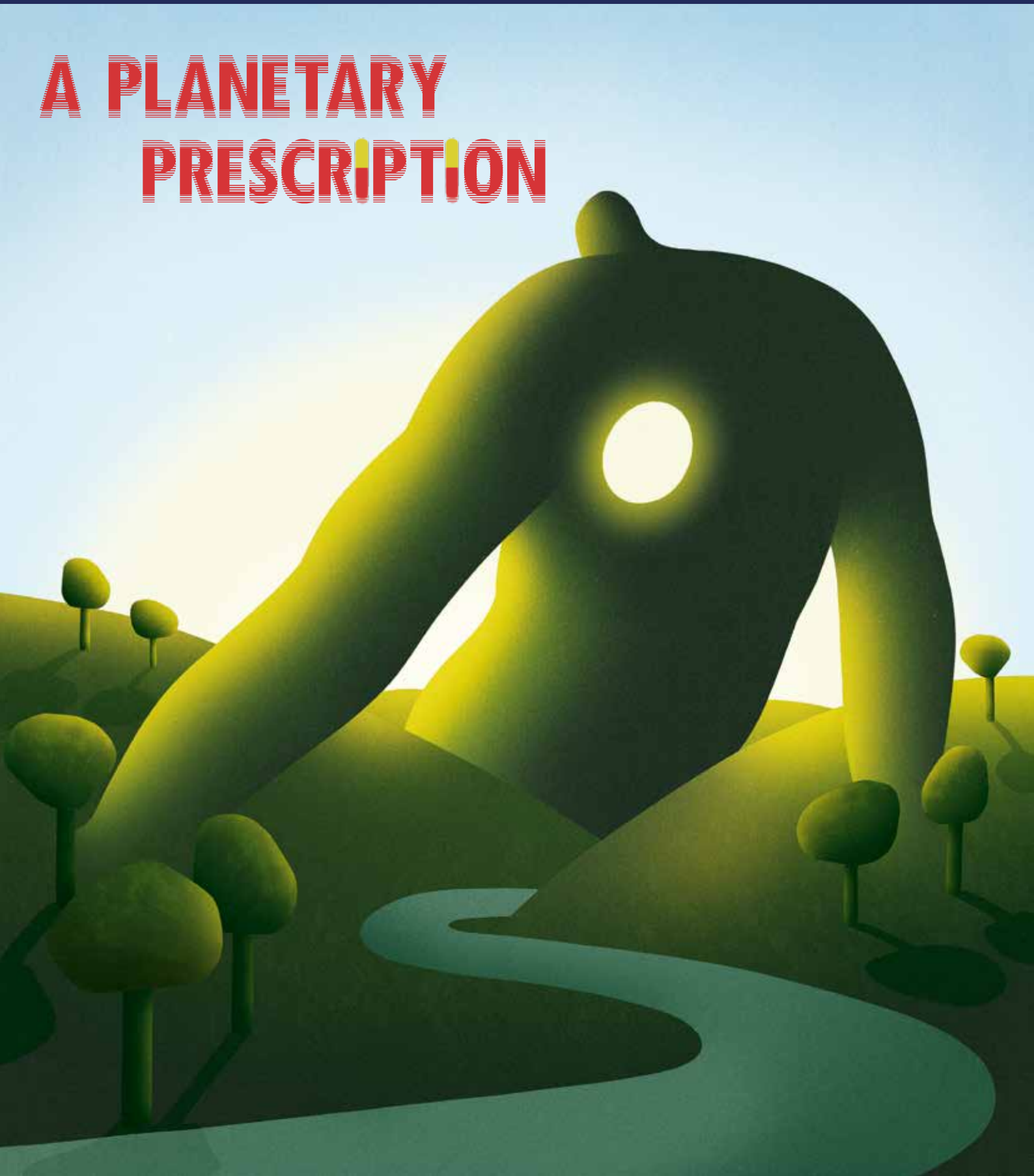
A PLANETARY PRESCRIPTION



EDITORIAL

The inextricable link between our health and that of our planet

It sometimes feels as if we are powerless in the face of the challenges presented by the climate emergency. But I do not think that is right. Stroud, where I live and work, is the birthplace of Extinction Rebellion, Ecotricity and dozens of small start-up companies in the fields of energy and sustainable living, working to create a healthier environment. Here, possibly more than anywhere else in the UK, we take our environmental responsibilities seriously.

As a GP and former head of the Stroud Locality NHS, my interest naturally centres on bringing together health and sustainability to tackle climate change. Whether as individuals or as a government, I believe that there are (at least) four areas we can focus on.

Firstly, and this is mostly governmental, we have to set and promote those strategies that reduce carbon emissions and improve health – for example, from agricultural and industrial policy through to household recycling, or eating more healthily. Creating the right strategic framework makes all the subsequent decisions easier.

Secondly, public health policy and programmes must specifically protect and mitigate the risks that climate change presents: not only cure them but prevent them. The impacts on health of a warming world should be an essential planning consideration at every level and in every area of policy.

Thirdly, we must change the way we work as health professionals. The NHS is responsible for some 4 per cent of the country's carbon emissions. As Chair of the All-Party Parliamentary Health Group of MPs, my focus is on how we can decarbonise the NHS, insulate our property estate and seek low-energy solutions. We can cut energy consumption and increase recycling. We should be putting solar panels on the roof of every NHS building. We need to look at how treatments are administered – for example, some inhalers are dreadful for the environment – and we need to work with pharmaceutical companies to reduce their emissions. In surgeries, it should be possible to do all monitoring blood tests on a single annual visit, and we need to think more about taking the consultant to the community (one car journey) rather than the other way round (maybe 20 car journeys). Community care is the way ahead.

Lastly, and most importantly, we must address inequality. Locally and globally, levels of inequality are unsustainable – in every sense. In Stroud, the difference in life expectancy varies by up to 10 years by postcode. Across the planet, by country, the difference is as much as 30 years. The wealthy are the worst polluters, while the poor bear the consequences and are least able to deal with them.

For all our sakes, this cannot go on.

Editorial: Dr Simon Opher MP is the Labour MP for Stroud, in Gloucestershire. Before that, he worked for 30 years as a GP in Dursley (and still holds surgeries when time permits). He went into politics because he realised that ill health is largely caused by inequality. Simon was one of the first champions of social prescribing, which helps people to improve their health and well-being.

Image Credit: Roger Harris | Wikimedia Commons | CC-BY-3.0

Cover design: Hayley Wall is an illustrator based in London, whose work highlights the struggles and joys of queer and disabled people as their bodies move through the world. With an aim to make art that challenges and reframes dominant perspectives around disability, mental health, queerness and gender, Hayley's illustrations aim to invite viewers to embrace a more inclusive and empathetic world view.

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The environmental SCIENTIST provides a platform to discuss key issues within the environmental sciences, hosting original articles written by professionals, academics and experts working across the sector.

The views expressed in the journal are those of the authors and do not necessarily reflect IES views or policy.

INTRODUCTION

Health: the complex link between people and the environment

Anna Hansell and **Samuel Cai** piece together the interdependencies of human health and a healthy planet.

We are delighted to act as guest editors for the first ever health-themed edition of *environmental SCIENTIST!* As individuals and as a society, we affect the environment and, in turn, the environment affects our health and society – sometimes in surprising ways. For example, access to green spaces is associated with better mental and physical health, as Dominic Higgins' article discusses. One of the recent studies at our own organisation, the Centre for Environmental Health and Sustainability – which researches the health effects of air pollution, transport noise and environmental chemicals – at the University of Leicester, has suggested that traffic noise reduction is associated with a reduction in violent crime levels.[1]

Our own research is strongly influenced by the concept of planetary health. This emphasises that humans depend on a healthy Earth for survival and, in turn, that the sustainability of Earth's systems is dependent on human behaviours.[2] University of Leicester research colleagues were some of the key figures in putting forward the concept of the Anthropocene: that human activities from the mid-20th century have accelerated to such an extent that they now impact planetary health – and, therefore, human health.

Climate change is one such example, but there are at least eight other key Earth systems that are necessary for our current ecosystem health. An international group of scientists has been monitoring these since 2009. They concluded in 2023 that the boundaries have been crossed in six of the nine key systems – including climate change, biodiversity and chemical pollution.[3] However, one such system – stratospheric ozone (whose depletion is often referred to as the ozone hole) – is now operating within safe limits due to the landmark 1987 Montreal Protocol. This historic international agreement dramatically reduced the manufacture of over 100 human-made chemicals that had harmed and created a hole in the stratospheric ozone layer, the protective shield against harmful levels of the sun's ultraviolet radiation.[4] The ozone hole has been shrinking since then but it will take many more years to heal completely. The chemicals damaging the ozone layer included greenhouse gases, and reducing their production has been the single largest contribution made to mitigating climate change. The Montreal Protocol is a good example of the progress that can be made through global cooperation between scientists, societies, politicians, businesses and individuals.

NATIONAL AND LOCAL EFFECTS

At a more local level, there are a lot of concerns about how to deal with our household waste and its impacts on health. Imperial College London published work on landfill sites in 2001, finding that 80 per cent of the population at that time lived within 2 km of an existing or former landfill site.[5] Incinerators were suggested as a solution to running out of landfill space.

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In previous work at Imperial College, Anna Hansell led a team researching the health effects of incinerators, which resulted in the publication of a number of scientific papers (see **Further Reading**). This was the largest such study conducted, looking at 22 incinerators over eight years of operation. We did not find impacts from incinerator emissions on the health of babies (the most sensitive group in the population), looking at a wide range of health outcomes.

The UK Health Security Agency concluded that 'modern, well run and regulated MWIs [municipal waste incinerators] are not a significant risk to public health. While it is not possible to rule out adverse health effects from these incinerators completely, any potential effect for people living close by is likely to be very small'.[6] This is reassuring, but work on incineration more widely shows that:

- We produce too much waste and incinerators can offer perverse incentives to continue to produce it;
- Incinerators are a dirty form of energy in that they produce a lot of carbon and need careful maintenance and regulation;
- While no clear impacts on health have been demonstrated it is difficult to prove a negative (no health effects); and
- Ongoing regulation and monitoring of incinerator emissions remains important.

From a planetary health perspective we ought to be looking very seriously at how to reduce waste in the first place, which would be much better for both the planet and would reduce concerns about impacts of waste disposal on human health.

Air pollution is a global, national and local concern. Particulate matter pollution was the leading contributor to the global disease burden in 2021, accounting for 8 per cent of it.[7] The World Health Organization estimates that the combined effects of ambient and indoor air pollution are associated with 7 million premature deaths annually, with much of the burden falling on poorer countries.[8] The Chief Medical Officer highlighted the national problem of air pollution in his annual report for 2022. The impact of outdoor air pollution in England is currently estimated as corresponding to 26,000–38,000 deaths per year. The same report also highlighted the importance of indoor air quality.[9]

Anthropogenic emissions – for example, from transport, industry, construction and farming – are major sources of air pollution. But we are also starting to pay more attention to biological components in the air such as moulds and pollens, which may have wide-ranging health consequences. Climate change is starting to increase exposures to both moulds and pollens, as evidenced by 52 years of data held at Leicester.[10]

Chemical exposure in daily life is also of concern and in the news.[11] It has been estimated that there are over 80,000 chemicals in daily use, including in personal care products and building materials, but we only have limited information on their health risks. While there are a number of ongoing international research projects to define the products of most concern and to quantify those health impacts, one simple approach is the six classes system.[12] This observes that most chemicals of concern fall into six groups – PFAS (the chemicals in the film Dark Waters, sometimes referred to as forever chemicals), antimicrobials, flame retardants, endocrine-disruptors, some solvents, and some metals such as cadmium, lead, mercury and arsenic.

GLOBAL EFFECTS

Climate change is the biggest global health threat facing humanity in the 21st century. It affects health through changing, directly or indirectly, the natural, physical and social environments upon which we rely. Across Europe, the summers of 2022 and 2023 were among the warmest on record, leading to an estimated 61,672 and 47,690 heat-related deaths respectively, with more deaths occurring in women than men.[13,14]

High temperatures can increase ground-level ozone and particulate pollution due to strong sunlight and photochemical reactions. They also lead to more wildfires due to drier conditions, creating more air pollution. The potential synergy between heat and air pollution, including wildfire-related air pollution, can exacerbate existing health conditions, such as respiratory diseases.[15] Pregnant persons are particularly vulnerable to heat stress. For example, in California, both long- and short-term heat exposure during pregnancy have been linked to higher risks of severe and unexpected conditions during labour and delivery.[16] Evidence is also rapidly accumulating on the associations between heat exposure and a range of pregnancy-related and birth outcomes, including maternal mental health, gestational diabetes, cardiovascular events, miscarriage, pre-term birth and stillbirth.[17]

Flooding is another important climate change challenge faced by the UK and wider world. For example, in the UK, we have seen more frequent and intense winter storms in recent years (e.g. Storm Bert in November 2024 and Storm Darragh in December 2024), leading to widespread flooding to land and homes, and damage to infrastructure leading to power outages and contaminating drinking water, all of which will have significant physical and mental health implications, at least in the short term. Research evidence is still slowly growing regarding the potential and wide-ranging health impacts of flooding. Some evidence seems to suggest that certain health outcomes such as increased mortality, gastrointestinal diseases, malaria and respiratory diseases are linked to flooding.[18]


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As mentioned earlier, the presence of indoor mould could become increasingly prevalent due to climate-driven flooding events, and we have been actively researching the potential health effects of indoor mould on the population.

THE WAY AHEAD

We are very pleased that this issue's authors come from such varied backgrounds to discuss key environmental issues – ranging from non-governmental organisations, UK government agencies, academics and an MP. Due to space, we have not been able to include all the topics we would have liked but this first health issue covers a range of concerns from climate change to incinerators. The views expressed do not always reflect our own but provide a platform for debate and starting point for discussion. It is important to have a wide range of backgrounds represented, so that we can agree on solutions that provide the most benefit to everyone. While we, all 8 billion of us on the planet, collectively need to address a wide range of pressing environmental issues, we can take hope from the successful solutions already implemented to reduce the ozone hole and, at the time of writing, the ongoing global discussions to reduce plastic pollution. ES

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Anna Hansell is Professor of Environmental Epidemiology and founding Director of the Centre for Environmental Health and Sustainability at the University of Leicester. She trained as a public health doctor after working for six years in hospital medicine and has been working in environmental health research for the past 25 years.

Samuel Cai is a Lecturer in Environmental Epidemiology at the Centre for Environmental Health and Sustainability at the University of Leicester. His research has focused extensively on how multiple environmental exposures impact people's health and well-being in different settings and contexts.

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Pesticides, PFAS and our food

Nick Mole, Policy Officer at the Pesticide Action Network (PAN) UK, talks to **Bea Gilbert** and **Lucy Rowland** about PAN's recent report, 'Forever chemicals' Found in UK Food, its work on pesticides, PFAS and how policy and food systems need to change to minimise health and ecosystem impacts.

BEA GILBERT (BG): Hi, Nick. To begin, could you tell us a little about how PFAS are used in pesticides?

NICK MOLE (NM): There are two main ways that PFAS are used in pesticides. Firstly, the pesticides themselves are active substances – such as glyphosate – and then there are specific pesticide products, like Roundup. Roundup itself is the active substance, and together with a lot of other ingredients makes the pesticide work properly. Some of the active substances themselves can be classified as PFAS because of their chemistry. Thirty-one of these substances have been identified, and 25 are licensed for use in the UK.

OPINION

Secondly, PFAS can also be used within a pesticide product, even if they are not the active substances within it. Unfortunately, which ones and in what quantities is more opaque because of commercial confidentiality, so at PAN we focused on the active substances in our report.[1] But in terms of PFAS entering the environment via agricultural use of pesticides, we suspect that the findings in our report were a significant under-underestimation.

BG: PFAS have now been discovered in our food chain. What should this mean for national policies?

NM: We need to look closely at their use, particularly when we're growing food, and we need to look at the entire process, right from the growth stage to the transportation and the storage of foods further down the line. We don't yet understand enough about dietary exposure to PFAS from this route – pesticides to food to humans – and the Government should be doing everything it can to address it given the prevalence of PFAS in the environment from many and varied sources. This can be easy to get on top of, and while it wouldn't solve the problem of forever chemicals in the environment, it would be quick to implement and is something that we could be doing right now.

So while we don't completely understand the health effects, we do know they are potentially harmful. And we already know that PFAS are harmful to the environment, and that they're persistent in the environment. So rather than call for more research, we need to stop PFAS pesticides entering the environment and the food chain in the first place instead of waiting years for research that might offer ambiguous answers.

From a policy perspective, we'd like to see the government take the initiative and ban the 25 PFAS pesticides, as well as look more closely at co-formulants in pesticide products to identify other potential PFAS contamination, to a ban. But change can also come from other directions: the retail chains, for example. If retailers know these pesticides are being sold in their shops, they should tell their producers and suppliers that they don't want crops and products grown using them. This could be really effective, as retail chains respond to consumers far better than governments respond to voters.

BG: Can you give some examples of the foods that show the highest presence of PFAS and why that is?

NM: Last year, we looked at the results of the Government's pesticide residue testing programme – which are limited in nature, so they don't cover a vast array of products, and certainly not everything that's available. But from the small snapshot in the available data, strawberries had the highest percentage of

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samples containing PFAS pesticides, which was also the case in in the EU as well. Things like grapes, cherries, spinach, tomatoes, peaches, nectarines and cucumbers also showed a higher proportion of contamination. A lot of this is to do with the fungicides that are applied post-harvest in storage to sustain the foods and stop them from spoiling. This is especially important when transporting produce across long distances, or if it needs to be stored for a long time (e.g. if certain foods are out of season locally).

LUCY ROWLAND (LR): Can you tell us more about the kind of work PAN is doing around PFAS contamination and pesticides, what your main goals are as an organisation in these areas and how to influence policy?

NM: There's a lot of work being done by others, such as Fidra, on PFAS specifically, and PAN aims to feed into that discussion and debate. Our overall goal is to end the use of hazardous pesticides, stop our dependence upon them and promote sustainable alternatives. At a policy level, we currently don't have a functioning pesticide regulatory system. It's very ad hoc since the UK left the EU; we don't have the capacity, the ability or (you could also argue) the desire to implement the necessary regulations. We're currently working on a national action plan following a Defra consultation on pesticide use, and we also work with UK retailers.[2] We've recently published our supermarket survey, which looks at a number of different pesticide issues, and how well (or not) retailers are tackling those.

We look at highly hazardous pesticides and retailers' approach to these, and we ask whether they are phasing them out or banning them. We also ask if they are supporting their suppliers to reduce pesticide use, and whether they are doing things to encourage biodiversity. Working with retailers is probably a more productive route in terms of global impact, because they can enact change across their global supply chains.

We have also recently published our Dirty Dozen analysis of pesticide residues in food, and that is about raising public awareness.[3] The other key strand of our UK work is the Pesticide-free Towns campaign, which is aimed at getting councils to stop using pesticides like glyphosate.[4] Currently, we've got about 100 councils of different sizes involved, from parish up to county level, that are stopping use or are dramatically reducing the amount that they use on the streets, pavements, parks and playgrounds. This work is also about raising public awareness: we support and encourage local groups to set up their own campaigns to influence their local councils.

LR: Do you think we know enough about how pesticides and PFAS contamination are harming human health? Is there anything individuals can do to limit their exposure?

OPINION

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NM: The answer to the first question is no. We know that some pesticide substances have intrinsic health consequences: they might be carcinogenic or endocrine-disrupting chemicals. And that's not us saying that; the companies that make them, as well as the regulators, acknowledge this.

The problem is that all chemicals are legislated for individually. This makes the health impacts of pesticides and PFAS an incredibly complex area, as there are millions of potential combinations. We aren't just exposed to one chemical, or even two, at a time. We are exposed every day to a combination of pesticide residues and other chemicals through our diet and through the air, and the effects of long-term exposure aren't fully understood. So while we're waiting for more research and greater understanding, we could be helping farmers and growers to reduce their input. The best way to avoid exposure is for these chemicals not to be used in the first place.

In terms of what individuals can do I would say, put pressure on politicians. Write to your MP, support organisations that have petitions, write to your local supermarket's chief executives and say you want them to address some of these key issues in their supply chains, because they will listen. I'd also advocate supporting organic agriculture in the UK, which currently is woefully low. We'd like to see a push for the Government to introduce targets for increasing land under organic agriculture: as a minimum, 10 per cent would be fantastic. We also support this in public procurement: all public organisations should have a target of 50 per cent local organic produce, which would help reduce food miles, support local producers and encourage organic production as well. So overall, there's quite a lot that could be done and the public can have a have a say in that as well. **ES**

Nick Mole joined PAN UK in March 2007 as the UK and European Programme Coordinator. Nick studied environmental science at university, focusing on hydrology, water quality and environmental hazards. Prior to joining PAN UK Nick spent six years working for the Environmental Investigation Agency as a campaigner, working on a diverse range of issues relating to investigating and exposing the illegal trade in endangered species.

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ANALYSIS

A natural health service for the 21st century?

Dom Higgins examines the growth of nature prescribing and the benefits to health and society.

Nature transforms people's lives. Evidence shows that a thriving, wildlife-rich environment benefits both physical and mental health and that people with better access to nature are more active, more mentally resilient and have better all-round health.[1]

HEALTH AND NATURE: YESTERDAY AND TODAY

The nature and health conversation has been around since at least the late nineties – from the development of green gyms at The British Trust for Conservation Volunteers (now The Conservation Volunteers, or TCV) – one of the original 'green prescriptions' – to today and the cross-government green social prescribing demonstration programme.[2] Most noticeable over the years is that the question has changed from 'Where is the evidence?' to 'How strong is the evidence?' That is progress.


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As far back as 1948, the World Health Organization defined being healthy as a 'state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity'.[3] Will a conventional medical approach achieve this? No. Should it step in when we are ill and need medicine and expert care? Absolutely.

Back to the present day, and the Government has issued a rallying cry to fix the National Health Service (NHS), asking organisations and the public about how they would go about it.[4,5] Importantly, the consultation is seeking views on three key shifts as the Government builds the next 10-year health plan for England. Two of these are a significant opportunity for the natural environment sector:

- Spotting illnesses earlier and tackling the causes of ill health; and
- Moving care from hospitals to communities.

Shifting the focus from treating to preventing illness, stopping health problems from developing in the first place, makes sense whichever way you look at it. Prevention, whenever possible, is better for people, the economy and the NHS – and nature has a fundamental role to play. The shift towards community-based health and care is an equally important element: a recognition that a social approach to health and well-being is part and parcel of a sustainable NHS and an essential part of making it fit for the future.

PREVENTING ILLNESS

The NHS cannot cope with the ever-increasing demands placed on it, especially in the winter months. Community-based models of health and well-being, such as social prescribing, are an essential part of a 21st-century health service. Activities that get people together and support them with a wide range of needs, from debt advice to taking up a new interest or hobby, can help ease the pressure on the health system and relieve the burden on mainstream services. With the right policies and investment in prevention, this cycle can be broken.

Local Wildlife Trusts have been partnering up with the NHS for some time, most recently on the Government's green social prescribing programme. Green prescribing is an evidence-based pillar of social prescribing, which


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harnesses the power of nature to improve people's physical and mental health. It involves doctors, health care providers and community groups 'prescribing' nature-based programmes to help people overcome preventable health problems. This includes helping those struggling with mental and physical health as well as addressing challenges such as loneliness, physical inactivity and a lack of contact with nature.

HOW DOES GREEN PRESCRIBING WORK?

Social prescribing link workers (and other trusted professionals in allied roles) connect people to community groups and agencies for practical and emotional support, based on a 'what matters to you' conversation – rather than a 'what's the matter with you?' one. The original referral can come from a GP clicking a button or from a local community organisation that helps people through a range of non-medical issues that can lead to illness.

The Wildlife Trusts delivers a range of projects and programmes that do this. One example is giving people the opportunity to join one of its regular conservation volunteering groups, which carry out a wide range of tasks – from tree planting and path maintenance to supported smaller-group therapeutic activities, such as food growing, nature walks or crafting. These activities offer participants a wide range of health, well-being and social benefits, particularly those with restricted mobility, older people, carers and those who are economically inactive. It is not unusual for people to come away with new skills and qualifications or with the confidence to progress to more learning or to a job.

A major evaluation of the pilot programme has been published.[6] Seven green prescribing pilots began in 2020 – each with involvement from local Wildlife Trusts. Over 8,000 people participated, with 57 per cent coming from the most economically under-served places. This is important because access to high-quality natural places is not equal. Too many people in the UK live in polluted, nature-deprived neighbourhoods:

- One-third of the population does not have nature-friendly places near home. That is nearly 9.5 million households in England;
- 6.7 million children live in areas of the UK where the air is unsafe to breathe – beyond legal limits – leading to 36,000 child deaths every year;[7]


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- People from Black and ethnic minority groups are twice as likely to live in a nature-poor neighbourhoods;[8] and
- Access to safe natural spaces for play is unequal, with children in affluent areas being nine times more likely to have access to green places.[9]

Why does this matter? In 2008, a team at Glasgow University published a study in the *Lancet* showing the impact of a lack of green space access on health inequalities.[10] The study found that the more well-off you are, the greener the neighbourhood where you live is and the less illness you have. Those who were less well-off experienced more illness; however, their health improved with increased exposure to nature where they lived. The poorest in income terms suffered the worst health of all but, critically, the greatest benefit from living somewhere green.

The cross-government demonstration programme also had strong outreach in terms of ethnic diversity, with 21 per cent of people coming from ethnic minority communities. The fact that link workers were able to reach those in areas of high socio-economic deprivation was an important result.[6] The Defra report has some eye-catching findings:

- There were big reductions in anxiety and depression symptoms and significant improvements across well-being measures, with big increases in happiness and life satisfaction alongside an increase in people's feeling that 'life is worthwhile'.[6]

- In financial terms, there was a return on investment of £2.42 per £1 invested by HM Treasury: social prescribing generates an economic return. It also compares well with other NHS interventions when looking through a cost-effective lens.

And it seems that HM Treasury is also convinced by this Government-commissioned report, as it has already invested a further £2.3 million in the pilot programme, taking it to March 2025.

The Wildlife Trusts' 2023 report *A Natural Health Service: Improving Lives and Saving Money* proves that investing in green prescribing – providing nature-based activities as a health-improvement strategy – is not just the right thing to do for individuals but is also financially prudent for both the public and private sectors.[11] Governments, local authorities and businesses all need to get behind a new wave of community-based health programmes and green prescribing is a good place to start.

The economic analysis for the report was carried out by health economists at Ricardo Energy and Environment and the Institute for Occupational Medicine. They analysed five Wildlife Trusts programmes that deliver health-focused nature-based activities. The findings provide compelling evidence that getting involved in nature projects effectively improves people's health and happiness, which in turn reduces the strain on health care providers – saving the NHS both time and money. The findings suggest that if 1.2 million people took up these kinds of programmes, the NHS could save £100 million a year. By improving individual health and addressing the root causes of health issues, green prescribing leads to an overall decrease in health care needs and associated costs.

The added benefits of the activities offered by organisations like The Wildlife Trusts, Thrive and TCV is that they are relatively inexpensive, easy to replicate and widely accessible. The activities and courses that The Wildlife Trusts run, for instance, are as varied as the people joining them – ranging from gardening to woodwork to wildlife conservation, although they can also be as simple as meeting up with others to enjoy a walk in the park.

WIDER SOCIETAL BENEFITS

It is not just individuals that benefit from doing these kinds of things – the knock-on effects help our entire society. For example, Gwent Wildlife Trust's Wild Health programme was one studied in the report. Participants get to try outdoor activities like coppicing, hedge laying and tree planting. Some become motivated by the work and go on to seek jobs or further opportunities in related areas. This ripple effect positively impacts local economies while improving community spaces. It is a win–win–win story for health, community and business.

Beyond that, it is a huge boost for nature. We need to create wilder and healthier natural places and we need an army of people with skills, knowledge and passion to do the work. Nature's recovery will not happen overnight, but empowering people to take charge of projects in their communities or to embark on nature-based careers will speed things up at a time when nature needs us most.

There are plenty of commentators talking about the long-term survival of the NHS. Nature can provide some of the answers to these challenges by shouldering the burden on mainstream services. To have the biggest impact, we need to integrate these kinds of programmes into health and social care services across the country.


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We know green prescribing works, and The Wildlife Trusts report underlines how it makes economic, social and environmental sense to scale up programmes now, not decades into the future. Of course, that requires initial investment, but the returns in terms of social and health benefits are far greater – making green prescribing excellent value for money.

Many illnesses and ailments are preventable – for example, social isolation and loneliness can lead to depression, while physical inactivity can lead to cardiovascular conditions. Green prescribing can help avoid these and stop other health conditions worsening; it can also help people to stay well while they wait for an operation. To put this into context, in May 2023, around 7.3 million people were waiting for an operation – a record high; that is predicted to rise to 10 million, meaning that one in five people could be on a waiting list.[12]

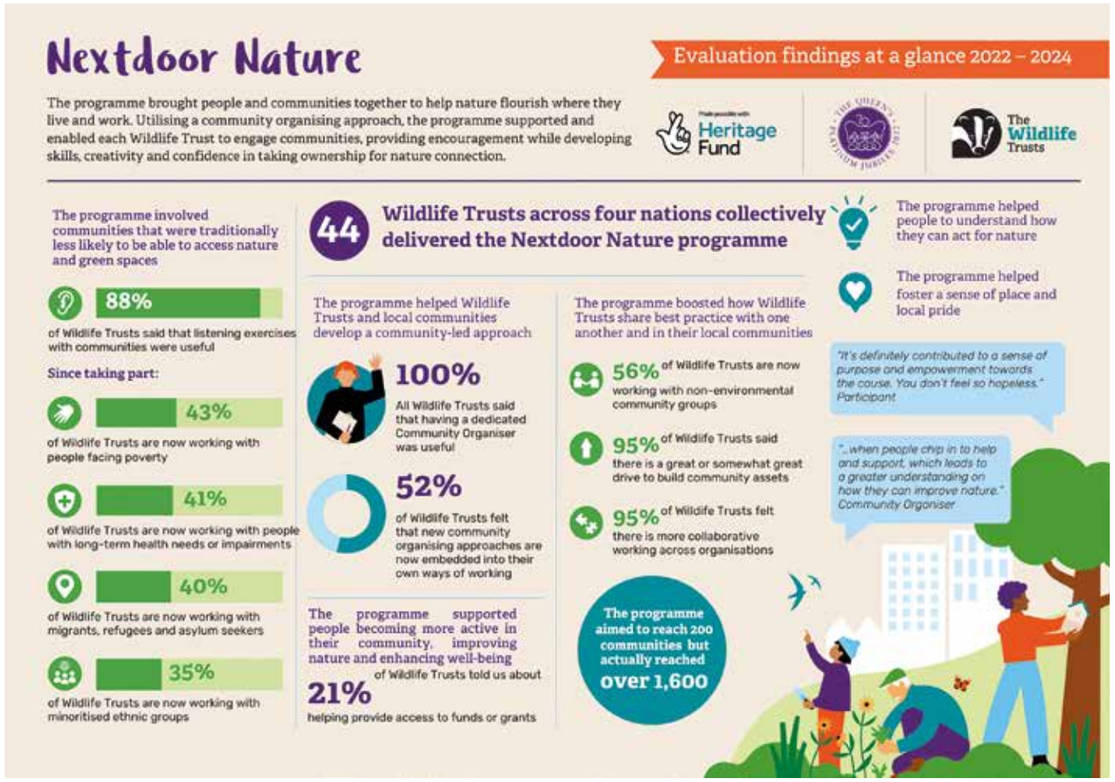
What is more, the public is crying out for greener, healthier and more natural neighbourhoods. And it is a rather sad indictment of our society that nearly 10 million people in England live in the 1,108 neighbourhoods that are the most deprived of green space.[13] Nature is becoming commoditised and a preserve of those who can afford it.

This is not good enough – but it is avoidable. The UK Government has committed to protecting 30 per cent of land for nature by 2030. If this target were achieved in every town and city across the country, far more people would benefit from a wilder, restored natural world, in addition to the health boost for those that live and work near them.

HOW CAN THIS BE ACHIEVED?

People need to be at the heart of nature's recovery, and this can happen by working together. An example of this is the Nextdoor Nature project from The Wildlife Trusts. The concept is simple: bring communities together to help nature flourish where they live and work.

Wildlife Trusts across the UK regularly go out into their local areas, knocking on doors and striking up conversations, asking people what they like and what they want to change about their neighbourhoods.



▲ **Figure 1. Nextdoor Nature statistics for the first two years of operation. (© TheWildlife Trusts)**

From there, skilled staff support those that want to make a change but may not know how. They help them self-organise – sometimes by forming official community groups, other times by coming together around campaigns or local neighbourhood greening projects. Thousands of groups across the UK have been supported by Nextdoor Nature to date, and hundreds more are continuing the work shoulder to shoulder with Wildlife Trusts across the country (see **Figure 1**).

Why does all this matter? The more time people spend outside enjoying and learning about nature, the more likely they are to help protect and restore it. We must also provide opportunities for people to spend quality time doing positive things in nature, improving their health, learning new skills, meeting others and fostering deeper connections with the natural world. Approaches through Nextdoor Nature and green prescribing do all these things and more.

We know that nature is an essential part of a community-rooted approach to health and social care: a Natural Health Service to run alongside the National Health Service. But we are not maximising that potential. Green prescribing works, and the more we can develop these kinds of programmes, the greater the benefit to society. The impact it has on societal health is enormous and investing in this work is clearly worth every penny. ES

Dom Higgins is Head of Health and Education at The Royal Society of Wildlife Trusts where he leads on policy and campaigning. Prior to joining The Wildlife Trusts, he was Director of External Affairs at TCV where he led on the development of a strategic unit to grow the impact of green gyms (one of the original green prescriptions). Previous roles include working for the Department for Education and Skills on its youth and citizenship programmes. Dom chairs Wildlife and Countryside Link's Nature and Wellbeing Strategy Group and is a member of the Green Social Prescribing Programme board and of the Health Foundation's strategic advisory board for its Health Equals campaign. He also coaches rugby league and plays in brass bands when time allows!

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The link between fungi, climate and public health

Emma-Jane Goode, Holly Lam, Sani Dimitroulopoulou and **Emma L Marczylo** consider how a changing climate may impact our health through altered fungal exposures.

TECHNICAL

We continuously breathe in airborne fungi and their components within our indoor and outdoor environments. While most fungi do not generally cause harm to healthy individuals, there are some fungal taxa that can induce respiratory infection or allergic disease in susceptible people. Climatic factors such as weather, temperature and humidity are key drivers of fungal seasonality, determining airborne fungal spore levels. It is therefore likely that our changing climate will lead to increased and more prolonged fungal exposures due to warmer and wetter weather, increased flooding, unintended consequences of net zero policies, and adaptation of fungi to such conditions that may increase their ability to cause disease through enhanced infection or release of toxins.

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This has implications for future public health, particularly for those with fungal allergies or at risk of developing allergies and disease. The UK Health Security Agency (UKHSA) has been working to determine the health impacts of fungal exposures, which includes research pertinent to climate health. This involves better understanding the fungal composition of different environments under various climate change scenarios, the associations between specific exposures and health outcomes, and the biological mechanisms underlying these associations. All are key to informing future interventions, urban planning and green infrastructure, health co-benefits and trade-offs, and public health advice.

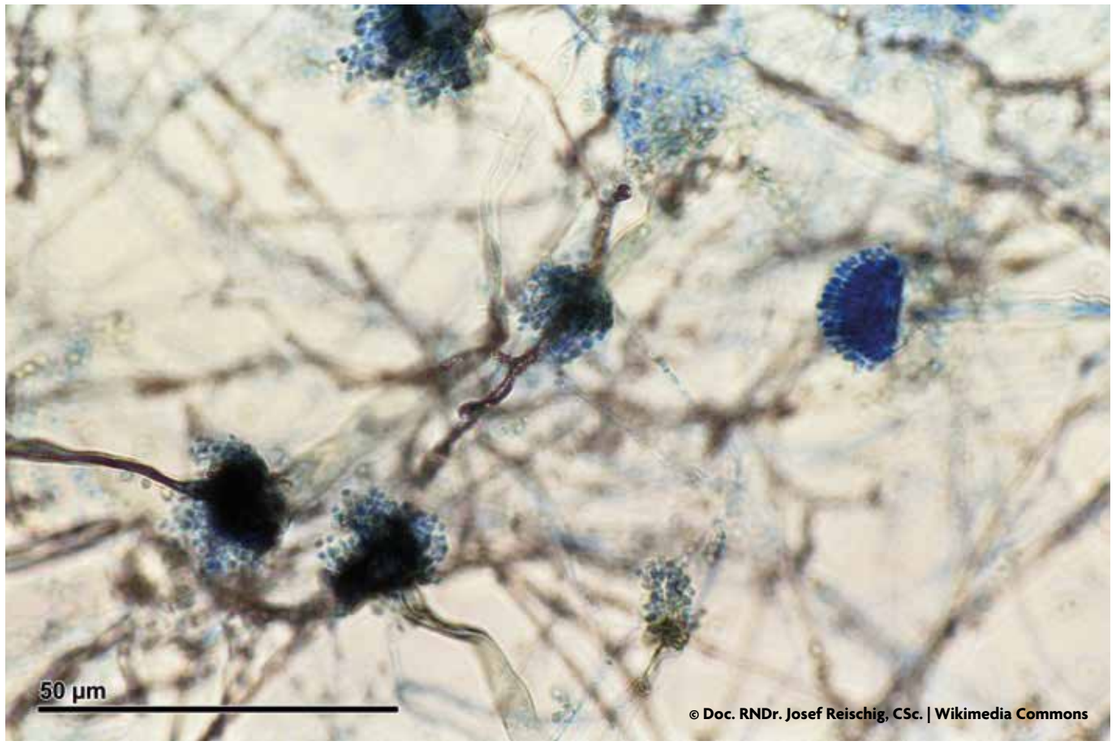
WHAT ARE FUNGI?

Fungi are ubiquitous in the environment, including in the air.[1,2] These fungal aerosols are generated when smaller particles are separated from larger fungal sources through natural processes – such as dispersion via weather conditions or human-made processes and activities, including composting, intensive farming practices and indoor activities.[1-5] People are exposed to different fungi throughout the day as they move through indoor and outdoor environments.[2,4,6,7] Climatic factors such as weather, temperature, humidity and time of year can all affect the composition and concentration of fungal spores.[8,9]

More than 18,000 fungal genera have been identified, most of which cause few adverse effects in healthy humans.[10] However, a minority (around 80 genera) can cause disease or respiratory allergy in individuals with pre-existing conditions such as asthma and other allergic airway diseases.[2,4,7,8,11,12] These include the most studied outdoor fungal aeroallergens in the UK, *Alternaria* and *Cladosporium*, and the key composting- and indoor-associated fungal genera, *Aspergillus*.[12,13,14]

Alternaria and *Cladosporium* are the only fungal spores for which there are published allergenic thresholds (with 100 and 3,000 spores per cubic metre of air, respectively, triggering symptoms in sensitive individuals).[15] These values are easily exceeded on many days during the fungal spore season in the UK.[16] While *Aspergillus* lacks such thresholds, it remains one of the most important genera for human health due to the ability of some species to both induce allergies and colonise human airways.[12] There are currently 27 fungal species from 15 genera with allergens that are officially recognised by the Nomenclature Sub-committees of the International Union of Immunological Societies, likely with others yet to be identified.[6,16,17]

Globally, diseases such as asthma and allergic rhinitis are estimated to affect 300 million and 500 million people, respectively.[18,19] Both have been linked to fungal spore



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exposure and sensitisation within outdoor and indoor environments.[7,12,13,20-26] Fungal sensitisation affects an estimated 3–10 per cent of the general global population, increasing to 7–20 per cent of asthma sufferers, 35–75 per cent of those with severe asthma, and 54–91 per cent of those with life-threatening asthma.[11,12,27,28] Up to 78 per cent of patients with allergic respiratory symptoms have been reported to be sensitised to *Alternaria*, and observational studies have measured increasing asthma and allergy symptoms in individuals living in houses with visible mould.[7,25,26,29] The prevalence of allergies, including allergic asthma and rhinitis, is increasing worldwide, including in the UK.[30]

Climate change has the potential to significantly alter the types and levels of fungi we are exposed to in different outdoor and indoor environments, potentially impacting public health by increasing the prevalence of allergic airways disease in the population and the duration of symptoms.

OUTDOOR FUNGAL SPORE SEASONALITY

A systematic review and meta-analysis of outdoor fungal spore seasonality across Europe included 74 studies published between 1978 and 2020. The most common genera, *Alternaria* and *Cladosporium*, displayed statistically significant increased season length in south-westerly (Mediterranean) versus north-easterly (Atlantic and Continental) regions. The *Alternaria* and *Cladosporium* spore seasons were six and seven months longer, respectively, in the most southerly region than in the most northerly. There was also a non-statistically significant trend for increased *Alternaria* and *Cladosporium* spore concentrations in more southerly locations, with peak concentrations of both genera exceeding clinical thresholds in nearly all locations. Temperature, precipitation and relative humidity were the main climatic drivers associated with fungal seasonality, although land use was also a key factor in agricultural and coastal areas. While there was some evidence of increased season lengths and altered spore concentrations with increasing temperature, there were too few longer-term studies across multiple decades to make any definitive conclusions.[8]

With this in mind, the associations between temperature and fungal spore seasonality were explored using the University of Leicester's unique 52-year fungal spore dataset.[9] Since 1970, the university has collected spores using seven-day volumetric spore traps operated at around 10 m above ground level, counting up to 26 key genera related to human health.[31,32] The analysis focused on four fungal genera: *Alternaria* and *Cladosporium* (dry-weather spores) and *Sporobolomyces* and *Tilletiopsis* (wet-weather spores). Associations between seasonal temperatures and accumulative daily concentrations

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within the study months were observed. In particular, the concentrations of *Alternaria* increased and wet-weather spores decreased with higher seasonal temperatures, with an earlier start of *Cladosporium* spore seasons. For every 1C increase in pre-season temperature it was predicted that the *Cladosporium* spore season would begin approximately eight days earlier. This is the longest aerobiological time-series analysis to date and suggests a warming climate will likely drive increased concentrations of, and earlier seasons for, key aeroallergens.

The ability of increased temperatures to drive earlier and longer fungal spore seasons, as well as increased spore concentrations, may cause greater fungal sensitisation in the UK population.[16] Indeed, numerous studies have correlated asthma-related hospital admissions with increased airborne spore concentrations.[33,34] Rising temperatures can also induce the adaptation of fungal species to better survive in a new climate, both in the air and on food crops, potentially increasing the ability of fungi to cause disease and resulting in the higher prevalence of fungal infection and allergy.[35-38]

In addition to increased temperatures, climate change can lead to more frequent extreme weather events including droughts, thunderstorms and flooding.[39] Fungal spores have been shown to increase directly preceding thunderstorms, and this has been linked to admissions to hospital with so-called thunderstorm asthma.[40,41] Flooding also increases the fungal burden within flood-affected homes, as well as lead to higher outdoor and indoor humidity, which induces the production of greater quantities of *Alternaria*, *Cladosporium* and *Aspergillus* allergens.[42,43]

INDOOR DAMP AND MOULD

Since the UK population spends a large proportion (up to 95 per cent) of time indoors (of which up to 66 per cent is in the home), the built environment is a key determinant of national public health.[44] UK dwellings include some of the oldest housing stock in Europe.[45] Such homes, designed during previous climatic conditions, may not function as well under changing and future climate scenarios. For example, increased flood damage to buildings and the unintended consequences of net zero policies could affect our exposure to indoor damp and mould.[45]

To reduce energy demand, achieve net zero and help alleviate fuel poverty, government initiatives have been introduced for large-scale retrofitting of homes with insulation, double or triple glazing and low-carbon heating using heat pumps. In tandem, draught proofing has been performed, and high levels of airtightness with mechanical ventilation and heat recovery, cooling measures, triple-glazed windows and low-carbon heating in new builds are promoted. However, when poorly installed, these efficiency measures can increase damp and mould growth and reduce indoor air quality.

The burden of disease from damp and mould in English housing was measured using an established epidemiological approach to estimate the number of new clinical cases and disability-adjusted life years lost (DALYs) based on 2019 data.[46] It was estimated that exposure to damp and mould was associated with around 5,000 new cases of asthma (around 2,200 DALYs) and around 8,500 lower respiratory tract infections (around 600 DALYs) among children and adults. It was also calculated that 0.9–1.8 per cent of new allergic rhinitis cases and 1.5–1.9 per cent of new bronchitis cases can be attributed to exposure to damp and mould. These estimations were based on the available English Housing Survey data, which may underestimate the prevalence of damp and mould such that the potential number of clinical cases and DALYs may be up to three- to eight-fold greater. Of particular concern is that the burden of disease was distributed unequally across different incomes and ethnicities, being 1.6–2.7 times higher for those living with a long-term illness, identifying as Black or another ethnic minority, and in the lowest income quintile.

Unfortunately, the health impact of mouldy homes was highlighted in the most tragic way by the death of two-year-old Awaab Ishak from severe respiratory disease caused by prolonged exposure to indoor mould in the Rochdale flat where he lived. As part of the Government's response to the Prevention of Future Deaths report, UKHSA together with the Department of Health and Social Care and the Ministry of Housing, Communities & Local Government jointly published guidance on damp and mould for landlords.[47,48] In particular, it addresses concerns raised by the coroner leading the inquest into Awaab's death that 'there was no evidence that up-to-date relevant health information pertaining to the risks of damp and mould was easily accessible to the housing sector'.

While the guidance is primarily aimed at social and private landlords in England, it applies to all types of accommodation providers and may also be useful for tenants and homeowners. It highlights the physical and mental health risks of damp and mould on tenants' and occupiers' health (identifying vulnerable groups), the imperative of a timely response, and practical steps to prevent and address damp and mould (stipulating the legal responsibilities of landlords in England and making recommendations for what they should consider when preventing and responding to reports of damp and mould in homes). The use of this guidance will help to improve standards in rented homes and prevent harm to tenants.

PUBLIC HEALTH AND FUTURE RESEARCH

To fully explore the fungal contribution to climate health, we need to:

1. Better understand the fungal composition of different environments under various climate change scenarios, including how fungal spores interact with air pollutants;
2. Identify associations between specific exposures and health outcomes; and
3. Determine the biological mechanisms underlying these associations.

The UKHSA has been using high-throughput sequencing (HTS) of fungal DNA – which enables the identification of a wider range of environmental fungi compared to conventional microscopy and culture – to characterise the fungal composition of different outdoor and indoor environments, including the soils from urban green spaces, outdoor urban and rural air, and railway stations.[49] This work has been performed under the National Institute for Health and Care Research (NIHR)'s Health Protection Research Unit (HPRU) in Environmental Exposures and Health (EEH) development award, in collaboration with the University of Leicester and the Health and Safety Executive; the work will continue under the new Chemical Threats and Hazards (CTH) HPRU in collaboration with the same partners.[50]

Future work will use innovative automated technology that combines artificial intelligence with holographic imaging and fluorescence profiling to measure airborne fungal spores in real time. As part of a Medical Research Council (MRC) Integrative Toxicology Training Partnership PhD grant (2019–23), the application of airborne fungal spore count, or HTS data for exposure assessment in an epidemiological analysis with seasonal asthma and allergy surveillance health data, was investigated to identify associations between specific fungal taxa and respiratory outcomes. Such health data can also be combined with real-time fungal spore monitoring in future epidemiological studies. The potential impact of the changing climate on outdoor and indoor fungal exposures and any associated health implications will continue to be explored as a cross-cutting project between the new CTH and Climate Change and Health Security HPRUs, the latter in collaboration with the London School of Hygiene and Tropical Medicine.

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A recent review of the cellular responses to fungal allergens in the lung has highlighted potential mechanisms that can drive fungal allergy and exacerbations of allergic airway disease.[2] The weight of evidence approach in this review identified the protease enzymes that fungi produce for their own growth, together with a specific receptor they bind to on the host cell surface and its associated downstream signalling pathway (the protease-activated receptor-2 pathway) as potential drivers of fungal allergy. Activation of this pathway induces increased production of mucus, disruption and thickening of the airway lining and ultimately narrowing of the airways. Other pathways of interest include those involved in airway changes (the epidermal growth factor receptor pathway), the generation and removal of damaging reactive species (the oxidative stress pathway) and modulation of the immune system (the Interleukin-33 pathway, known to be upregulated in asthmatics). Further work is required to fully elucidate these pathways and identify differences between healthy individuals and those who have a fungal allergy or sensitisation.

The review also noted the heterogeneity of models and methods used to investigate fungal allergy, which made comparisons across experimental studies difficult. This included the use of different cell models and types, and fungal species and components, with some direct contradictions between experimental studies. More physiologically relevant and fully characterised cell models are needed for further research. Such model validation is being done under the EEH award in collaboration with Imperial College London and the MRC Toxicology Unit. These models will be used in future experiments to compare the responses of airway cells to different fungal exposures, including co-exposures with different indoor and outdoor pollutants in ratios and concentrations relevant to varied climate change scenarios.[51]

CONCLUSIONS

It is likely that the changing climate will have a significant impact on both outdoor fungal spore seasonality and indoor mould exposures. Further multidisciplinary collaborative research is key to improving the assessment of fungal exposures, epidemiological associations and their causative biological mechanisms, and the potential impacts of climate change. This will help to better understand the contribution of fungi to climate health and, consequently, to develop improved interventions, urban planning and green infrastructure, health co-benefits and trade-offs, and advice to better protect the public, particularly those with or at risk of developing fungal allergies and disease

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Emma-Jane Goode is a Toxicologist in the UKHSA's Experimental Toxicology Programme. She has a background in microbiology, immunology and molecular biology. Her current research focuses on the development of in vitro models to test environmental exposures and their associated health impacts and on understanding the mechanisms behind fungal allergy. ✉ **Emma-Jane.Goode@ukhsa.gov.uk**

Holly Lam is an Environmental Public Health Scientist in the UKHSA's Air Quality and Public Health team and has a background in environmental epidemiology. Her research interests include the health effects of ambient exposure to air pollutants, aeroallergens, meteorological factors and climate change. ✉ **Holly.Lam@ukhsa.gov.uk**

Sani Dimitroulopoulou is an Environmental Public Health Scientist in the UKHSA's Air Quality and Public Health team, leading on indoor air quality and health. She is a Visiting Professor at the Institute for Environmental Design and Engineering at University College London, Chair of the UK Indoor Environments Group, and Fellow of the International Society of Indoor Air Quality and Climate Academy. ✉ **Sani.Dimitroulopoulou@ukhsa.gov.uk**

Emma L Marczylo is a Toxicologist in the UKHSA's Experimental Toxicology Programme, with a background in biochemistry and molecular biology. Her current research focuses on characterising environmental exposures and their associated health impacts, including the biological processes that link specific exposures such as airborne fungi with respiratory outcomes. ✉ **Emma.Marczylo@ukhsa.gov.uk**

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OPINION

Waste incineration: how necessary is it?

Josh Dowen and **Shlomo Dowen** explore how incinerator concerns go beyond worries about potential adverse health impacts.

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A 'NECESSARY EVIL'?

In November 2002 the UK Prime Minister's Strategy Unit (part of the Cabinet Office at the time) warned that 'at current rates of growth the amount of household rubbish will double by 2020'.[1] A 2008 Audit Commission report considered two scenarios for England's waste: stability or growth. The Commission did not investigate the possibility that waste volumes would fall. At that time the Chartered Institution of Wastes Management (CIWM)'s chief executive officer, Steve Lee, described waste incineration as a 'necessary evil'.[2]

The notion that waste was an ever-growing problem that could result in substantial financial penalties due to EU legislation gave rise to a number of waste incineration projects, in large part due to recycling and anaerobic digestion processes not being as well-developed as they are today. However, instead of either doubling or remaining stable, by 2022–3, the level of England's council-collected waste (including waste from households, businesses and recycling centres) had fallen by around 12.5 per cent from 2000–1 levels and by more than 13.8 per cent from 2007–8 levels, although there was a small rise in 2016–17 (see **Figure 1**).[3,4,5]

This downward trend is set to continue with the introduction of a statutory target to halve residual waste per person by 2042 relative to 2019 levels.[6] According to the UK Government, this will ultimately limit the volume of potential waste feedstocks available for incineration, which raises questions about the future role of incineration.[7]

So what are the so-called evils associated with waste incineration, and what can be done about them?

THE POSSIBLE HEALTH CONCERNS

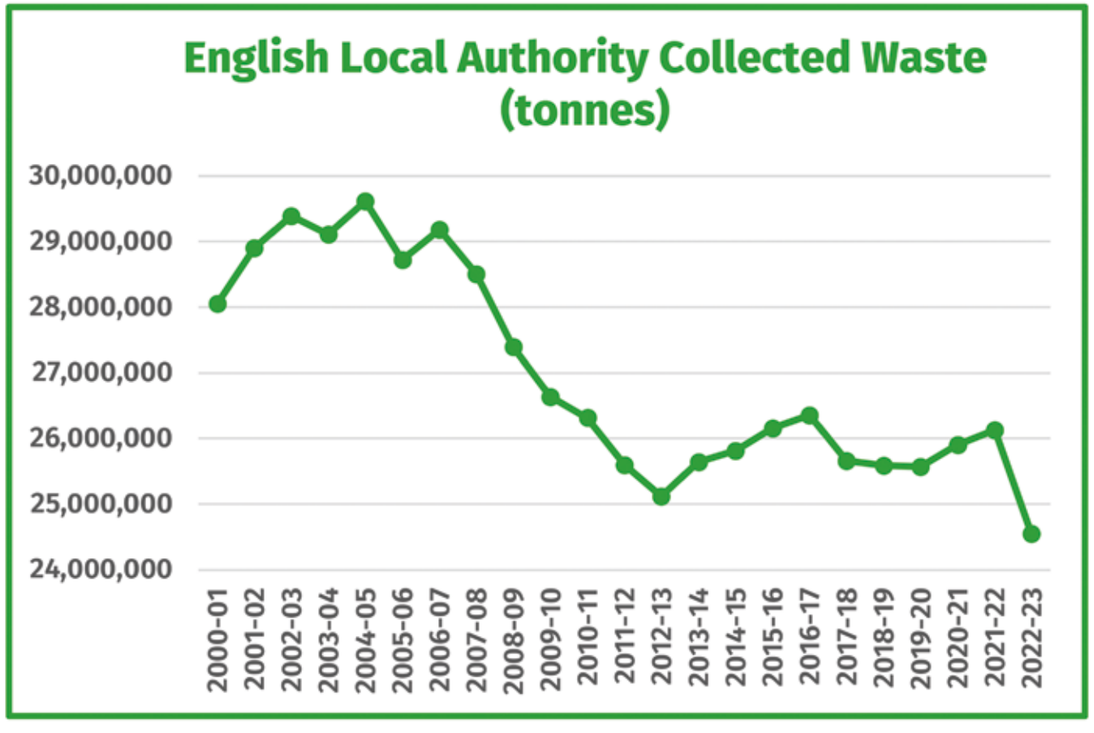
The combustion of waste results in the emission of various pollutants to air, soil and water. While the emissions to air are reduced significantly using filters, scrubbers and other measures, they are not eliminated. This results in public concern regarding the potential adverse health impacts. Some of these concerns relate to particulate matter and nitrogen dioxide – both released by waste incinerators, as well as by other industries and vehicles.[8]

While operators provide information about emissions through their annual performance reports and must comply with their environmental permits, one of the ways the public can learn about the contribution of incinerators to air pollution is through the free Plume Plotter service, which uses air quality dispersion modelling using the operator's predicted or reported emissions levels combined with local maps and real-time weather data (see **Figure 2**).[9]

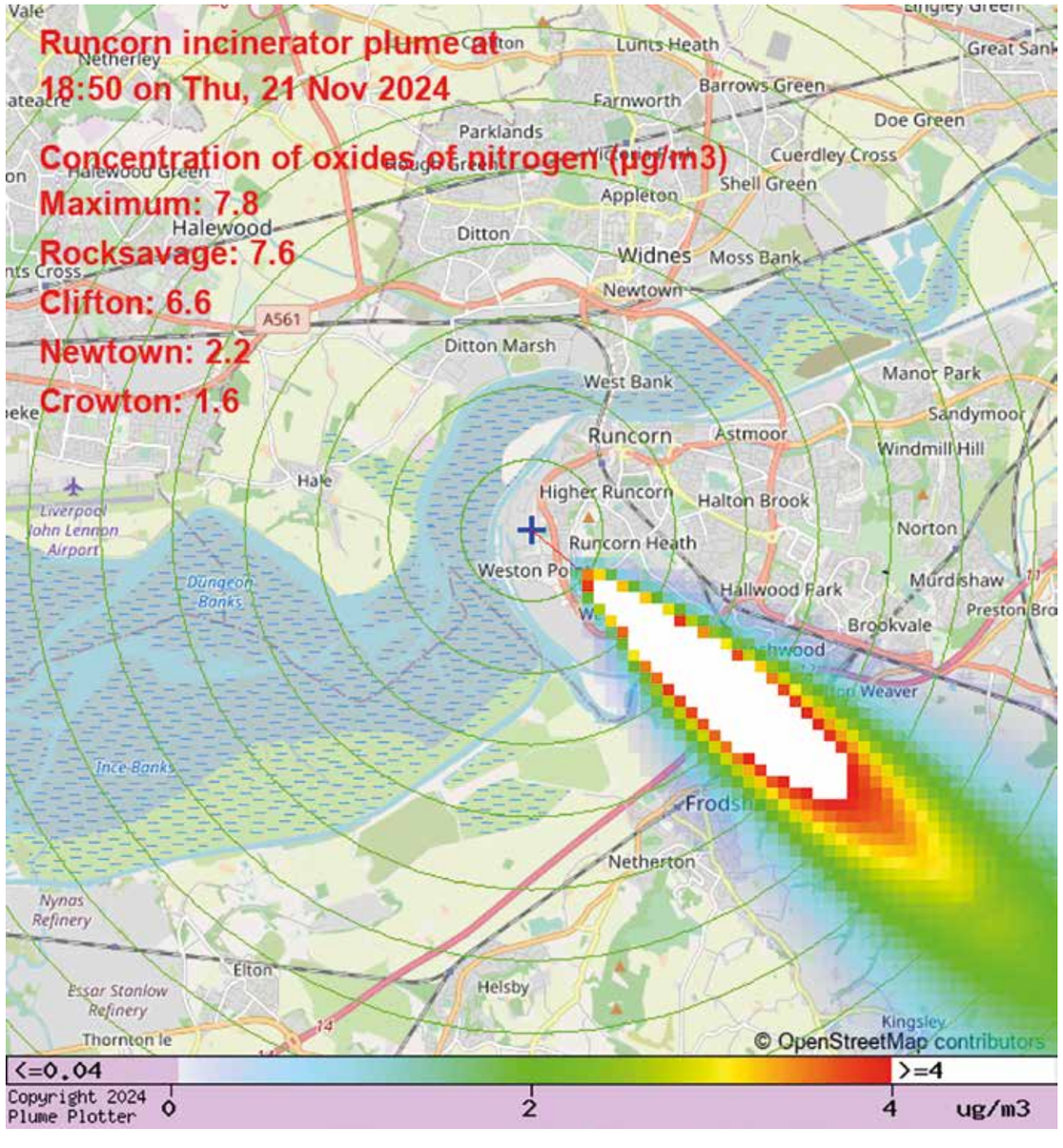
A study by Imperial College London's Small Area Health Statistics Unit assessed the risk of congenital anomalies in babies born to mothers living near municipal waste incinerators (MWIs). The study found that:

'[There is] no increased risk of congenital anomalies in relation to mean modelled PM_{10} concentrations from MWIs in England and Scotland as a proxy for MWI emissions more generally. Small increased risks (2–7 per cent) with proximity to the nearest MWI were observed for all congenital anomalies combined, congenital heart defects and genital anomalies, specifically hypospadias … It is not possible from these data to exclude a potential causal effect even in the absence of associations with modelled PM_{10} emissions; further monitoring of exposures and health outcomes near MWIs appears warranted.'[10]

The True Toxic Toll project coordinated by Zero Waste Europe and ToxicoWatch also carried out biomonitoring research focused on persistent organic pollutants, which are ingested through our diet. The research looked at chicken eggs, fruits and vegetables, and other vegetation grown near waste incinerators in the Netherlands and Spain. While high levels of dioxins were found within a 3 km radius of the incinerators,



▲ **Figure 1. Changes in waste arisings from 2000–1 through to 2022–3. (Source: Created by the UK Without Incineration Network based on Defra waste statistics[4])**



▲ **Figure 2. Plume of emissions to air from the Runcorn incinerator. (Source: Plume Plotter[9])**

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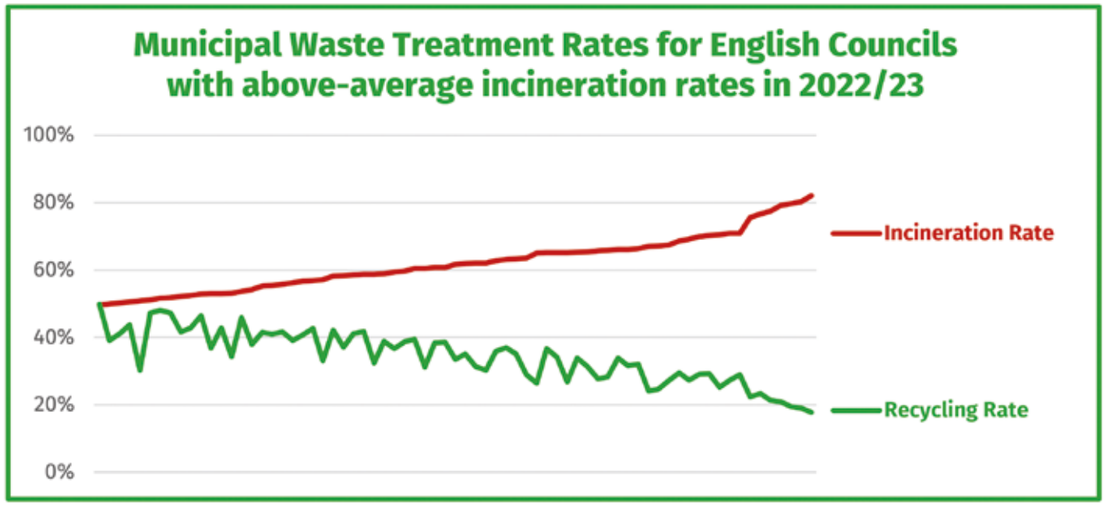

▲ **Figure 3. For councils with above-average rates of incineration there is a clear correlation between higher rates of incineration and lower recycling rates. (Source: Created by the UK Without Incineration Network based on Defra waste statistics[4])**

there is continued debate regarding the extent to which a link has been definitely established.[11] However, given these persistent organic pollutants accumulate in the body over time and remain in the environment for decades, they are of concern and further assessment is required. Similar research has yet to be published for UK incinerators.

THE AMENITY IMPACTS

An incineration company executive director, speaking about waste incinerators, told industry colleagues that he would not wish to live near one of his own firm's waste plants, stating: 'I don't think I'd want a waste facility near my home, I have to say'.[12] Many have no choice, as incinerators are often imposed on communities. In some cases where local planning authorities have rejected an incinerator proposal, the decision has been overturned following an appeal, as was the case at Portland Port in Dorset and Westbury in Wiltshire.[13,14]

The 2024 BBC documentary The Nightmare Next Door showed adverse impacts of incinerators on residents, including those living near the UK's largest incinerator in Runcorn, Cheshire. The programme quoted a resident stating: 'We have been inundated with flies, rats, smell, noise. It's just been horrendous'.[15] The BBC also found that 'the burden of the UK's waste is disproportionately falling on deprived areas such as Runcorn, which are 10 times more likely to have an energy-from-waste incinerator in their midst than in the wealthiest areas', corroborating earlier research from Greenpeace.[16,17]

In Runcorn 'around 100 people attended a meeting … to protest over the noise, smell, steam and pollution from the plant'. A local newspaper noted that residents were anxious, quoting one as saying: 'I've been awake most of the night and I'm losing the will to live. The wagons beeping their horns this morning followed by banging of containers'. The organiser of that meeting stated that 'the stress from the noise, smell and pollution is really worrying. People feel trapped. It's gone from a place where they could sit in their garden to closing doors and windows because it stinks'. The report also quoted the local MP: 'People have been complaining about a droning noise disturbing their sleep. These are genuine concerns about the vapour, noise and smells'.[18] Issues such as noise, vibration, pollution plume, flies and odours have also been reported for other incinerators over the years, including at Derby, Gloucestershire and Plymouth.[19]

THE POTENTIAL WIDER ISSUES

It has been said that even if incinerators could be made safe, they could not be made sensible, in the context of their adverse impacts on recycling, circular economy and climate.[20-23] A significant proportion of what is incinerated could and should have been recycled or composted. A Defra report found that 'of total residual waste from household sources in England in 2017, an estimated 53 per cent could be categorised as readily recyclable, 27 per cent as potentially recyclable, 12 per cent as potentially substitutable and 8 per cent as difficult to either recycle or substitute'.[24] Limiting feedstock to genuinely residual waste would free up more than half the UK's current incinerator capacity, undermining the rationale for building new ones.[25]

Many councils signed up to long-term waste contracts involving incineration. These contracts typically ensure


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that councils bear the risk of not having enough waste to burn, meaning they are penalised if they do not send enough waste for incineration.[21] Incinerators cost around £200 million to build, which is money that is not available to be spent on improving recycling. Many councils have blamed their incineration-based waste contracts for undermining their incentive or ability to invest in improvements to recycling services.[26] It is, therefore, unsurprising to find a correlation between high rates of incineration and low rates of recycling (see **Figure 3**).

The linear economy relies on extraction and processing, followed by consumption and disposal (e.g. via incineration or landfill). Extraction and disposal deplete finite resources and cause environmental and social harm. With a circular economy the value of resources is preserved, materials and nutrients that are needed to create new products are maintained, and existing resources are maximised. Incineration, seen as a 'leakage to be minimised', has no place in the circular economy, although it does generate some electricity.[27]

Incineration results in high levels of greenhouse gas emissions. For every tonne of waste burned, typically around one tonne of carbon dioxide (CO_2) is released, meaning that incineration has a higher carbon intensity than conventional fossil fuels. According to the Climate Change Committee:

'Achieving significant emission reductions in the waste sector requires a step-change towards a circular economy, moving away from landfill and incineration (and the associated methane and fossil CO_2 emissions), and towards a reduction in waste arisings and collection of separated valuable resources for re-use and recycling.'[28]

Research on the real-world performance information of incinerators in England found that they often performed significantly worse than predicted at planning and permitting stages, with the fossil carbon intensity of electricity exported to the grid around 49 per cent higher than predicted for the plants studied.[29] This is largely because incinerators emit both biogenic (i.e. from wood, paper, card and food waste) and fossil


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CO_2 (i.e. from plastic). One of the reasons that fossil CO_2 emissions are higher than predicted is because applicants under-estimate the proportion of carbon in the feedstock that would come from fossil rather than biogenic sources.

POTENTIAL INTERVENTIONS

Today's pollution abatement technologies are better than they were, and many UK incinerators operate towards the limit of what is currently achievable. In terms of reducing amenity impacts, there is often only so much more that can be done. For example, despite 'significant investment by the operator to reduce noise levels at the site', residents still complain about noise from the Runcorn incinerator.[30] Opportunities to further reduce the CO_2 released from incinerators are limited.[31]

If this plethora of problems is the price we must pay for incineration, it raises the question of whether it is worth it. Increasing numbers of countries, people and organisations think it is not. Wales introduced an incinerator moratorium in 2021. Following that ban, the local authority recycling rate rose from 65.4 per cent in 2020–1 to 66.6 per cent in 2023–4.[32] Similarly, Scotland imposed a temporary ban in November 2021, which it made permanent in June 2022 following an independent investigation into the role of waste incineration; the country's recycling rate from all sources subsequently rose from 57 per cent in 2021 to 62.3 per cent in 2022.[33,34] These figures contrast sharply with England's stagnating recycling rates of around 44 per cent (and its circa 50 per cent incineration rate).

In 2023, the Climate Change Committee called on the UK Government to introduce 'a moratorium on additional EfW [energy from waste] capacity until a review of capacity requirements has been completed'.[35] In July and September 2024, the UK Without Incineration Network (UKWIN), together with more than 50 environmental and health organisations, wrote to Government ministers highlighting the urgent need to ban new incineration capacity to enable the transition to a zero-waste economy.[36,37]

Following this logic, it could be concluded that we should not only stop building more incinerators than

we need but that existing plants across the UK should be phased out in line with falling levels of residual waste arisings and increased reuse and recycling. This principle must be at the heart of a UK-wide incineration exit strategy, with a priority on decommissioning those incinerators that are:

- Oldest, least-efficient or need costly upgrades to meet modern emissions standards;
- In areas of highest incineration overcapacity;
- Causing most amenity impacts to nearby residents;
- Causing the greatest adverse impact on human well-being; and
- In areas with high levels of air pollution from other sources due to traffic or other industries.

Many of the plants with the worst impacts also happen to be in the poorest and most disadvantaged areas, and so closure would also support greater social equity and the regeneration of these neighbourhoods.

Lastly, it is worth noting that alternatives to incineration are less costly, more flexible, quicker to implement and better for the environment. Rather than incinerating waste, local authorities should focus on maximising reuse and recycling alongside providing a weekly food waste collection for composting. ES

Josh Dowen and **Shlomo Dowen** are based in Mansfield, Nottinghamshire, and coordinate the UK's anti-incineration movement through the UKWIN campaign network. Over the past two decades they have written extensively about the adverse impacts of waste incineration.
coordinator@ukwin.org.uk
https://ukwin.org.uk/

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ANALYSIS

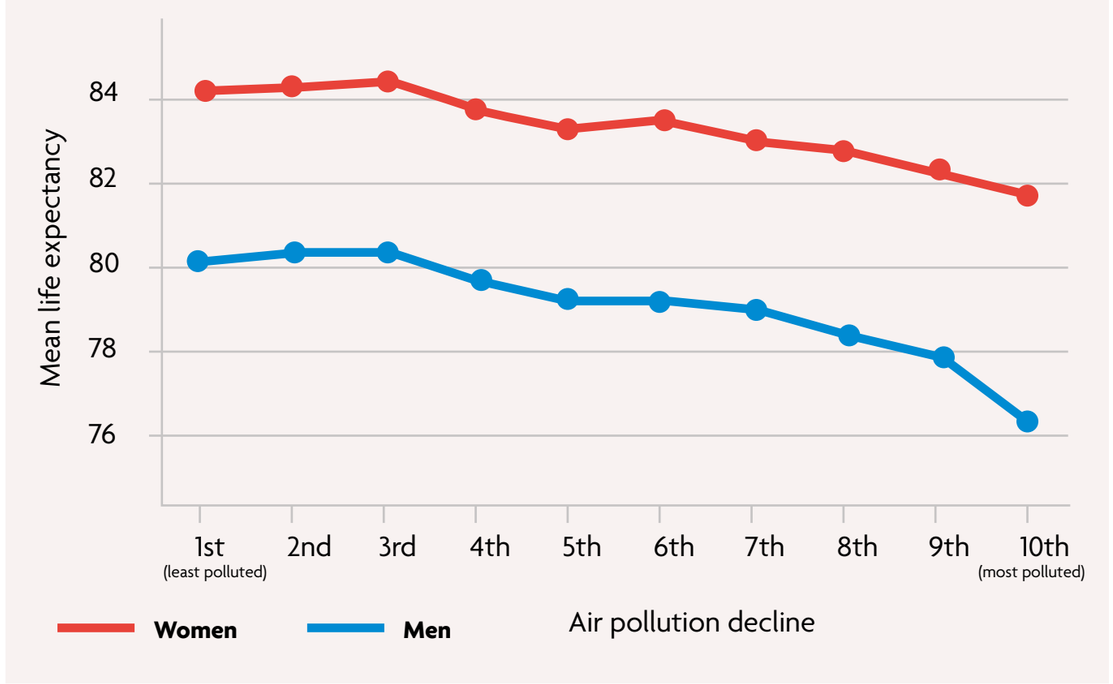
Air pollution and health

Claire Holman reviews national and international air quality guidelines and the risks to health of inaction.

It is widely recognised that air pollution is one of the greatest environmental risks to public health, despite significant improvements in air quality over recent decades.[1] In the UK the mortality burden of long-term exposure to air pollution in 2008 was estimated to be between 28,000 and 36,000 deaths.[2,3] Air pollution also adversely affects the natural environment and biodiversity and can damage crops.[1]

THE EVIDENCE

There is an extensive body of evidence to show that long-term exposure to particulate matter (PM) increases mortality and morbidity from cardiovascular and respiratory diseases. For example, long-term exposure can cause asthma, while in the short term it can exacerbate asthma symptoms, as highlighted by the coroner in the 2020 inquest into the death of Ella Kissi-Debrah. Ella, 9, lived very close to London's South Circular Road, and the coroner identified that air pollution due to road traffic was a contributory factor to her tragic death in 2013. Her death certificate is thought to be the first to include air pollution as a cause of death. Two years after the inquest into Ella's death, another coroner determined that two-year-old Awaab Ishak died due to exposure to another type of air pollution: the mould inside his home.



▲ **Figure 1. Life expectancy and air pollution levels. (Source: © The Health Foundation[4])**

In more recent years there has been an explosion in the number of studies showing other health effects of air pollution – ranging from conception to old age. Low birth weight, pre-term birth, stillbirth and congenital anomalies have been associated with exposure to air pollution.

Dementia is one of the greatest challenges for health and social care. In the UK it is estimated that 20 per cent of those over the age of 65 have mild cognitive impairment. It is thought that 5–10 per cent of people with this impairment will go on to develop dementia. Recognition that air pollution might accelerate the decline in cognitive function and contribute to the development of dementia came as a surprise when it was first suggested. Since then, a significant volume of research has been undertaken to confirm those early observations and to understand the underlying causal mechanisms.[5]

In 2022, following a review of nearly 70 studies, the Committee on the Medical Effects of Air Pollutants (COMEAP) concluded that it is likely that air pollution can contribute to a decline in mental ability and to dementia in older people. It is known that air pollution, particularly small particles, can enter the blood stream and some can reach the brain. It is also thought that particulate matter can reach the brain directly through the olfactory nerve in the nose. This is cleared slowly, if at all, from the brain and can therefore accumulate over a lifetime. This suggests that air pollution may be associated with significantly more deaths than those we already know about.

It is also well recognised that socio-economic factors play an important role, not only affecting individuals' susceptibility to the effects of air pollution but also because poorer communities are more likely to live in areas with high pollution levels or in poor-quality housing. A recent study shows that, with the exception of London, people living in neighbourhoods with lower air pollution levels tend to have a higher average life expectancy (see **Figure 1**).[6]

▼ **Table 1. World Health Organization 2005 and 2021 air quality guidelines for selected pollutants**

Pollutant	Average period	2005 (µg/m³)	2021 (µg/m³)
Nitrogen dioxide	Annual mean	40	10
Particulate matter (PM_{10})	Annual mean	50	5
	Daily mean	50	45
Particulate matter ($PM_{2.5}$)	Annual mean	10	10
	Daily mean	25	15

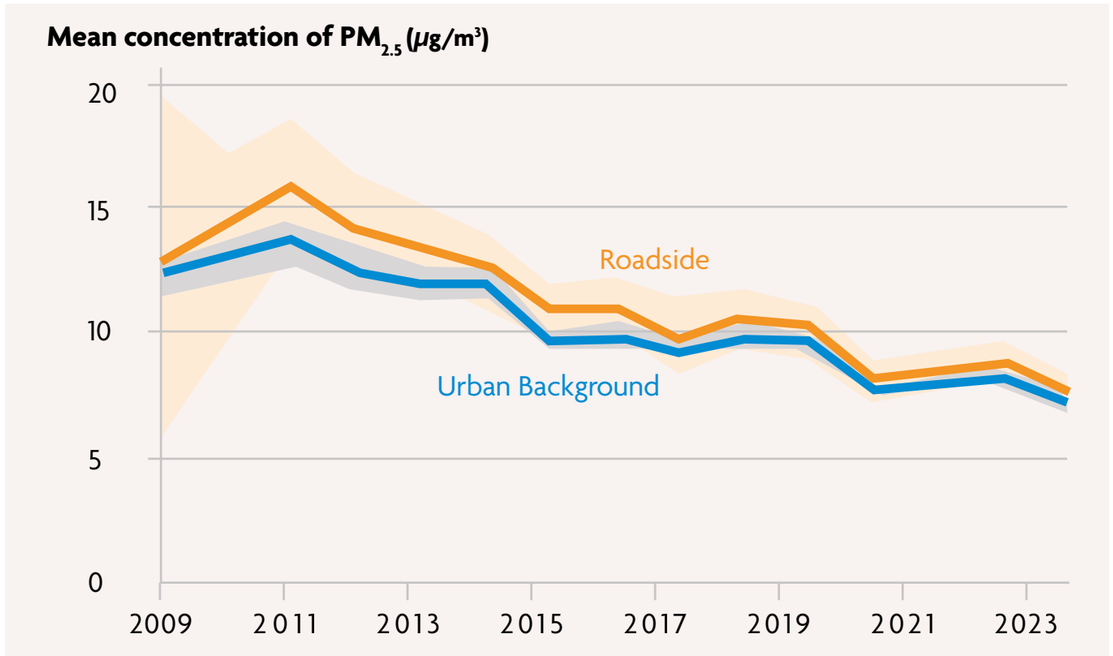
▼ **Table 2. UK air quality standards and World Health Organization guidelines**

Pollutant	Average period	UK limit values[a] [b] [c] and objectives (µg/m³)[d] [e]	WHO air quality guidelines (µg/m³)[f]
Nitrogen dioxide	Annual mean	40	10
	One hour	200 (allowed to be exceeded 18 times per year)	n/a
Particulate matter (PM_{10})	Annual mean	40 18 in Scotland	5
	Daily mean	50 (allowed to be exceeded 35 times per year)	45
Particulate matter ($PM_{2.5}$)	Annual mean	20 10 in Scotland	10
	Daily mean	n/a	15

Notes
(a) The limit values and UK (excluding Scotland) objectives are the same numerical value but compliance is measured differently. The limit values were derived from the 2008 EU Ambient Air Quality Directive
(b) Air Quality Standards Regulations 2010 (applies across the UK)
(c) The Environment (Miscellaneous Amendments) (EU Exit) Regulations 2020 (applies across the UK)
(d) Air Quality (England) Regulations 2000 (as amended)
(e) Air Quality (Scotland) Amendment Regulations 2016
(f) World Health Organization 2021 Air Quality Guidelines

▼ **Table 3. EU 2008 and 2024 Ambient Air Quality Directive limit values for selected pollutants**

Pollutant	Average period	2008 (µg/m³)	2024 (µg/m³)
Nitrogen dioxide	Annual mean	40	20
	Daily mean	n/a	50
	One hour	200 (allowed to be exceeded 18 times per year)	200 (allowed to be exceeded 3 times per year)
Particulate matter (PM_{10})	Annual mean	40	20
	Daily mean	50 (allowed to be exceeded 35 times per year)	45 (allowed to be exceeded 18 times per year)
Particulate matter ($PM_{2.5}$)	Annual mean	25	10
	Daily mean	n/a	25



▲ **Figure 2. Annual mean $PM_{2.5}$ concentrations at roadside and urban background sites 2009–23. The shaded areas show the 95th confidence interval of the mean. (Source: Defra[7])**

ANALYSIS

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AIR QUALITY STANDARDS

The UK's air quality standards are complicated and are comprised of a series of limit values, objectives and targets. Air quality is a devolved responsibility and as such there are some differences between the administrations. The standards are largely based on health evidence from the 1990s. Since then, there has been a staggering amount of research, particularly epidemiological studies, on the health effects of air pollution.

In September 2021 the World Health Organization (WHO) completed its evidence review and published new air quality guidelines for the most common air pollutants – including nitrogen dioxide (NO_2) and particulate matter ($PM_{2.5}$ and PM_{10}).[8] There are differences between the 2005 and 2021 guidelines for these pollutants (see **Table 1**). For most air pollutants these guidelines are significantly lower than the UK standards (see **Table 2**). This is because the air quality standards across the UK have, in the main, not been updated to reflect the medical evidence from the last 30 years. When setting these air quality standards, account was taken of the technical and economic feasibility of meeting them, as well as the medical evidence.

The domestic annual mean NO_2 objective should have been achieved nearly 20 years ago, in 2005, while the limit value, derived from EU legislation, was to be achieved almost 15 years ago, in 2010. The NO_2 limit value (which has the same numerical value as the UK air quality objective), continues to be exceeded in nine of the 43 UK zones.[9]

In 2021 a new Environment Act was agreed by parliament. This required the Secretary of State to set a long-term target for $PM_{2.5}$ and allows for targets to be set for other pollutants, but only applies to England. The mandatory English annual mean $PM_{2.5}$ target set in 2023 was 10 µg/m^3 to be achieved by 2040 (i.e. it is the same as the 2005 WHO guideline level, and the Scottish air quality objective introduced in 2016 that was to be achieved by the end of 2020).[10,11] A population exposure reduction target of 35 per cent by 2040 compared to 2018 levels was also set for England. Interim targets of 12µg/m^3 and 22 per cent exposure reduction were introduced in 2023, which are to be achieved by the end of January 2028.[1]

One roadside monitoring station at London's Marylebone Road exceeded the 10 µg/m^3 target in 2023. In the same year, no monitoring stations exceeded the interim target of 12 µg/m^3 (see **Figure 2**).[9]

EU DIRECTIVE LEAPFROGGING THE UK

At the same time as legislators in England were agreeing the new $PM_{2.5}$ targets in 2023, the EU was discussing revisions to the 2008 Ambient Air Quality Directive. The objective of the revised directive is to achieve zero pollution 'so that air quality within the Union is progressively improved to levels no longer considered harmful to human health, natural ecosystems or biodiversity'. The revised directive was agreed in October 2024 and formally published in December.[12]

These new ambient air quality standards are to be achieved by 1 January 2030 (see **Table 3**). However, Member States can postpone compliance for zones that will exceed the standards if they have produced a roadmap for compliance by the end of 2028, which demonstrates that compliance will be achieved in the shortest possible time. Compliance can be delayed until 1 January 2040, if justified by site-specific dispersion characteristics (such as mountainous terrain and adverse climatic conditions), transboundary contributions or where the necessary reductions can only be achieved by replacing a considerable fraction of the existing domestic heating systems that are the source of pollution causing exceedances.

In the interim period, before 2030, the 2008 limit and target values will continue to apply and Member States

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are permitted to introduce more stringent requirements. The European Commission is required to undertake five-yearly reviews of the scientific evidence related to effects on human health and the environment, with the first to be completed by the end of 2030. As well as complying with the new standards, Member States are required to provide information to the public on air quality including in relation to the 2021 WHO guidelines.

SUMMARY

We are in danger of being left behind the EU in terms of air quality standards, and there is no evidence that Defra has an appetite to revise the standards in England. Tighter objectives exist in Scotland for particulate matter, and the Welsh government is currently in the process of setting its own objectives. Because so many different factors affect our health, the responsibility for improving the health of the UK population must rest across all of society: it cannot just be the job of the health and social care system. Indeed, the NHS was never meant to act alone but was conceived as part of a comprehensive system of social insurance and welfare. Improving air quality should have an important role to play in the health debate but this does not seem to be happening. ES

Dr Claire Holman is President of the Institute of Air Quality Management and a Director of Kalaco, formerly Air Pollution Services. She is an air quality scientist with over 40 years' experience of working on air quality management. She has acted as an expert witness for high-profile air quality litigation including at Ella Kissi-Debrah's inquest.

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Stefan Bouzarovski – Professor of Human Geography
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PFAS: health and policy impacts in the UK

Stephanie Metzger spoke to *environmental SCIENTIST* about the existing and potential future policy landscape of these forever chemicals and other contaminants of emerging concern.

FEATURE

CONTAMINANTS OF CONCERN

The current policy landscape for per- and poly-fluorinated alkyl substances (PFAS) and other chemical contaminants in the UK is complex and uncertain. There are a lot of contaminants that we are only just recognising as being of concern – better known as 'contaminants of emerging concern'. This does not necessarily mean that these chemicals are new; rather, the emerging concern is that we now realise they may pose a risk of some kind, even if in some cases they have been around for a long time.


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Therefore, there is a growing amount of work and advocacy that addresses the need to get a better handle on where these chemicals are in the environment, to understand how they move around within it, and how they get into it in the first place. We can then examine how people and wildlife are exposed and how this exposure could be affecting us, which in turn will inform how we manage these chemicals.

As part of the goal to establish a clearer framework of how we study and manage contaminants of concern, the Royal Society of Chemistry (RSC) recently released a report advocating for a national chemicals agency.[1] Part of the impetus behind this report was that, prior to the UK leaving the EU, the UK was part of the wider European Chemicals Agency (ECHA), which had all 28 Member States contributing to its work. At that time, there were agencies in the UK that were tasked with feeding into the ECHA and with implementing its findings in the UK.

However, when the UK left the EU, these responsibilities were transferred back to the UK Government, with some involvement from the devolved administrations, and our system took on a lot more tasks than it was previously set up to do. As such, it has become overloaded and under-resourced, and we do not currently have enough skilled staff in the civil service to deal with a lot of the issues that have arisen, especially if new hires do not have experience of dealing with the complexities of the regulatory framework. The chemicals regulation regime is also now split across different departments including the Department for Work and Pensions, which hosts the Health and Safety Executive, Defra, the Department of Business and Trade and the Environment Agency. In some cases, these departments do not communicate effectively or efficiently, and work is sometimes duplicated.

The RSC believes that there needs to be a new system that improves the coordination across all these areas – one that takes a 'one substance, one assessment' approach. A new strategic approach should also improve the efficiency of the system: for example, the process for registering and getting decisions about chemical evaluations is slow, which presents barriers for business.

A more coordinated system could also improve our ability to rapidly respond to new developments in science and to cohesively address emerging public health and environmental issues. For example, under the current system, if one department (e.g. the Environment Agency) is dealing with the effects of pollution downstream, but there has not been the necessary coordination with other departments to prevent the pollution from entering the water system upstream in the first place, the problem will persist.

The RSC's proposed approach could involve a physical location for a national chemicals agency, with staff under this banner taking ownership of chemicals policy. Alternatively, it could be a coordinating framework that synthesises work across the existing departments. The implementation of the approach is up for discussion, but the central point is that we need a system that provides a joined-up, cohesive and strategic approach, providing efficiency and clarity for businesses and protecting public health and the environment.

PFAS: PROPERTIES AND HEALTH IMPACTS

PFAS are just one example of where it would be beneficial to have a coordinated response across governing bodies. PFAS are a large group of chemicals (currently comprising over 10,000 individual chemicals) that is continuously growing.[2]

The backbone of each PFAS chemical is an extremely stable carbon–fluorine bond. This bond renders the chemicals extremely strong and durable, making them ideal for certain products and purposes. They are oil-resistant, water-resistant, slippery and generally very stable in numerous multiuse applications. However, that stability and durability also mean that the chemicals do not break down easily in nature, and when they enter the environment from a factory or product, they persist for a long time. They are also mobile in the environment: PFAS have even been found in polar bears, which demonstrates that they do not stay in place once they have entered the environment.[3]

PFAS also bioaccumulate, meaning that they build up in our bodies (as well as in wildlife), as we cannot break them down at the same rate that we accumulate them. Unfortunately, some PFAS are also toxic, but we currently only have information on the toxicology of a handful of them. There are three broad categories that frame our overall understanding of PFAS toxicology. Firstly, there are some PFAS that we think are less of a health risk. An example of these is fluoropolymers; polymers are large molecules, so they are less likely to get stuck in our bodies. However, the science on this is evolving, so our understanding may change in the future. Secondly, there is a group of PFAS that we know is toxic. The third category is a much larger group of chemicals – the majority of PFAS for which we do not yet know enough about their health effects.

Because it would be far too time and labour intensive to perform toxicology tests on every individual molecule of the 10,000 chemicals under the PFAS banner, scientists are trying to classify PFAS by their chemical structure and assess them as a group. In the USA, the Environmental


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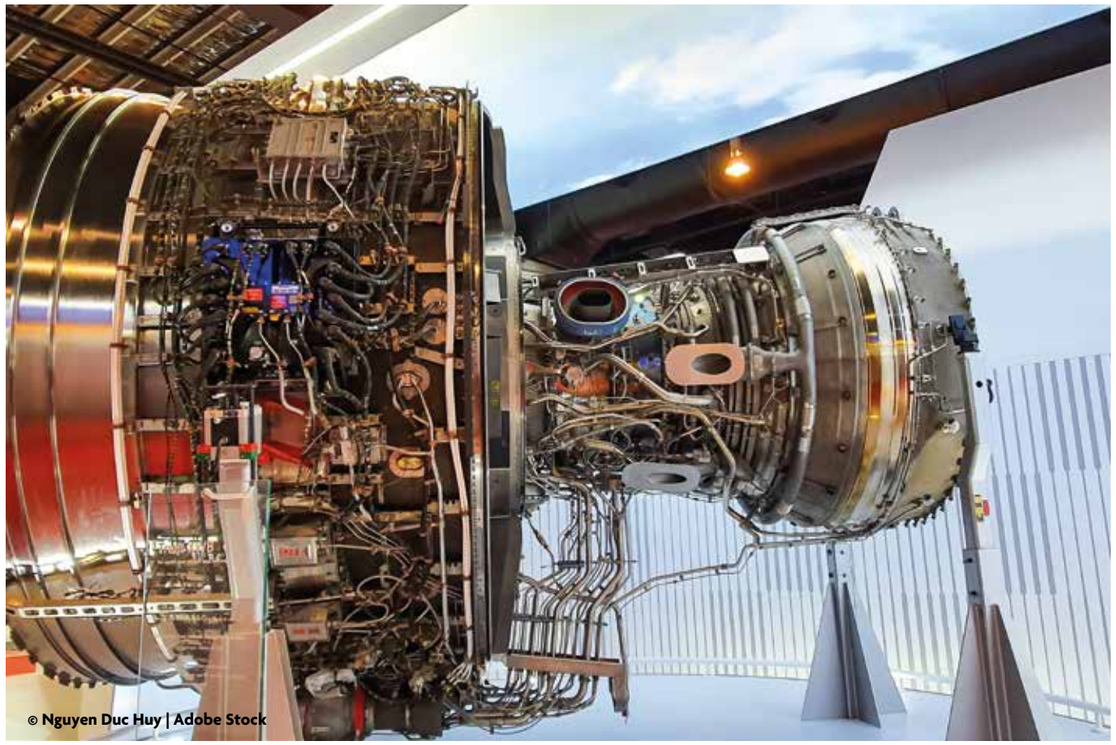

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Protection Agency applied a testing programme that categorised PFAS into a number of groups. These were then broken down into around 70 subgroups.[4] The goal was to find a representative molecule for each subgroup, taking the view that understanding that representative molecule and its properties might be applicable to the wider group's chemicals. From a policy perspective, this approach could help us to prioritise which subgroups we need to focus future research and policy interventions on.

For the group of PFAS chemicals that we already know are harmful, actions must be taken to protect and mitigate harm. This is relevant to two of the oldest kinds of PFAS: per-fluorooctane sulfonate (PFOS) and per-fluorooctanoic acid (PFOA). These chemicals have been shown to affect human health: they have been associated with liver and kidney cancer, thyroid issues, immune suppression, high cholesterol, developmental issues and fertility problems, to name a few. PFOS was restricted by the Stockholm Convention on Persistent Organic Pollutants in 2009 – the first PFAS chemical to come under international regulatory action. PFOA was also added to the Stockholm Convention restriction in 2019 and, in 2022, per-fluorohexane sulfonate (PFHxS) was also included.

PFHxS is part of a newer generation of PFAS chemicals that were developed as replacements for PFOS and PFOA when they were phased out. Another example is hexafluoropropylene oxide dimer acid (HFPO-DA), nicknamed Gen X. Originally, these newer chemicals were intended to be less toxic; unfortunately, it was revealed that they are still toxic but with a slightly different mechanism to PFOS and PFOA due to their different molecular size. This changed how the chemicals move within our bodies and how they affect our biological mechanisms. The international agreement to either heavily restrict or ban the use of PFHxS was therefore a necessary and timely step in PFAS regulation.

As is the case with many contaminants of emerging concern, the health effects derive from cumulative exposure over time; they are not acute. With an acute type of contamination, such as an *E.coli* outbreak in our water supply, there is an immediate and identifiable health issue that can be addressed immediately. However, PFAS and many other contaminants of emerging concern have an impact on health that is gradual as they accumulate over time. PFAS levels in drinking water are measured in micrograms to nanograms per litre, so while the amounts are small, the impacts can add up over time. It can take years or even decades to identify these impacts, and it is difficult to separate them from the impacts of contaminants from other environmental, genetic, lifestyle or dietary factors that can also affect health. Consequently, if we do not deal with PFAS and other contaminants of emerging concern soon, it will be too late by the time we see health effects.

CHANGES NEEDED TO PFAS MANAGEMENT

Ongoing research into PFAS is important, but it can depend on available funding. It is also difficult to ascertain which areas of research should be prioritised. One area that is not currently well understood is PFAS in soil and sediments and its mobility within these environments. There are many questions around how contaminants of emerging concern in soil might affect agriculture and how they are transmitted into the soil through sewage sludge and its use in fertilisers. It is imperative that we begin to understand the state of contaminants such as PFAS in our soils, and this is an area in which the environmental sciences and environmental chemistry are crucial. Yet in terms of addressing their presence, there is a lot more work to be done. For example, in the source–pathway–receptor model, we can query the source of PFAS, how they arrived in a particular location and where they end up.

However, this is the end point. We need to prevent PFAS from getting into the environment in the first place. There are various ways we can address this fundamental issue: the first is questioning where PFAS usage is necessary in our manufacturing and supply chains. For example, a raincoat might be coated with PTFE or another fluoropolymer molecule to make it fully waterproof, but there now numerous companies that are making raincoats with coating technology that is free of PFAS; so we can look at substitution options. There are likely to be some areas of industry that will need to continue using PFAS, at least for now. There are some very high-tech applications. For example, PFAS are used in airplane wiring – a use case where the applied chemical is essential to the functioning of the plane, and, therefore, critical.

In important cases like this, another way of preventing PFAS from entering the environment might be to ensure that products or materials are marked to indicate that PFAS has been used. For example, when the airplane is decommissioned, the PFAS can be taken out and disposed of appropriately. We must also ensure that there is suitable environmental permitting in place to control these particular uses and to prevent the release of contaminated factory effluent. In this instance, the Environment Agency could use its permitting powers to ensure that facilities using PFAS test their wastewater and treat it before it gets into the environment in order to prevent pollution.

CONCLUSION

Contaminants of emerging concern, particularly PFAS, are divisive in environmental and policy circles, with some calling for an outright ban and others advocating for their use due to their stability and durability. While there is undoubtedly a middle ground, the most important factor is that we consider the entire life cycle of these chemicals from manufacture to disposal. Historically, our paradigm for regulation was to focus solely on use of chemicals, rather than asking whether the products were sustainable and ensuring people and the environment were protected from potential adverse effects from waste and pollution. Thankfully, we are now approaching a paradigm shift in chemicals policy and regulation: we are realising that the whole life cycle must be considered, which is a much more robust approach to using chemicals and materials responsibly – and this will protect human health and the environment in the long term. ES

Further reading

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Stephanie Metzger is a Policy Adviser at the RSC and works on sustainable chemicals policy. Her background in policy and economics helps bridge the gap between science and policy on complex questions about chemicals, waste and pollution. Her current work is focused on PFAS risk management, UK chemicals strategy and international action on pollution at the United Nations Environment Programme.

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CASE STUDY

Health, gender and climate justice: a solutions-based approach

Jainaba Badjie and **Ana Bonell**
investigate the role of women in The Gambia in bringing about change.

The Gambia is a country that is highly vulnerable to the impacts of climate change and where that reality is experienced in many people's daily lives. Despite the country and the wider West Africa region having contributed almost nothing to anthropogenic climate change, both are particularly affected by the extreme weather events, food insecurity and changing exposures to vector-borne diseases that result from climate change.

There is an argument to be made that climate impacts are gendered and, therefore, that effective solutions must be gender-focused. For context, The Gambia has shown remarkable progress over the last 30 years, with increased life expectancy and reduced infant, child and maternal mortality. It is also one of the few countries that has committed to making Nationally Determined Contributions to meet the Paris Agreement requirements.[1] However, while there is strong political will to tackle climate change and there have been improvements in the country's Human Development Index ranking, inequality remains a serious challenge and gender inequality a major issue.[2]

ENVIRONMENTAL IMPACTS AFFECTING WOMEN

There are several reasons why climate change impacts men and women differently. Women still make up the majority of those living in extreme poverty, which makes them both more vulnerable and less able to adapt to climate stressors.[3] The Global Gender Gap Index documents progress towards gender parity in terms of economic opportunities, education, health and political leadership. No country has yet achieved full gender parity. One aspect of this is the cultural and social pressures in many countries, where women bear the responsibility of being the primary family caregiver, and this holds true in most parts of The Gambia. This means that women are responsible for purchasing or growing food, for collecting water and firewood or fuel for cooking, for preparing meals, for childcare and for children's education.

Environmental and climate changes affect many of these tasks and, in turn, the physical and mental strain placed on women. For example, there is clear evidence that environmental change threatens the ability to both grow and buy food, with a resultant impact on health and nutrition.[4] In an effort to understand the impact of climate change and heat on pregnant subsistence farmers in The Gambia research showed that almost all female farmers interviewed experienced stress related to food scarcity.[5] This will worsen in the coming years as the supply–demand gap in The Gambia increases due to climate change impacts on crops and population growth.[6] The health impacts of under-nutrition (e.g. increased risk of mortality, morbidity, and infection, and longer-term outcomes on cognitive function) have been well documented and are particularly harmful during pregnancy when intergenerational effects (i.e. impacts that affect multiple subsequent generations) can occur.[7]

The pressures of food insecurity are often compounded by extreme weather events, including heat events, storms and floods, all of which can have particularly harmful effects during pregnancy and in early life.[8,9] Pregnant people and their unborn children are at particular risk from heat stress. Heat exposure increases the risk of developing pre-eclampsia, gestational diabetes, and severe conditions such as sepsis and bleeding.[10] Exposure to extreme heat increases the risk of these maternal health outcomes, and of anxiety and depression, and has been linked to an increased risk of intimate partner violence.[11,12,13] The evidence of the harmful effects of heat exposure on pregnancy outcomes is even stronger than that of the impacts on the mother. Almost all studies examining the effects of heat stress on pregnancy have found that it increases the risk of pre-term birth, stillbirth, miscarriage, congenital abnormalities and low birth weight.[14–18]

These gendered climate change impacts demonstrate that any interventions and actions taken to mitigate its effects must also address gender inequality and the extra health burden placed on pregnant people and mothers.

THE HEALTH BENEFITS OF SOLAR COOKERS

When viewed through a climate justice and gender lens, finding more sustainable and healthy fuel alternatives is predominantly a challenge for women in industrialising countries. Transitioning to clean cooking alternatives would primarily benefit women both directly through improved air quality and indirectly through the climate change mitigation potential of cleaner energy sources.[19]

The use of solar cookers in The Gambia was explored based on previous engagement activities around youth-led climate solutions, where these cookers were championed.[20] Solar cookers work by capturing direct sunlight and converting it to heat for cooking. They have been regularly promoted as an alternative solution to the energy crisis, especially in sub-Saharan Africa where the abundance of sunlight creates an ideal environment for this technology to thrive.[21] However, uptake has been low, including in The Gambia.[22]

To learn about solar cooker use with and from women in The Gambia and to evaluate the potential of scaling up the use of these cookers, two prototypes (parabolic and box ovens) were tested in the community. The objectives were to share knowledge about climate change and its environmental effects, offer opportunities to become familiar with solar cookers, develop and test different dishes and hold a community engagement event (see **Figure 1**).

The community event included women's groups, students, government representatives, research scientists and climate change activists to allow cross-fertilisation of ideas and to disseminate information (see **Figure 2**).

There were several key take-home messages on the implementation and scalability of this option for reducing reliance on fossil fuels. Although solar cookers can be made using locally available materials, their construction requires specific technical skills and

▲ Figure 1. Experimenting with cooking a staple local dish (benechin) using a parabolic solar cooker. (© Medical Research Council Unit The Gambia at the London School of Hygiene and Tropical Medicine)

▲ **Figure 2. Master of ceremonies, Alhagie Ndow, explaining the principles and benefits of solar cookers. Parabolic models are shown in the top row and oven models are shown on the tables. (© Medical Research Council Unit The Gambia at the London School of Hygiene and Tropical Medicine)**

knowledge to ensure solar energy can be effectively focused to reach the required cooking temperatures.[20] Therefore, it would be especially powerful if women learned the necessary technical skills to build the cookers, further taking ownership of the challenges they face and influencing their health outcomes.

Additionally, end-product costs for even the simplest solar cooker remain relatively high and local producers are unable to scale up their efforts to lower these costs for consumers. Lastly, although technical advances are continually improving the efficiency of solar cookers, participants still considered cooking times to be too long compared to using coal or wood.[23] However, some of the positive elements reported included an ability to perform multiple tasks simultaneously while cooking, improved cleanliness, health benefits due to reduced exposure to smoke, reduced environmental impacts and medium-term economic savings on fuel.

By understanding the climate stressors on everyday lives and listening to potential alternatives from within the community, solutions can be found. Empowered women can be impressive drivers of change in adapting to the challenges of climate and environmental change and becoming climate action leaders in their communities. It is a reminder that when we invest in women, we strengthen communities and make lasting progress toward a greener, healthier and more resilient future. ES

Jainaba Badjie is a Scientific Officer at the Medical Research Council Unit The Gambia at the London School of Hygiene and Tropical Medicine. She is currently running a project aimed at understanding the impact of heat stress on pregnant people in The Gambia through a multi-stakeholder approach and at co-producing potential solutions.

Ana Bonell is an Assistant Professor and clinical academic at the Medical Research Council Unit The Gambia at the London School of Hygiene and Tropical Medicine. Her work focuses on understanding the impacts of extreme heat and climate change on vulnerable populations, including women and children, and she explores the developing evidence for sustainable, health- and gender-focused solutions.

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ANALYSIS

Air pollution and environmental justice in the UK

Jo Barnes draws on a forthcoming Air Quality Expert Group report, looking at the links between exposure to pollutants and social inequalities.

WHAT IS ENVIRONMENTAL JUSTICE?

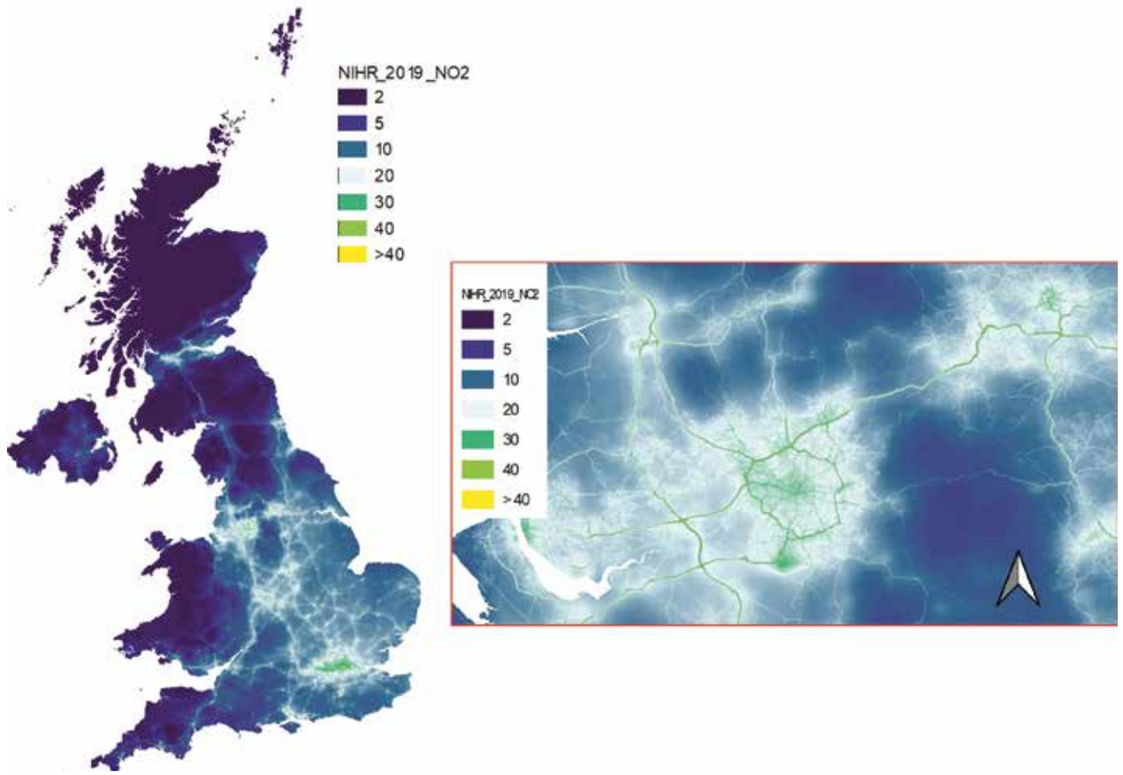
To fully get to grips with understanding environmental justice in relation to air quality in the UK it is useful to consider two things. First, how vulnerable groups are unequally affected by air pollution (distributive justice) and, second, whether there are systemic processes that perpetuate those inequalities in terms of decision-making (procedural justice) and policy implementation (policy justice).[1]

In the USA, environmental justice is well established having grown out of the civil rights movement and generally been driven by citizen activist groups. It has subsequently been the subject of a series of Presidential Executive Orders that have established environmental justice as a holistic, whole-of-government, cross-sectoral

responsibility that covers air, land and water, and which attempt to tackle the systemic, underpinning structural issues that have led to such inequalities.[2]

We have not had the same experience in the UK, although there are relevant policies in place such as the 1998 Aarhus Convention, the Equality Act 2010, the Levelling-up and Regeneration Act 2023, and Defra's 25 Year Environment Plan. The latter aims 'to ensure an equal distribution of environmental benefits, resources and opportunities' and 'to improve social justice by tackling the pollution suffered by those living in less favourable areas'.[3]

Taken at face value, most UK air quality policy has tended to apply equally to all members of society irrespective of their social group, but also irrespective of their specific needs. Whether this is deemed fair may depend on an individual's concept of justice. Different people may have contrasting beliefs about the role of distributive considerations in decision-making, the relative importance of progressive versus regressive policy and, ultimately, about what is fair.



▲ **Figure 1. Model-estimated UK-wide annual average nitrogen dioxide concentrations ($\mu g/m^3$) for 2019, at 20 m resolution close to roads. Inset red box section shows Manchester and the broader northern England region. (Source: Sean Beevers, Air Quality Expert Group[4])**

POLLUTANT DISTRIBUTION

It may be argued that unequal distribution of air pollution is not necessarily unjust. Air pollution concentrations vary across the country depending on many factors, not least the pollutant itself. On the one hand, nitrogen dioxide (NO_2), for instance, has historically come from fossil-fuelled traffic in our urban areas (although this is reducing as vehicle fleets become cleaner) and, as a highly reactive pollutant, drops off quite quickly away from roads. Consequently, those living in more densely trafficked areas and close to busy roads are more likely to experience higher NO_2 concentrations (see **Figure 1**). Ozone (O_3), on the other hand, due its inverse chemistry with NO_2 demonstrates the opposite pattern: higher concentrations in rural areas and lower near roadsides.

Particulate matter (PM) more closely resembles NO_2 in distribution, being higher in urban areas. However, there is less local variation, as fine particulate matter ($PM_{2.5}$) has a relatively long atmospheric lifetime (several days) and a range of primary and secondary sources that create high background concentrations. There is also

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a large-scale gradient in $PM_{2.5}$ (and NO_2) distribution from south-east to north-west. This is driven partly by sources on mainland Europe, English Channel shipping and higher population densities in the south-east, and partly due to greater rainfall and windspeeds in the north of the UK, which lead to greater $PM_{2.5}$ washout and dilution. Within an individual urban area, the gradients in long-term average concentrations will be determined by local primary sources that are superimposed on to background secondary pollutants. However, the UK north–south difference in $PM_{2.5}$ concentrations may have a more significant effect on differentials in air pollution than intra-urban differences.

The backdrop of potential differential exposure to a small range of health-damaging pollutants is therefore complex. However, one consequence of an uneven distribution of air pollution is an uneven distribution of health and ecosystem impacts, with some locations and communities experiencing higher pollution (and therefore greater impacts) than others. Distributional environmental justice occurs where these uneven effects are disproportionately related to social factors, such as socio-economic status. Evidence has shown the combined health effects of air pollution exposure and deprivation are greater than the sum of their respective parts, with modified and strengthened associations identified that relate to all-cause and respiratory disease mortality, especially in the most deprived areas.[5] Not accounting for such socio-economic differentials in managing air quality, therefore, will likely lead to policy inefficiencies (and potentially issues with policy justice), as doing so fails to recognise that, in more deprived communities, per person per unit of exposure will lead to greater damage and associated health costs.[6] To gain a more accurate representation it is important, however, to consider a range of pollutants and different sources cumulatively.

ENVIRONMENTAL JUSTICE STUDIES IN THE UK

Existing environmental justice studies in the UK have largely focused on single pollutants and sources; therefore, there is a risk of presenting a skewed or biased picture. That is not to denigrate these studies, which have been conducted for a specific remit or as part of a larger study, and have usefully highlighted areas where there are clear differentials in exposure to concentrations of NO_2 and particulate matter relating not only to socio-economic status but also to ethnicity and age.[7,8,9]

Other studies have looked at the differential relationships between pollutant sources and people.[10,11] Although exposure to pollutant concentrations is more


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closely related to health outcomes, using emissions data enables studies to look at disparities in relation to specific emission sources, which can be useful in terms of managing such emissions. Considering where activities that produce air pollution emissions occur, and who is producing them, allows us to explore environmental justice issues.

Most studies use quantitative approaches to assess differentials in distribution of air pollution in relation to these social factors. These include proxy methods (e.g. proximity between properties and a polluting source), using personal monitors to assess exposure levels throughout the day; dispersion modelling to predict pollutant concentrations from specific sources; ecological (or area-based) analysis, matching pollutant concentrations with census data based on census geographies; or a blend of methods.

Some studies have used qualitative approaches, engaging directly with affected communities to understand their lived experiences. As well as determining exposure effects, qualitative methods can be used to evaluate differences within social and economic groups' attitudes to air quality policies.[12] There is evidence to suggest that inequitable access to air quality data may also result in differential exposures, as some sectors of society may be better-informed and take evasive action.[13,14] There is arguably a need for more qualitative approaches in providing depth of understanding to complement the quantitative studies.

ENVIRONMENTAL JUSTICE STUDY LIMITATIONS

As mentioned, studies that focus on a single pollutant or source in isolation might result in a potentially misleading assessment of the impact. Central to this issue is an understanding of the differential impacts that pollutants have on human health and their relative exposure-effect timescales, which remains uncertain. Studies often use long-term average values (annual mean) to determine differential exposure, but these may miss differentials relating to short-term pollution episodes. Similarly, using average (mean/median) values may miss the disparities associated with higher outliers. Areal-based analyses (e.g. based on census geographies) normally present population-weighted means, so do not accurately reflect the variability of air pollution concentrations within – limiting the conclusions that can be drawn for inhabitants.

Using residences as indicative of long-term exposure may not accurately reflect personal exposure throughout the day (i.e. by excluding workplaces and commuting), whereas focusing on outdoor air quality alone may miss differentials relating to indoor exposure. While many of the existing studies would benefit from being updated, when it comes to better reflecting disparities in individuals' total exposure there is clearly a need for further research and policy focus.

RESEARCH AND POLICY POTENTIAL

Indoor exposure. So far, most studies have focused on outdoor air pollution, but some research has started to look at differentials in exposure to indoor air pollution. As well as ingress of pollution from outdoor sources, there are numerous sources of indoor air pollution (including gas cooking, solid fuel and incense burning, cleaning, decorating, smoking and mould).

How these emissions sources and residents' exposure to them vary with socio-economic or demographic variables is complex and under-researched. For instance, there is some evidence that lower-income households may be more exposed to emissions related to cooking practices; whereas, the trend for wood-burning stoves in more affluent households means this group may be more exposed to $PM_{2.5}$ emissions.[15,16] Smoking is closely linked to socio-economic status, and the presence of mould, particularly in rental properties, can be fatal (as in the case of Awaab Ishak, the two-year-old boy in Rochdale, Greater Manchester, whose death sparked new legislation to force landlords to inspect and repair mould within set time limits[17]).

Other factors linked to socio-economic status will also play a role, such as the size of the property and the number of residents, which will affect their ability to avoid sources within the home. The upkeep of the property will also matter, not just regarding the presence of mould but also around whether extraction fans are present (and working) or whether windows can be opened. While poorer households, perhaps in poorly insulated properties, may feel forced to keep windows closed to conserve heat in colder weather, newer buildings designed for energy efficiency can also have poor ventilation, leading to higher concentrations of indoor pollutants. In properties close to outdoor pollution sources, such as busy roads, residents may prefer to keep their windows closed.

Travel exposure. Returning to the outdoor environment and considering how people are exposed to air pollution throughout the day, it is important to consider differential exposures related to travel modes. Up to a third of daily exposure can happen in the relatively short period spent travelling between locations; yet how much pollution an individual experiences will also depend on the mode of transport. Typically, users of motorised modes tend to have higher exposures to NO_2 and $PM_{2.5}$, with those commuting by car having the greatest, and underground rail users also being exposed to high concentrations of PM_{10}.[18] Lower-income households, which are less likely to have access to a vehicle, may benefit from lower exposure if walking and cycling more, but their dependence on public transport and associated longer journey times can lead to greater exposures. Children can also be at risk on their routes to school, but their exposure can be significantly reduced if able to use back streets to walk or wheel (e.g. cycle or scooter) rather than be driven.

Occupational and workplace exposure. Although exposure to air pollution when at work comes under health and safety legislation – and so is not assessed in the same way as public exposure to air pollution –


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it is still important to consider the differential exposures experienced by different occupations. Professional drivers – including couriers, waste removal workers, heavy freight drivers, utility services, bus drivers and emergency services providers – risk elevated exposure, with taxi drivers in London identified as particularly affected.[19] Other outdoor occupations, such as street cleaners, refuse workers, traffic police, cycle couriers, construction workers, maintenance workers, newspaper sellers, gardeners, teachers and security guards are all professions where there is the potential to be exposed to higher levels of air pollution. The British Safety Council has called for employers to take more steps to protect outdoor workers from air pollution and for more action to reduce sources and exposure.[20]

For those working or studying in indoor environments, exposure to air pollution may be lower or higher than if just using their residential location as a proxy for exposure. Taking workplace exposure into consideration can increase overall exposure for those in the least-deprived and white ethnic groups, thereby reducing the differentials observed in studies based on residence alone.[21]

CONCLUSION

The varied distribution of pollutants and sources across the UK may underpin some of the differentials experienced nationally, with higher concentrations of NO_2 and $PM_{2.5}$ found in the more affluent south-east. However, several studies have identified environmental justice issues related to differential exposures to specific air pollutants or sources, which are frequently linked to urban areas. While there is scope to update these studies with the most recent concentrations, emissions and census data, there is also a need to consider cumulative exposure to the range of pollutants a person experiences throughout their day. To inform this further research we need to understand the extent to which differentials apply to individuals' total exposure, including on their commute, at work or place of study, or within other indoor environments. By furthering our understanding of environmental justice issues in the UK, we can inform policy to reduce these differentials and their disproportionate health and economic impacts. ES

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Dr Jo Barnes is Professor of Clean Air and Director of the Air Quality Management Resource Centre at the University of the West of England Bristol. She has more than 20 years' research experience in air quality management, policy and practice at local, national, European and international levels.
https://people.uwe.ac.uk/Person/JoBarnes

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