National
Engineering
Policy Centre

Royal Academy
of Engineering

DECEMBER 2021

Engineering a reduction in air pollution

Meeting Note from the joint National Engineering Policy Centre and Chief Medical Officer roundtables on air pollution.

Context

The Chief Medical Officer (CMO) for England, Professor Chris Whitty invited the Royal Academy of Engineering and National Engineering Policy Centre to help inform the 2022 CMO Annual Report.[1] The report intends to focus on evidence for potential solutions to reduce the public health impacts of outdoor and indoor air pollution and offer recommendations based on this evidence. We organised two virtual roundtables in December 2021 to provide an overview of the roles of engineering in reducing the harmful health effects of air pollution. The first explored transport solutions to reduce air pollution and the second focused on solutions for the built environment. The roundtables were chaired by the CMO with support from Academy Fellows Professor Neville Jackson FREng and Professor Catherine Noakes FREng and a full list of the attendees is provided in the annex.

National Engineering Policy Centre

We are a unified voice for 42 professional engineering organisations, representing 450,000 engineers, a partnership led by the Royal Academy of Engineering.

Discussion summary

The roundtable discussions explored a range of interventions that can work together to reduce indoor and outdoor air pollution. The discussions also reflected on the significant progress made over the last decade to reduce air pollution, considered the implications of current trends and identified several gaps where targeted interventions might be beneficial. The interventions have not been prioritised because the effectiveness of any intervention will depend on the local context. Below is a summary of conversations and views from the two meetings, presented in the following sections:

1. **Transport interventions to reduce air pollution**
2. **Built environment interventions to reduce indoor and outdoor air pollution**
3. **Challenges to improving air quality**
4. **Further research and air pollution monitoring**
5. **Cross-cutting themes**

1. Transport interventions to reduce air pollution

Participants at the roundtables discussed engineering solutions across the different vehicle types and the construction industry to reduce air pollution. Below are some areas where engineering interventions could have significant impact on air pollution.

Hybrid vehicles: hybrid vehicles can provide improvements in air quality when compared with conventional vehicles powered solely by combustion engines by reducing tailpipe emissions when operating in electric mode and by using sophisticated emissions control and after treatment systems. Hybrid vehicles use regenerative braking that can significantly reduce friction brake wear and thus reduce particulate emissions from braking. Future hybrid vehicles will also be compatible with 'geo-fencing' to ensure that zero tailpipe emissions operation is enabled for more sensitive locations where people congregate such as near schools, hospitals and dedicated shopping areas.

Electric vehicles (EVs): Whilst EVs do not produce tailpipe emissions, they will continue to create particulate emissions from brake, tyre and road wear. The lack of gaseous emissions will improve air quality if mass take-up can be achieved but tyre and road wear may increase due to the higher mass and increased tyre/road contact pressures. However measuring and quantifying brake and tyre/road wear emissions are extremely difficult, but a good deal of research is now underway to understand and explore this area and this must be closely monitored and studied. To increase EV adoption, public confidence, user experience, range and cost of EVs need to be at an acceptable level. The recent introduction of a wide range of new EV models from most of the vehicle manufactures and an accelerating take-up by consumers has increased the demand for more charging infrastructure. As demand for EVs increase, it is likely that the take-up of EVs will be limited by the capacity to build an accessible and interoperable charging network. Rural communities with low densities may also pose challenges to build the infrastructure required. Hybrid and battery electric solutions may be viable for most light duty and some medium duty vehicles, but this is unlikely to be viable for heavier and/or long-distance applications where the weight, cost and associated re-charging power will be prohibitive.

Hydrogen: There are uncertainties raised by some policymakers about the levels of Nitrous Oxide (NO_x) produced from the use of hydrogen as fuel in transportation. However, the characteristics of hydrogen in terms of flammability and combustion products provides an opportunity to significantly improve air quality, reducing NO_x emissions to near zero and to operate without hydrocarbon or carbon emissions. Minor engine particulate emissions can also be limited to near zero through the use of conventional gasoline type particulate filters. The roles hydrogen could play in transport systems will also depend on a range of varying regional factors such as the infrastructure provision, business models and energy demand among others.

Extreme polluters: The largest source of road transport emissions come from older vehicles that have less capable emissions control systems. The most efficient way to reduce emissions from road vehicles is fleet renewal. One option to improve air quality would be to retrofit the latest emissions control technology to these vehicles. Studies to explore retrofit options for passenger cars have shown this to be uneconomic but retrofit technologies for commercial and public transport vehicles have proved to be effective and economically viable. Refrigerated lorries are a unique concern as the refrigeration units are not regulated in the same way as the propulsion system, creating much higher gaseous and particulate emissions than the vehicle itself, as the refrigerators are running even when the vehicle is parked.

Commercial vehicles: The option to reduce emissions from commercial vehicles are less clear than for passenger cars. Retrofitting commercial vehicles such as buses, trains and refuse collection vehicles is a cost-effective way to improve air quality. The technology available is effective but is considered too expensive and complex for cars. However, urban buses can be retrofitted to meet the European emissions standard Euro 6.

Construction industry: There is a need for further research on the contribution of air pollution from construction vehicles and sites. A potential solution for lighter duty applications is the use of electrically powered vehicles and equipment on construction sites, though battery size and cost remain a challenge. Both fuels cells and dedicated hydrogen fuelled combustion engines may also play a role to significantly reduce harmful pollution in construction. Whilst the availability of low-carbon hydrogen and the supply and distribution infrastructure is a major hurdle for use in road transport, the logistics of supply to construction sites may prove to be an easier pathway for more widespread use, improving both air quality and reducing carbon emissions.

Metro/underground rail systems: Whilst underground metro systems can significantly reduce road transport in cities, studies have shown that the London underground system produces of the highest concentration of particulates, made up from brake, rail and wheel wear. This is a particular issue on station platforms where particles deposited on the ground are re-suspended from the motion of trains passing through the station. Simple air filtering of Particulate Matter (PMs) with improved ventilation systems is an effective intervention to improving air quality. Separating people from these pollutants by introducing barrier doors on station platforms is another effective measure, but these are difficult to apply in practice unless the platforms are sufficiently straight.

2. Built environment interventions to reduce indoor and outdoor air pollution

Participants at the roundtables discussed traffic, building and planning solutions to reduce indoor and outdoor air pollution across the built environment. Below are some interventions that could have significant impact on air pollution.

Reducing traffic: Reducing traffic through several interventions can improve air quality. Locating consolidation centres outside of the city may reduce traffic into cities. Creating Clean Air Zones (CAZ) where infrastructure, incentives and messaging limit vehicle access, encourage cleaner technologies, walking and cycling can together benefit air quality. However, the impacts from diversions need to be considered. In relevant geographies, maximising the use of waterways and canals can help ease traffic. Machine learning and artificial intelligence can also improve the efficiency of traffic lights to reduce congestion.

Modal shifts in transport use: Air quality and health effects studies have shown that proximity to emissions sources is a key factor in reducing impacts from poor air quality. Separating vehicles and traffic from pedestrians and cyclists is widely recognized as a good strategy. How transport is used will have implications for how effective interventions are. Increasing occupancy rates of passenger vehicles significantly reduces the number of vehicles on the road, thereby reducing air pollution. Improving safety, accessibility and provision of green spaces and active transport routes in urban environments may also encourage walking and cycling which can reduce air pollution. During the pandemic, a reduction in pollution and traffic on roads saw the popularity of cycling increase.

Green spaces: Landscaping with trees along roads can be effective in reducing air pollution, but this needs to be reviewed carefully as vegetation can also deposit pollution. Vegetation has other important benefits such as promoting wellbeing and preventing urban flooding. Actively protecting higher risk groups is important, for example, providing accessible hospital bus stops that are not next to car parks with ambient air pollution.

Building ventilation: Technologies such as mechanical ventilation with heat recovery (MVHR) can enable good indoor air quality while at the same time minimise energy use and carbon impacts. Understanding people's interaction and use of new ventilations and heating technologies are crucial to enabling their effective deployment. Designing ventilation for new buildings should be considered as a different challenge to retrofitting existing buildings to improve air quality; tackling the latter is more complex but likely to impact more people. Small homes require small ventilation equipment, but this isn't readily available. Businesses can also be encouraged to optimise indoor air quality as it can improve productivity. Wider use of indoor air quality sensors can enable better understanding of indoor air quality and support both behavioural response (e.g. reduced use of products that have a negative impact on air quality) as well as effective use of ventilation.

3. Challenges to improving air quality

The discussion highlighted several issues regarding improving indoor air quality. Indoor air quality is connected to outdoor air quality and in some environments, tackling poor outdoor air quality will yield better results. There is a need to improve our understanding of how outdoor air quality affects indoor air quality and to utilise this to collectively improve overall air quality. Another challenge to improving indoor air quality is that building regulations only apply to new construction work or when new work is being carried out on existing buildings. When the building is in use, lack of compliance or poor maintenance of systems can be an issue as there is no longer a requirement for testing or evaluation. When undertaking refurbishments and renovations, the building regulations could be more ambitious towards positive change. At present, these only require that the state of the building should not be worse than what it was before. The regulations do address ventilation, but have limited consideration of indoor air quality, and including this more explicitly would encourage improvements in the quality of indoor environments. Maintaining good air quality of buildings depends on the provision of skills in facilities management to support good performance long term.

Improving ventilation and indoor air quality and maintaining (and decarbonising) building heating was identified as a challenge. Within buildings, people are less likely to recognise the poor indoor air quality in the same way as they do for thermal comfort and more likely to open windows in response to temperature than air quality. Gas boilers contribute to air pollution yet alternatives such as heat pumps and hydrogen are expensive. Underfloor heating can reduce air pollution when heating is at low temperatures but there is the challenge of VOCs from the flooring with temperature rise. Solid fuel burning (including wood burning stoves) continue to be a major source of pollution with minimal intervention even in areas designated as smokeless zones. Impacts from solid fuel burning are within the house as well as to the outdoor air, which can impact the indoor air of neighbouring properties. There are differences in burning wood blocks versus wood pellets and there are some improvements in new eco-design stoves, however, there is no requirement to maintain wood burning stoves which is an issue when fibreglass seals wear out in 5 to 10 years. Improved control measures and regulations on polluting components in household products and materials may also reduce indoor air pollution.

The role for planning was also recognised. New homes are being built that are only accessible by private transport which will have implications for air pollution as well as climate mitigation, it would be beneficial to undertake early air quality environmental impact assessments. This could be used early in the planning process as a strategic decision-making tool rather than after problems have been identified. There is a need for checks and health impact assessments to promote appropriate levels of indoor air quality during building use.

4. Further research and air pollution monitoring

Researching and monitoring air pollution were discussed broadly at the two roundtables. The discussions identified that currently air quality data is siloed. There would be benefits to identifying where the data streams exist and how to access them. As well as filling gaps, this would increase the opportunities for data sharing which can result in innovation. There are particularly gaps in indoor air quality data, where there is currently only information on a narrow range of buildings. As low-cost sensor technology has improved an observatory for indoor air quality data would be useful to better understand these environments. Roadside air pollution monitoring is widespread, this is used to identify high risk areas and evaluate the effectiveness of policy changes, it is important this infrastructure remains in place long enough to provide a feedback loop. Whilst roadside monitoring stations provide an aggregate measure of pollutants, they do not provide any information on the sources of emissions. More specific information from vehicles and locations can be obtained via laser spectroscopy technology which can measure NO_2, CO_2 and PM from individual vehicles – this approach can identify individual vehicles via automatic number plate recognition (ANPR) and target the worst polluters for either repair or removal.

Further research is also needed to improve the understanding behind the harmfulness of particulates so that it can feed into guidance. For example, the World Health Organisation 2021 Report was unable to set a limit value for Ultrafine Particles (UFPs) which are considered a new health hazard, yet PM2.5 is an inadequate standard for monitoring UFPs.[2] New technologies for monitoring and modelling air pollution can fill in research gaps as well as optimise transport networks and the built environment to improve air quality. Modelling can be used to analyse pollutant dispersion and the resulting individual exposure, and to also help evaluate the effects of previous policies. Local authorities need to be equipped with the necessary skills and resources to use these tools where appropriate.

5. Cross-cutting themes

A broad discussion across the two roundtables identified some general points of consideration for interventions to reduce air pollution.

- Interventions are often introduced in isolation and there is a need to consider the complex interactions and secondary effects from other policy interventions as well as human needs and behaviours. There is value in applying systems thinking to explore the policy interventions and identify the interdependencies.
- Long term planning is needed in order to give consideration to the different timelines that are required for changes to take effect in the interventions for vehicles and energy systems.
- Clear targets set by government allow engineers and businesses to develop innovative solutions.
- With the emergence of more sustainable technologies, there needs to be improved user guidance and general public awareness to enable users to make full use of the sustainability and health improvements made possible by these technologies.
- Public awareness of air pollution needs to be improved, wearable technology along with live air pollution monitoring could provide individual exposure information.

- More specificity on the policy interventions might be beneficial as not all polluters have the same options available, for example the best end of pipe treatment technologies are much easier to fit to larger cars.
- Interventions to reduce air pollution should align with the broader aims of achieving net zero greenhouse gas emissions.
- More data sharing between Local Authorities, departments, transport and industry would create opportunities for innovations to reduce air pollution.

Annex

Joint Royal Academy of Engineering – Chief Medical Officer virtual roundtables on air pollution

7 DECEMBER 2021
Transport solutions to reduce air pollution

Attendees

Professor Chris Whitty FMedSci,
Chief Medical Officer for England (Chair)

Dr Thomas Waite
Deputy Chief Medical Officer for England

Justin Bishop, Transport Consultant, Arup

Tim Burnhope FREng
Chief Innovation and Growth Officer, JCB

Ian Constance
CEO, Advanced Propulsion Centre UK

Professor Theo Damoulas
Professor of Machine Learning and Data Science, University of Warwick

Andrew Fraser
Chairman, IMechE, Automobile Division

Professor Colin Garner FREng
Professor of Applied Thermodynamics, Loughborough University

Professor Peter Hansford FREng
Honorary Professor of University College London

Professor Neville Jackson FREng
Chairman, RAC Foundation

Yang Lu, CTO and co-founder Vivacity Labs

Professor Ricardo Martinez-Botas FREng
Professor of Turbo-machinery, Imperial College London

Dr John Saffell
Co-founder and CTO of Alphasense Ltd

Dr Josh Vande Hey
Lecturer in Environment and Health, University of Leicester

Observers

Dr Alexandra Smyth
Senior Policy Advisor, Royal Academy of Engineering

Shema Bhujel
Policy Officer, Royal Academy of Engineering

Marc Masey
Head of Office and Senior Private Secretary to the Chief Medical Officer

Helen McAleavy
Private Secretary to the Chief Medical Officer

Constance Chamberlain
Diary Manager to the Chief Medical Officer

Dr Deborah Jenkins
Public health registrar to the Chief Medical Officer

13 DECEMBER 2021
Built environment solutions to reduce air pollution

Attendees

Professor Chris Whitty FMedSci
Chief Medical Officer for England (Chair)

Dr Helen Freeman
Network Co-ordinator for the Future Urban Ventilation Network

Dr Julie Godefroy
Head of Sustainability, Chartered Institute of Building Services Engineers

Dr Robert Harwood
Chief Operating Officer, Slingshot Simulations

Mr Richard Little, Jenton International

Dr Nick Martin
Science Area Leader, Air Quality and Aerosol Metrology Group, National Physical Laboratory

Dr Andrew McMullan
Aerospace and Computational Engineer Group, University of Leicester

Dr Helen Meese
Chair, Biomedical Engineering Group, Institution of Mechanical Engineers

Professor Catherine Noakes OBE FREng
Professor of Environmental Engineering for Buildings, University of Leeds

Professor Timothy Sharpe
Head of Architecture, University of Strathclyde

Dr Maarten van Reeuwijk
Senior Lecturer in Environmental Fluid Mechanics, Imperial College London

Dr Nick Starkey
Director of Policy, Royal Academy of Engineering

Dr Abhishek Tiwary
Senior Lecturer, Computing, Engineering, Media, De Montfort University

Dr Thomas Waite
Deputy Chief Medical Officer for England

Professor Alan Williams CBE FREng
Research Professor, University of Leeds

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References

1. Chief Medical Officer (CMO): annual reports, Department of Health and Social Care, HM Government, 2021.
2. New WHO Global Air Quality Guidelines aim to save millions of lives from air pollution, World Health Organisation, 22 September 2021.

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