AIR QUALITY EXPERT GROUP

Air pollution horizon-scanning: Seven potential risks of relevance to the UK.

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This is a short advice note from the Air Quality Expert Group (AQEG) to the Department for Environment, Food and Rural Affairs; Scottish Government; Welsh Government; and Department of Agriculture, Environment and Rural Affairs in Northern Ireland. It summarises an air quality horizon-scanning exercise undertaken at AQEG Meeting 66 on 28th September 2023. The information contained within this summary represents the authors views based on understanding and evidence available at the time of writing.

Introduction.

Horizon scanning is used to help identify potentially significant societal, economic or technological shifts which if they occurred would have major impacts on society.

AQEG generally approaches the science and technology of air pollution either through retrospective analyses – what has happened to air quality and why, - or *via* future projections. These future projections are generally short to medium term and bounded by well-established science, but it is also AQEG's role to identify evidence gaps that include uncertainties. It is valuable to periodically look beyond established evidence, towards emerging science to identify potential perturbations and assess risks that might plausibly lead to unexpected and large future air quality changes, for example those arising from climatological, technological and behavioural shifts.

Since atmospheric chemistry is often non-linear in the generation of secondary pollutants and has dependencies on weather and climate, there exists the potential also for chemical and physical tipping points that may amplify changes in air quality (either positively or negatively). Often unanticipated air quality outcomes occur not because of a single large event but instead through the accumulation or interaction of multiple smaller changes. Air quality outcomes are closely linked to policy and regulation but also to hard-to-predict public choices around transport, diet and lifestyle. A possible impact from these types of future changes can be difficult to capture and often requires in-depth knowledge of the science field. Also noteworthy is that the chemical nature of air pollution is not fixed; it changes over time as sources change reflecting wider regulatory, technological and social trends.

New perspectives can also arise from new scientific knowledge. The history of air pollution science is littered with events and discoveries that revealed new risks and required rapid evolution of policy and regulation . Examples include the great smog of London in 1952 and the Clean Air Act of 1956, the discovery of the pervasive harm from lead additives in fuel and the measurement campaigns of the 1970s that revealed that photochemical ozone was not just confined to warmer climates but affected air quality in western Europe too. On the health front research from the 1990's revealed that the health-harm from long-term exposure was far greater than that from short-term smog events laying the foundations for modern air quality regulation.

At AQEG meeting 66 a roundtable discussion on the long-term future for air quality in the UK was undertaken. Members each highlighted up to three areas of possibly under-recognised significance in a horizon scanning context. The focus of the discussion was on events, changes and processes that required specialist knowledge of the air pollution science field to discern rather than more generalised high impact and extreme events on air quality such as war and terrorism, chemical, biological, radiological or nuclear releases (CBRN) or major chemical accidents. These latter types of events are already identified in Defra Futures Team horizon scanning activities and more broadly are well-captured in the Cabinet Office National Risk Register. A wide range of issues related to atmospheric emissions, novel materials, human behaviours, monitoring, regulation, atmospheric processes and social factors were discussed.

A number of consensus themes emerged which are summarised in this short note.

It is important to stress that the workshop did not explore the **probability** or **likelihood** of individual and/or cumulative outcomes occurring, only that the events or changes to processes were plausible based on current scientific understanding and that if actualised they could lead to large and currently unanticipated impacts on air quality.

The existence of a scenario should not be interpreted as meaning it is likely to occur, and the existence of related risk is not a criticism of current technologies, regulations or policies in the relevant sectors. The intended audience for this paper is horizon scanning professionals within Defra, Government Office for Science and related Departments that have responsibilities for sectoral atmospheric emissions. The paper is made accessible publicly since it may be of wider interest and in line with AQEG principles of open and transparent communication of its work.

Seven key horizon scan air pollution risks were (in no particular order):

- Systemic underperformance of technical and regulatory air pollution abatement.
- Multi-causal increases in atmospheric ammonia over the UK.
- Increasing concentrations and health impacts of ultrafine particles (UFP).
- Emergence of novel airborne materials and health effects
- Climate-driven drought effects and increasing PM pollution.
- Enhanced emissions of biological particles and antimicrobial resistance (AMR)
- Loss of confidence in air pollution science and increasing uncertainty in forecasting

Systemic underperformance of technical and regulatory air pollution abatement.

Very large air quality improvements have been delivered in recent decades often arising from the implementation of innovations that supported emissions abatement. However, a key learning from the past is that technical interventions to reduce pollution emissions are often less effective than anticipated at the policy design phase, and can take longer than expected to generate the desired benefits. More broadly, introducing retrospective ‘fixes’ to air pollution problems once technologies or processes are established is much less efficient and effective than pro-active avoidance of emissions as technologies are developed and approved for use. Underperformance can sometimes arise because of sub-optimal regulation, for example setting standards for total air pollution emissions from a sector or source, but not the subset of those emissions that occur in close proximity to people or sensitive ecosystems and that consequently give rise to a greater health or other adverse impacts.

The effectiveness of regulation is a key cross-cutting future issue for air quality since the pathway to net zero will require successful use of abatement technologies to manage air pollution emissions arising from a profoundly changed energy, food, buildings and transport system. For example, net zero will require the widespread use of low carbon fuels (e.g. hydrogen and biofuels) that will often be burned. It may use new chemicals at industrial scale for carbon capture and storage, create energy efficient homes that need ventilating, and deliver carbon drawdown *via* large-scale afforestation.

Abatement options for each are notionally available – for example the use of Selective Catalytic Reduction (SCR) to manage NO_x emissions from burning low carbon fuels or the selection of low VOC emitting tree species. However, should past experiences be repeated then the cumulative effects of widespread abatement under-performance on air quality may be significant. From a narrow legal compliance perspective higher than anticipated air pollution emissions in a net zero future may lead to non-attainment of outdoor air quality targets. However more important would be increased consequential productivity losses and health service costs.

The impacts of net zero on air pollution may not be evenly spread; lower income households may retain legacy combustion systems such as cars and gas boilers longer, whilst the more affluent may transfer to low carbon alternatives. Whether this will further increase disparity in exposures to air pollution would depend ultimately on differences in emissions between new and old technologies.

More broadly, widespread air pollution technological or regulatory under-performance may engender a public perception that climate-positive policies lead to negative impacts in other areas and with detrimental health outcomes. A perceived failure of air quality and public health controls in support of delivering government net zero objectives, similar for example to the 2015 ‘VW scandal’ may substantially weaken the social license for action on climate change.

the air. Unlike discharges to freshwater there is no obligation on those producing new chemicals to evaluate their atmosphere fate and potential subsequent toxicity. Materials may undergo atmospheric oxygenation or nitration, or indeed be formed via mechanical wear and abrasion in the case of tyre particles and microplastics. There is no routine atmospheric surveillance for airborne chemicals outside of a small number of species that are specified in air quality regulations. The emergence of new risks to health from novel materials would likely only be apparent once environmental prevalence of the material was well-established; only after developments in analytical science has an airborne and inhaled component arising from plastic degradation been detected and the health effects of this are yet to be ascertained.

As has been seen historically in the cases of asbestos, certain persistent organic pollutants (POPs) and lead in gasoline, many years can pass between a material entering the air and the major health effects being detected. There exists therefore an ongoing risk that a novel chemical product is developed and then subsequently used in large quantities that has acceptable *prima facie* toxicological properties in its native form, but that generates unanticipated harmful secondary products once in air. If those health effects are life-course and accumulating, for example carcinogenicity or mutagenicity, then many years may pass before effects can be attributed. This is a key issue being considered by the UN Science Policy Panel on Chemicals, Waste and Pollution Prevention.

Climate-driven drought effects and increasing PM pollution.

Climate change has many different impacts on air quality, some that lead to improvements and some that may degrade it. Climate change driven changes in rainfall and atmospheric circulation patterns have been published on extensively. A specific under-recognised risk may be associated with accumulative effects on air quality arising from multiple processes that are sensitive to drought conditions. Whilst individually many of these risks are already known, the potential effect of their concurrency is less appreciated.

In dry conditions there is the potential for an increase in the generation of PM *via* agitation of surface dust, for example released from vehicles on roads or windblown soils from agricultural land. Drought conditions elevate the risks of PM emissions from wildfires from forests or moorland that may be linked to both accidental and arson events. Net zero policies may well also lead to greater areas of the UK being forested. There is also an enhanced risk of urban fires in drought.

Drought in summer is frequently associated with periods of prolonged higher temperatures, meteorological conditions which lead to increased biogenic emissions of VOCs which in turn generate secondary PM and ozone. A reduced rate of dry deposition during drought can further increase peak ozone concentrations. During high temperature periods vulnerable individuals have increased susceptibly to air pollution effects due to heat stress.

Concurrent and additive effects of additional PM from surface dust, fires, and biogenic PM are all potentially amplified by climate change. These may be coincident with an increased population vulnerability to air pollution because of immediate heat stress conditions and a more general aging population demographic in the UK. PM pollution effects during droughts may therefore give rise to significantly larger short-term increases in health service demand.

Increasing emissions of biological particles and antimicrobial resistance (AMR)

Bioaerosols are ubiquitous in the air however their composition and abundance are heterogeneous reflecting both local (such as indoor microbiomes) and global (such as the emergence of contagious SARS CoV) ecological processes and environmental change. Associative links between antimicrobial resistance (AMR) and $PM_{2.5}$ have been documented, however the causality that underlies this association is not well known. Better understood are the drivers of emerging multidrug resistant fungal pathogens, whereby selection by agricultural fungicides in the environment appears to be leading to a near-ubiquitous UK exposure to pathogenic AMR fungal spores (for instance *Aspergillus fumigatus*) in the $PM_{2.5}$ range and that are resistant to clinical antifungal therapies.

It Is possible that green-waste recycling processes (introduced in part with the aim to reduce application of synthetic fertilisers in farming) may be leading to an exacerbation of AMR spores owing to increases in circular processes and regenerative farming practices. New mode-of-action fungicides will be introduced into the British farming system and there is no adequate risk assessment mechanism for assessing the potential off-target consequences of dual-use agricultural/clinical drugs on pathogens that may be widely aerosolised.

Housing quality, flood risk and rising humidity are likely leading to increases in cold or damp homes that are prone to mould overgrowth with known, and unknown, health consequences for vulnerable groups. Changes in housing type (more energy efficient homes) and increasing energy costs leading to fuel poverty may change and exacerbate exposures to indoor bioaerosols. There is no UK-based guidance on a safe level of mould growth in homes, however opportunities exist to develop predictive environmental DNA (eDNA) and other non-culture based methods to rapidly assay exposures in homes. eDNA methods for characterising the abundance and type of bioaerosol are also appropriate for use outdoors to establish baselines and to detect unusual or previously undescribed bioaerosols with unwanted health consequences. There may also be unwanted ecosystem impacts, for example crop diseases and forest fungal diseases.

Loss of public confidence in air pollution science and increasing uncertainty in forecasting.

For many years there has been broad consensus on the desirability of good air quality albeit with some media and public debate on issues related to government and corporate responsibilities, costs, and benefits of action. Recently aspects of air pollution science evidence have been challenged by the wider public, including foundational links to health and the effectiveness and benefits of interventions. This “non-expert” challenge and

A further factor that may influence public confidence in air quality science may be the emergence of commercial forecasts and warnings for air quality from large technology companies. These may differ in their messaging and attribution from those generated by government or academic sources.

In combination, all these unconnected factors may impact negatively on the perceived strength of air quality scientific evidence, potentially weakening the social license for action and disincentivizing public, business and political engagement.