

Considering the steady improvements in nitrogen dioxide concentrations over the last decade, what do you envision to be the key future challenges in air quality, and how can we address them?

The Illusion of Victory

Improvements in nitrogen dioxide (NO₂) levels mark a significant step in air quality management; however, the issue of creating 'clean air' remains unresolved. The dangerous misconception that air pollution is now solved may itself impede further progress by diminishing public and policy engagement. Achieving the 40 µg/m³ threshold is a milestone, but stricter limits (such as 20 µg/m³) would further decrease health risks, and legislation must keep up. Simultaneously, concentrating solely on NO₂ conceals emerging threats, including ultrafine particles (UFPs) and ground-level ozone (GLO). Without increased public awareness and regulatory measures, these urgent risks could negate recent advances, presenting a major challenge for the future.

The Invisible Threats

It has been recognised that UFPs (PM_{<0.1}) pose greater health risks than PM_{2.5} due to their ability to penetrate the lungs and translocate throughout the bodyⁱⁱⁱ. Grouped under PM_{2.5}, UFPs are often overlooked, despite contributing the greatest number of particles per unit volume in the atmosphereⁱⁱⁱ. Due to their unique characteristics, policies to manage ambient PM_{2.5} and PM₁₀ cannot be applied to UFPs, and yet, existing air quality legislation has neglected both the regulation of UFPs and the necessary public education on their emerging risks. This lack of engagement will become a major obstacle once the health impacts become undeniable and regulation is required.

Another overlooked emerging threat is GLO. Ozone, typically associated with the stratosphere, differs from GLO; GLO is formed via chemical reactions between nitrogen oxides and volatile organic compounds in the presence of sunlight and affects the troposphere. Because ozone is widely perceived as a distant problem, the risks of GLO are underestimated. Unlike NO₂ and UFPs, which peak in traffic-heavy cities, ozone is often worse in rural areas where fewer nitrogen oxides break it down, creating a geographical divide that demands region-specific strategies. Despite the generalised ozone regulation under the Air Quality Standards at a maximum daily eight-hour mean concentration of 120µg/m³ ^{iv}, these standards do not fully capture exposure, and authorities are not required to warn the public when levels are high, nor on a regional basis. How can people actively react to an air pollution problem when they don't know that it's even there?

Strategies to Close the Gap:

Although different in their chemistry, these pollutants share a common issue: the public is largely unaware of their dangers. Closing this awareness gap involves making the invisible visible; for instance, locally, this can be achieved through real-time air quality displays at bus stops, schools, and online platforms, or regionally, with tools like augmented reality apps that overlay pollution data onto cityscapes. Systems such as DEFRA's forecast and the AQI website already provide this

information, but poor visibility and promotion mean most people remain uninformed when pollution levels become harmful. Increased investment in education and public displays could transform awareness into action, encouraging local engagement and fostering future legislation.

Looking forward, AI-powered monitoring can integrate satellite data, ground sensors, and weather forecasts to predict pollution spikes before they occur, with models such as Random Forest already proving accurate results for NO₂⁹. Beyond general alerts, these systems could deliver personalised warnings, for example, notifying asthma patients when ozone is projected to exceed safe thresholds. This helps vulnerable groups take protective action. Alongside such advances, requiring authorities to issue public warnings when UFP or GLO levels are high would ensure transparency, while collaboration with healthcare could provide tailored exposure advice based on individual health profiles and local data.

Conclusion

The dramatic reduction in nitrogen dioxide marks a significant milestone in air quality progress, but represents only a partial resolution of a broader problem. Complacency is dangerous; just because the air looks clean, it does not mean that it is safe. Only by sustaining vigilance and innovation can we ensure that the invisible threats of air pollution are kept firmly in sight.

ⁱ HEI Review Panel on Ultrafine Particles, 2013. Understanding the Health Effects of Ambient Ultrafine Particles. HEI Perspectives, vol. 3. Health Effects Institute.

ⁱⁱ K. Chen, A. Schneider, J. Cyrys, K. Wolf, C. Meisinger, M. Heier, W. von Scheidt, B. Kuch, M. Pitz, A. Peters, S. Breitner. Hourly exposure to ultrafine particle metrics and the onset of myocardial infarction in Augsburg, Germany. *Environ. Health Perspect.*, 128 (1) (2020), pp. 1-10.

ⁱⁱⁱ Air Quality Expert Group. (2018, July 27). Ultrafine Particles (UFP) in the UK. Department for Environment, Food & Rural Affairs; Scottish Government; Welsh Government; Department of the Environment Northern Ireland.

^{iv} The Air Quality Standards Regulations 2010 (S.I. 2010 No. 1001). (2010, June 11). Statutory Instrument 2010/1001. UK. Made: March 25, 2010; Laid before Parliament: March 30, 2010. Commenced: June 11, 2010

^v Alzu'bi, F., Al-Rawabdeh, A., & Almagbile, A. (2024). Predicting air quality using random forest: A case study in Amman-Zarqa. *The Egyptian Journal of Remote Sensing and Space Sciences*, 27(3), 604–613.