Indoor air quality standards for particulate matter: how will it work

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Keywords: indoor particulate matter, indoor air quality standards, low-cost sensors; indoor airborne pathogens.
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The COVID-19 pandemic has thrown a spotlight on indoor air quality, demonstrating not only the inadequacy of existing control measures to keep it clean and healthy, but indeed, the gross lack of such measures. Now, as the importance of airborne transmission of respiratory infections is accepted after a long struggle (1), the measurement of CO_2, its proxy, mandated by some jurisdictions (2), and ventilation rates under scrutiny, the question arises as to what pollutants, or their proxies need to be routinely monitored and controlled indoors to keep us healthy.

Ideally, we would like to monitor not only the six pollutants included in the 2021 WHO air quality guidelines (3) ($PM_{2.5}$, PM_{10}, NO_2, SO_2, CO and O_3), which are typically monitored outdoors, but also the seven pollutants included in the 2010 WHO indoor air quality guidelines (4) (benzene, formaldehyde, naphthalene, polycyclic aromatic hydrocarbons, radon, trichloroethylene and tetrachloroethylene), as well as pathogens causing airborne infections. In reality, however, this is not possible.

There are three reasons why we cannot routinely monitor indoor air in the same way as outdoor air.

Firstly, every indoor space is different, so monitoring needs to be conducted in every public indoor space. Contrast this with outdoor monitoring, which does not have to be conducted on every street corner. Secondly, we cannot use bulky and expensive compliance monitors for every indoor space. And thirdly, pathogens related to indoor airborne infection transmission cannot yet be routinely monitored indoors in real-time.

Therefore, we must carefully choose what to monitor, balancing the need to gather information on pollutants that are key health risks or their proxies, but also considering which pollutants can realistically be routinely measured for compliance with indoor air quality standards based on existing technologies.

An obvious answer to the question of what to monitor (in addition to CO and CO_2, which are not discussed here), is $PM_{2.5}$. Exposure to $PM_{2.5}$ has been assessed as one of the ten leading risks by the Global Burden of Disease study (5). Guidelines for $PM_{2.5}$ are set in the WHO air quality guidelines (3), and most countries include $PM_{2.5}$ in their outdoor air quality standards. Importantly, technological advances in low-cost sensors for particulate matter mean that large-scale indoor monitoring is already feasible.

Over recent decades there have been major advances in low-cost sensors for $PM_{2.5}$ based on optical particle detection (*6*). The stability and durability of $PM_{2.5}$ sensors have been demonstrated in numerous studies, including Jayaratne et al., 2020 (*7*), Liu et al., 2020 (*8*), and García et al., 2022 (*9*). These qualities are essential in monitors to be used for compliance monitoring.

There are, however, three scientific challenges that still need to be resolved.

Firstly, the existing health-based particle guidelines (and national ambient air quality standards) are mass-based, while optical particle detection technologies are number-based. It is unlikely that new health-based epidemiological studies will be conducted soon to link exposure to particles measured by number concentration (and in different size ranges) to health endpoints. Therefore, a scientific bridge must be developed between particle number concentrations monitored by sensors and particle gravimetric mass concentrations to relate to the existing health guidelines.

The second challenge is in situ calibration of low-cost particle sensors. Calibration is a key requirement for compliance with standards, but because of the scale of monitoring (every public indoor space), the current costly and labour-intensive methods used to calibrate existing regulatory monitors will not be practical.

And finally, efforts must be made in sensor data interpretation to enable determination of the origin of the particles (from indoors or outdoors), to inform control measures (in simple terms, whether to open or close the windows). The work of international teams is carried out to address these challenges.

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