What we know and should know about air cleaning

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SUMMARY

Air cleaning has been considered an alternative method of improving indoor air quality and, in some cases, as a supplement to ventilation. The need for energy reduction to reduce the emission of CO_2 into the atmosphere and subsequently combat the consequences of climate change has brought air cleaning into focus in recent years. The increased interest also is a consequence of increased particularly ambient air pollution in some parts of the world, but also indoor air pollution such as formaldehyde, and the need to protect the building occupants against the adverse effects of pollutants in ambient air. The recent COVID-19 pandemic has further amplified the interest in air cleaning and accelerated emerging of different new and advanced air cleaning methodologies. Zhang et al. (2011) documented some of these trends in their review paper.

There are several air cleaning technologies (ASHRAE, 2013). The three major types of air cleaning are classified depending on the air pollutants removed. These are air filtration, which is used to remove particles, gas-phase air cleaning, that is, removing gaseous pollutants, and air cleaners, which remove biological pollutants; some air cleaners remove different types of pollutants and can be classified across these categories. There are also air cleaners that combine different technologies to remove different types of air pollutants. The pollutants are removed using passive or active methods, by collection, removal, and transformation. In active air cleaners, the mechanical force needs to be used to remove pollutants. Some air cleaners are installed in the ventilation systems (in-duct), and some are portable.

The performance of air cleaners is characterized by efficiency and effectiveness. The former characterizes how effectively the pollutants are removed. The latter characterizes how effective an air cleaner is in improving indoor air quality compared to other methods such as e.g., ventilation. High efficiency does not guarantee high effectiveness (Stephens et al., 2022). Air cleaners are also characterized by clean-air delivery rate (CADR) - a pollutant-free air delivered by an air cleaner equivalent to outdoor air delivered by ventilation.

Zhang et al. (2011) evaluated the performance of different air cleaner technologies in terms of their efficiency in removing different pollutants. They concluded that there is no single technology that effectively removes all pollutants. Among the different technologies reviewed based on the information available in the literature, particle filtration and sorption of gaseous pollutants were found to be the most effective. The review could not provide credible information on the clean-air delivery rate of different air cleaning technologies; thus, they could not well characterize their effectiveness.

ASHRAE (2013) published the position document on filtration and air cleaning to provide information on their health consequences, thus extending the work performed by Zhang et al. (2011). They concluded that there is limited direct evidence of the health consequences of using air cleaning. The only evidence for health benefits found was for particle filtration, and there was suggestive evidence for other technologies, but no firm conclusions could be made. Although claimed, the information on health benefits is notably missing for new and emerging technologies, many of which use special methods to remove and/or destroy pollutants; the lack of adequate and credible information also applies to their overall performance (Lei et al., 2022).

There are several challenges associated with the use of air cleaners. Among the few that need to be mentioned is the lack of standard methods to characterize the performance of air cleaners, maintenance requirements, and information on the long-term performance of air cleaners. In many cases, one or two pollutants are used to test the efficiency of air cleaners, but air cleaners are claimed to improve indoor air quality as if they removed all pollutants, similar to other methods such as ventilation. Many air cleaners produce the by-products during the process of removal of pollutants. Many of them are more toxic than their precursors. There are basically no regulations concerning the by-production of air pollutants by air cleaners. Some air cleaning technologies use, and some produce ozone or other highly active reagents during the air cleaning process. The presence of ozone during the air cleaning process results in a relatively high ozone concentration downstream air cleaners and the risk of chemical transformations within the air cleaner reactor and in a space that negatively impacts. These processes limit the use of air cleaning indoors.

The major challenge in the future is to produce standard methods to test air cleaning technologies. This challenge applies especially to gas-phase air cleaners and some that remove biological pollutants; an example of the method for testing gas-phase air cleaners will be presented. Minimum criteria should be defined based on which different air cleaning technologies could be classified. One potential is to develop labeling systems considering clean air delivery rates, by-product production, and energy use. The above is a minimum prerequisite for the broad application of air cleaning technologies in buildings without bringing unnecessary risks to their occupants.

KEYWORDS

Filtration; Gas-phase air cleaning; Clean-air delivery rate; Maintenance; Perceived air quality

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