

SUPPLEMENT ARTICLE

Role of air pollutants mediated oxidative stress in respiratory diseases

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Abstract

Airborne particulate (PM) components from fossil fuel combustion can induce oxidative stress initiated by reactive oxygen species (ROS) that are strongly correlated with airway inflammation and asthma. A valid biomarker of airway inflammation is fractionated exhaled nitric oxide (FENO). The oxidative potential of PM_{2.5} can be evaluated with the dithiothreitol (DTT) dosage, which represents both ROS chemically produced and intracellular ROS of macrophages. This correlates with quality indicators of the internal environment and ventilation strategies such as dilution and removal of airborne contaminants.

KEY WORDS

asthma, fractionated exhaled nitric oxide, indoor air quality, oxidative stress, particulate air pollution

Airborne particulate (PM) components, especially those deriving from anthropogenic activities such as the combustion of fossil fuels, can induce oxidative stress triggered by reactive oxygen species (ROS). The reported associations between asthma morbidity and exposure to air pollutants, mainly PM_{2.5}, could be related to the oxidative potential of PM capable of inducing oxidative stress and airways inflammation, which are the hallmarks of asthma disease.¹ However, the oxidative potential of PM may be, in part, independent of the PM mass. Therefore, a potentially small fraction of chemical components can even produce the same effects. Many aerosol components have redox activities (e.g., polycyclic aromatic hydrocarbons (IPA), transition metals), and epidemiological associations can be influenced if the analyzes are based only on mass concentrations and not on the chemical characterization of PM_{2.5} and/or of PM₁₀. Few studies have addressed this possibility by characterizing

the overall oxidative potential of PM_{2.5} and correlating it with daily changes in fractional exhaled nitric oxide (FENO), which is a pivotal biomarker of airway inflammation in children with asthma.² One of the most used methods to evaluate the oxidative potential of PM components in acellular mode is the dithiothreitol (DTT) assay. DTT assay is used to demonstrate the ability of PM to transfer electrons from the DTT to oxygen, resulting in the generation of superoxide. DTT is an indicator of redox activity, positively correlated to the content of IPA, organic carbon (OC), metals, and partially inhibited by metal chelators.³ DTT consumption is highest in ultrafine PM (<0.15 μm) and combustion sources of organic chemicals and transition metals, which have a high oxidative potential. The intracellular response to exposure to PMs with high OP (oxidative potential) consists in the production of ROS, with the parallel activation of signals for the synthesis of pro-inflammatory cytokines, determining an

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important trigger of airway inflammation. The characteristic of PM can be evaluated by studying the alveolar macrophages, which constitute the first line of defense against lung lesions, including lesions by polluting particles and whose activation is directly proportional to ROS.⁴ Measurements of oxidative potential (DTT, macrophages, and PM ROS) strongly correlate with the mass of PM_{2.5}, EC, OC, and WSOC. In pediatric studies, OP correlates with the value of FENO that is significantly increased (8.7%–9.9%) and correlates with increases in ROS and macrophages levels.⁵ In these scenarios, O₃, WSOC, organic aerosol tracer, and biomass combustion correlate with alterations in FENO, with a potential pro-inflammatory role and the finding of a more significant number of emergency room visits and hospitalizations for asthma children.^{1,6} This characteristic of the polluting particles is important because many secondary organic chemicals are soluble in water (due to the high oxidation) and can be quickly released from the particles deposited in the airways, capable of inducing redox reactions in the respiratory epithelium. This is mainly related to personal, domestic, and environmental exposures to PM_{2.5}, followed by OC and EC.⁷

The EPA (Environmental Protection Agency) Positive Matrix Factorization (PMF5.0) model is used by either including the OP values in the input or offline using multilinear fits (MLR) of the source contributions estimated by the model with the measured values of OP. Recent applications to PM_{2.5} near an industrial area have identified six sources of PM_{2.5}: secondary sulfate, biomass combustion, industrial emissions, vehicular traffic, secondary nitrate, and marine spray. The PM produced during the combustion processes consists of a carbonaceous core "coated" with other organic and/or inorganic materials, whose role in ROS production is unclear. It seems that pure "naked" carbonaceous particles (graphite flakes practically free of organic and inorganic impurities, as opposed to PM samples, commonly called "clothed") catalyze the transfer of electrons with the production of ROS and decrease in cell viability resulting in a potential health hazard.⁸ A large number of experimental evidence indicates that particulate matter and ultrafine particles (UFP) can produce toxicity by increasing intracellular levels of ROS, resulting in inflammation and oxidative DNA damage. Despite many experimental data, it is debated whether cellular oxidative stress is determined only by the components adsorbed on the surface of the particles or whether the carbon core is directly involved. This type of pollution should be correlated with identifying other quality indicators of the indoor environment, including IAQ, thermal and visual comfort, and acoustic conditions. The accumulation of indoor air pollutants contributes significantly to the so-called sick-building syndrome whose occupants have worse health conditions than those who live in better buildings and a greener context. Poor ventilation is undoubtedly a precursor of various respiratory disorders, while its increase represents an excellent engineering control strategy for the dilution and removal of airborne contaminants and is closely related to IAQ. Such ventilation can be promoted with mechanical systems, natural forces, or a combination of both. The first can cause energy efficiency problems, while in the second, the external environment is limiting; hybrid ventilation includes the benefits of both, with a low energy cost.

Key Messages

Particulate matter (PM) air pollution is the leading risk factor for respiratory morbidity and mortality globally. Particulate matter <2.5 μm (PM_{2.5}) is the most commonly implicated constituent that causes a disproportionate number of global deaths and contributes significantly to global disability. Mechanisms of oxidative stress mediate the inflammatory pathways in the airways that can be measured with fractionated exhaled nitric oxide.

The COVID-19 pandemic highlights the need to prioritize design strategies to improve IAQ, including ventilation. However, the success of these approaches must be supported by targeted policy changes in public health, urban planning, and architectural design. Limited to the antimicrobial aspect, for example, it has been determined that distant UVC light (wavelength 207–222 nm), when applied to large buildings, effectively inactivates viruses and bacteria using UV light intensities that are safe for humans.⁹ Therefore, future studies will focus on the passive purification of indoor air by creating a more biophilic indoor environment. Biofiltration technology is gaining attention precisely for its environmental, cost-effectiveness, and social benefits. For future projects, increasingly human-centered buildings will require an IAQ, increasingly essential and less luxurious, with a holistic management plan, including proper ventilation, air filtration, humidity regulation, and temperature control. These are vital strategies for improving IAQ and protecting residents from airborne disease. The disposal processes of air purifier filters must be disposed of as medical waste to prevent cross-contamination.¹⁰ In conclusion, the oxidative potential of PM is associated with inflammation of the airways in young subjects with persistent asthma is now a factor to be taken into account, together with the modern concepts of ventilation and decongestion of internal spaces, as a solution to reduce bioaerosol contaminants and give concrete answers to IAQ problems.

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CONFLICT OF INTERESTS

Authors declared they have no conflict of interests.

AUTHOR CONTRIBUTIONS

Giovanni Traina: Conceptualization (lead); writing—original draft (lead); formal analysis (lead); writing—review and editing (equal). **Ezio Bolzacchini:** Conceptualization (supporting)—review and editing (equal). **Maira Bonini:** Review and editing (equal). **Daniele Contini:** Review and editing (equal). **Paride Mantecca:** Methodology (lead).

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