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Editorial

Air Pollution, Health Effects Indicators, the Exposome, and One Health

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Ambient air pollution is the seventh highest risk factor for human health, being responsible for millions of premature deaths per year globally [1–8]. This constitutes an economic and societal challenge for policymakers [9,10]. It is widely recognized that exposure to fine particulate matter ($PM_{2.5}$), ultrafine particles (UFPs), and black carbon (BC) are associated with many health outcomes [1,5–8]. However, remaining knowledge gaps include the associated primary health impacts (e.g., neurodegenerative diseases [11]), the mechanisms of toxicity (e.g., the role of oxidative stress [12]), and how different aerosol components can act and interact to influence observed particulate matter toxicity under real-world conditions [13]. Regarding the latter issue, the literature indicates factors like particle size and surface properties, the generation of Reactive Oxygen Species (ROS), and transition metal and polycyclic aromatic hydrocarbon (PAH) content [13–16]. Novel approaches and techniques are needed to fill these gaps, especially in real-life scenarios. Indeed, different toxicological indicators (i.e., acellular, in vitro, and in vivo) may yield different results and lead to uncertainties in choosing metrics that could better represent health effects at different sites and conditions [17–20]. Understanding the role of combined exposures to gaseous and particulate phase pollutants from complex sources (such as traffic-related air pollution, which has been associated with several health outcomes [5]) is important. The toxicological effects of gaseous atmospheric pollutants, even if generally lower and less studied than those of particulate matter, could act synergically in several environments [21]. It is increasingly clear that we must investigate how anthropogenic and natural sources, such as biomass and fossil fuel burning [4–6,22], generate air pollution toxicity. This is needed to plan targeted strategies for mitigating health effects rather than more general strategies based only on reducing atmospheric pollutant concentrations [23].

This Special Issue collected insightful and influential contributions on air quality and health, pollution-related indicators of health effects, the mechanisms linking air pollutant exposure to health threats in real-life scenarios, and multicomponent approaches to identify the way highly interconnected physical, chemical, and biological stressors can influence humans, animals, and the environment (One Health). The Special Issue includes 16 publications, 14 original research articles, and two reviews covering different aspects of characterizing air quality and health.

In contribution 1, Reche et al. quantified the health impacts of exposure to traffic-derived $PM_{2.5}$ and NO_2 and assessed the potential health benefits of traffic interventions. The health benefits modeled were intended to provide comparable data to support decision-makers in designing healthier cities. Targeting a large geographical coverage, 12 European cities from nine countries were comparatively assessed. In the scenarios analyzed, all cities showed a 1.7% (0.6–4%) mean reduction in premature mortality due to traffic-derived $PM_{2.5}$ exposure, and 1.0% (0.4–2%) due to NO_2 exposure. This suggests that more ambitious pollution abatement strategies than the investigated scenarios should be implemented.

In contribution 2, Begou and Kassomenos applied the AirQ+ software, proposed by the World Health Organization (WHO), to assess the health outcomes of long-term $PM_{2.5}$

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exposure in the Attica Region (Greece) from 2007 to 2018. The results showed that the burden of mortality (from natural causes in people above 30 years old) associated with $PM_{2.5}$ exposure decreased from 4752 (3179–6152) cases in 2007 to 2424 (1598–3179) cases in 2018. However, the mortality from COPD (chronic obstructive pulmonary disease) was stable: 146 (79–220) cases in 2007 and 147 (63–244) cases in 2018.

In contribution 3, Zhu et al. investigated the premature deaths attributable to long- and short-term exposures to $PM_{2.5}$ and O_3, as well as their driving forces, in Shandong from 2014 to 2060 in Shandong (China). Both county-level near-real-time air pollutant concentration datasets and projected concentrations were used. The results showed that the cumulative premature mortality associated with long- and short-term $PM_{2.5}$ and O_3 exposure ranged from 848,797 cases in 2014 to 95,141 cases in 2020. Premature mortality attributable to short-term O_3 exposure was 36.08% higher than that due to short-term $PM_{2.5}$ exposure in 2020. The driving force analysis indicates that the health benefits from the improved air quality have been offset by the changes in the population age structure.

In contribution 4, Lee et al. studied the potential association of the long-term inhalation of indoor air pollutants from ambient essential oil with cardiopulmonary events in 200 participants in Northern Taiwan. The mixed-effects models used showed a significant association between heavy essential oil usage and adverse cardiopulmonary effects. No significant association between essential oils usage and adverse cardiopulmonary effects was observed among participants not using essential oils or with mild use (less than one hour per day).

In contribution 5, Hussein et al. studied the potential exposure to aerosols released by common heating combustion sources in Jordan as an example of an Eastern Mediterranean area. The indoor air quality (IAQ) was evaluated versus the use of kerosene (K) and liquified petroleum gas (LPG) heaters in a test room reflecting the typical conditions of Jordanian dwellings during winter. The particle number (PN) concentration during the LPG operation was in the range of 6×10^4–5.9×10^5 cm^{-3} while K heater operation increased the PN concentrations up to a range of 4×10^5–8×10^5 cm^{-3}. The results call for immediate interventions to improve the IAQ by turning to cleaner heating processes indoors.

The review by Franchitti et al., contribution 6, focuses on aerodisperse biological matter, which composes about 25% of atmospheric aerosol particles and could have different health effects. The review discussed 24 papers that used next-generation sequencing (NGS) techniques for characterization and seasonal analysis. The aerobiome can include threats to human health, such as pathogens and resistome spreading; however, its diversity seems to be protective for human health and reduced by high levels of air pollution. Evidence of the urban aerobiome's effects on human health is urgently needed for urban public health purposes.

In contribution 7, Van Roy presented an improved sniffer sensor to monitor compliance with MARPOL Annex VI Regulation 14 regarding sulfur dioxide and NOx emissions from ocean-going vessels (OGVs) used by the Belgian Coastguard. The data analysis of sampled OGVs showed that compliance levels notably improved between 2019 and 2020 (from 95.9% to 97.3%), coinciding with the implementation of the Global Sulfur Cap. The study's findings also demonstrated that OGVs equipped with emission abatement technology (scrubbers) are are more susceptible to non-compliance with Regulation 14 of MARPOL Annex VI.

In contribution 8, Bernardo et al. investigated the influence of ship traffic on air quality at Ponta Delgada City (Azores). As the largest city of the mid-Atlantic Azores archipelago, it has become a hotspot for transatlantic cruise ship (CS) lines in spring and autumn. They retrospectively investigated whether the background levels of air pollutants increased following the CS influx. No major correlation was found between CS parameters and the recorded pollutant values, although a noticeable NOX increase signal of southern origin was observed on spring days with CS presence. Daily data suggested that CS influx did not strongly influence background air quality; however, a near-source real-time monitoring network should be implemented to provide data at high spatial and temporal resolutions for tracking short-term concentration fluctuations during CS arrivals and departures.

In contribution 9, Costabile et al. outlined the preliminary results of the RHAPS (Redox-Activity and Health-Effects of Atmospheric Primary And Secondary Aerosol) project, which investigated the toxicological effects of atmospheric particles in the Po Valley in northern Italy. The results indicated that, at the real atmospheric conditions observed (i.e., daily PM_1 from less than 4 to more than 50 $\mu g\ m^{-3}$), high/low mass concentrations of PM_1, as well as black carbon (BC) and water-soluble oxidative potential (WSOP), do not necessarily translate into high/low toxicity. The findings suggest a higher complexity in the relations observed between atmospheric aerosols and toxicological endpoints that go beyond the currently used PM_1 metrics.

In contribution 10, Carlino et al. reviewed the automated and online systems used to assess the oxidative potential of atmospheric particulate matter as a global indicator of potential adverse health effects. Online measurement devices give fast results and can obtain data at high temporal resolution, and several of these devices have been implemented in the field, which is a crucial point for real-time measurements. Spectrophotometric analysis is a common technique for detecting changes in the concentration of a specific molecule. Although the detection methods described have limitations, developing online and automated systems for the OP measurement of PM is attractive and promising. Alternative probes in addition to better and miniaturized detection technologies may benefit the development of portable devices, improving air quality monitoring in limited laboratory settings and on-field measurements.

Contributions 11 (Bounakhla et al.) and 12 (Benchrif et al.) discussed PM_{10}, $PM_{2.5}$, and BC concentrations, their relationships with meteorological variables, the chemical composition, and the source apportionment in the urban area of Kenitra and Tetouan in Northwestern Morocco. The results revealed significant seasonal trends for PM_{10}, $PM_{2.5}$, and BC. Relative humidity (1–2 days earlier) was negatively correlated with PM concentrations (except in winter), and temperature (1–3 days earlier) was negatively correlated with $PM_{2.5}$ in winter and summer and positively correlated with PM_{10} in autumn. Ambient $PM_{2.5}$ samples collected in the urban area of Tetouan city were used for source apportionment. The analysis revealed that $PM_{2.5}$ emission sources, regarding their typical tracers, were ammonium sulfate (SO_4^{2-}, NH_4^+, K^+, NO_3^-), road traffic and biomass burning (OC, BC), fresh sea salt (Cl^-, K^+, NO_3^-), aged sea salt (Mg^{2+}, Na^+, Ca^{2+}), and oxalate-rich sources (oxalate, NO_3^-).

Contribution 13 by Jurado et al. provides tools for urban planners, engineers, researchers, and public authorities for improved monitoring of annual air pollution at a lower cost for particulate matter. Annual concentration is a key element in assessing air quality but obtaining annual concentrations from sensors may be costly. Several strategies were studied to assess annual particulate matter concentration from monthly data to overcome this issue. When applied to a French dataset, the error spanned from 12–14% with one month of measurement to 4–6% with six months of measurement for PM_{10} and $PM_{2.5}$, respectively.

In contribution 14, Ivanovski et al. investigated the daily, monthly, and annual concentrations of five typical air pollutants (SO_2, NO_2, NOX, PM_{10}, and $PM_{2.5}$) in the Republic of Slovenia (RS) from 2017 to 2021 at five monitoring stations: traffic, industrial, and background. The results showed decreased average concentrations of all the studied air pollutants throughout the years. Meteorological parameters (temperature, wind speed, and relative humidity) were also studied, and high temperatures were associated with high air pollutant concentrations.

Di Fiore et al., in contribution 15, investigated the heavy metal pollution in the Molise region (Italy) using honeybees (*Apis mellifera* L.) as an environmental bioindicator. The results showed honeybees' capability to record the variability of heavy metal concentration in the environment, suggesting that this approach could be useful for a better understanding of contamination sources in different areas.

In contribution 16, Muhammad et al. investigated the selection of plant species for particulate matter (PM) removal in urban environments. The study ranked 61 plant species using three models: (i) leaf traits, (ii) leaf saturation isothermal remanent magnetization (SIRM), and (iii) ecosystem services and disservices. A scenario analysis was performed to determine a change in the ranking of plant species when the criteria weights were modified in the services and disservices model. The plant species with increased ecosystem services and reduced ecosystem disservices were *Tilia cordata* (Mill.), *Tilia platyphyllos* (Scop.), *Alnus incana* (L.), *Acer campestre* (L.), and *Picea abies* (L.). These findings are relevant to urban planners for recommending suitable plant species for the development of urban green spaces.

In conclusion, the findings show the complexity of programming strategies for improving the assessment and monitoring of health-relevant air pollution (contribution 13) outdoors and indoors (contributions 4 and 5). The results call for immediate actions to find new approaches for health-relevant air pollution studies. These should go beyond the monitoring of a single pollutant (e.g., only $PM_{2.5}$) or a few key pollutants (e.g., $PM_{2.5}$, NO_2, and O_3) (contributions 1 and 3) and target specific toxicological endpoints (contribution 9) and health outcomes (contributions 2 and 9). New approaches are particularly needed in real-life scenarios (contributions 4, 5, 9, 13). In the typical range of air pollutant concentrations found in European cities, the currently used air pollution metrics such as PM_1, black carbon, and oxidative potential (OP) may not represent the phenomena's overall complexity (contribution 9). The development of online and automated OP measurement systems is highly promising (contribution 10). More research is needed on new nature-based approaches, such as honeybees for heavy metals (contribution 15) or specific plant species for particulate matter (PM) removal (contribution 16), and on the human health effects of the urban aerobiome (contribution 6). We envisage a better understanding of emission sources, e.g., fossil fuels and ship emissions (contributions 7 and 8), in urban areas of developed and developing countries (contributions 11, 12, 14).

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