Editorial

Air Quality and Sustainable Development of Urban Agglomerations in the Mediterranean Area: Science, Technology and Policies

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Air quality in urban areas is one of the main challenges of sustainable development. This is still more true for urban agglomerations. Cities account for 3% of the Earth's surface but are host to over half of the world's population, consuming 78% of the world's energy and producing more than 60% of greenhouse gas emissions and 50% of global waste [1]. Mediterranean urban areas represent a peculiarity among worldwide urban agglomerations. They are characterized by high population densities and very narrow streets, conditions that can result in serious air pollution impacts on their populations.

As suggested by the title of this Special Issue, the fields of interest and research are broad, including monitoring, modeling, economy, architecture, transport, medicine, social sciences and policy. As a matter of fact, this topic is highly interdisciplinary and requires the cooperation of science, technology, and policies to reach the final aim. A close relationship exists among social, natural and economic systems, as highlighted by the pandemic due to SARS-CoV-2 [1].

The aim of this Special Issue is to highlight the first steps required toward an interdisciplinary approach to the problem of the sustainable development of urban agglomerations in the Mediterranean area, with a special focus on air pollution.

Contributions to this Special Issue include 9 research papers and 1 review, covering different topics.

Following the recommendations of the United Nations, "human wellbeing" must be at the center of sustainable development strategies [1]. Human wellbeing depends on factors and actions that go beyond the health sector, such as air pollution in urban areas. Mediterranean urban areas are characterized by narrow streets and high population densities, which were designed to be walked on by foot and for an economy that was far from being industrial, rather than for vehicular traffic [1]. Vehicular traffic emissions can significantly jeopardize air quality in historical centers, as demonstrated [2] by a monitoring campaign of fine particles (FPs) ranging in size from 20 to 1000 nm in Naples, Italy. The historical center of Naples extends for about 17,000 km^2 and is the largest in Europe (about 14.5% of the whole urban area). In 1995, it was listed among the UNESCO world heritage sites for its abundance of historical sites, social organization, and cultural traditions. As a matter of fact, a dramatic difference in the concentrations of FPs was observed [2] between vehicular (8.0×10^4 #/cm^3) and pedestrian streets (average 3.3×10^4 #/cm^3). The streets are remarkably close to each other, with similar aspect ratio height of buildings/street width (H/W) and the same orientation. Therefore, it must be concluded that local vehicular traffic is the main source of the high FP concentration observed in the monitored area [2].

Air quality in urban areas is continuously monitored by networks of fixed stations all over the world, however they are not always able to capture the spatial variability of air pollutants, such as that occurring in Mediterranean urban areas due to the presence of very narrow streets [2]. To address this issue, it has been proposed that networks of

low-cost sensors be implemented to [3] supplement the regulatory stations. The location of this study [3] was Portici, a city in Southern Italy, lying at the foot of Mount Vesuvius and consisting of 56,000 habitants, with a population density of 13,000 inhabitants/km^2. A site suitability map of low-cost, multi-sensor, traffic-orientated stations was generated for monitoring of NO$_x$ and PM$_{2.5}$ concentrations across the city, with the aims of achieving spatially dense urban air quality monitoring, minimizing costs and enhancing participation of both urban authorities and residents. Coupling several models of the urban geometry and of the urban road network, a street canyon layer was generated, classifying the road sections as street canyons if W/H < 3, otherwise as open roads. Finally, through a hot spot analysis, statistically significant spatial clusters of high-concentration and low-concentration values were identified. The result [3] was the identification in Portici of 16 highly suitable sites and 73 moderately suitable sites on which a network of low-cost, traffic-orientated sensors could be installed for monitoring of urban air pollutants.

The aim of sustainable development based on the concept of the circular economy is to develop an organizational urban model capable of reducing the disadvantages of the trade-off between environmental health, community health and the "health" of the economy, focusing attention on the implementation tools for human-centered urban development [1]. In this sense, community participation is crucial. A community science campaign (#CHEARIATIRA) was carried out in February 2019 in Torino (Italy) [4], with the aim of engaging the public in measuring NO$_2$ concentrations in an urban area that often exceeds air quality standards. NO$_2$ diffusion tubes were employed by the community under the supervision of the authors of the study. The main outcomes of the #CHEARIATIRA campaign were compared with the results of the urban dispersion model SIRANE. The results were validated against the available public air quality monitoring stations (AQMS). The community passive samplers and the modeled data showed good responses in central districts both during the campaign period and in annual projections. Traffic hotspots and sensitive receptors (schools, hospital) have high concentrations of NO$_2$. Most of the study area (83% of the tubes) is subject to an increased risk of premature death according to epidemiological studies.

Sustainable development of urban areas also encourages the use of vegetation (i.e., street trees, green roofs, and facades) to reduce temperatures and air pollution [1]. The use of green roofs has been investigated to reduce the urban heat island effect and to improve thermal comfort [5], however other benefits included increased biodiversity, decreased water run-off and decreased air pollution. One study [5] was focused on the city of Turin, Italy. The results demonstrated how temperatures—both land surface and air temperatures—decreased as the green area increased. The developed methodology used a simple 2D model to rapidly quantify the city's green areas, with a more accurate 3D model applied only in the city's areas of interest. The intervention scenario proposed for Turin [5] included requalification of the most critical areas in the city, with the use of green roof technologies, parks and rows of trees along the streets in order to improve thermal comfort conditions and reduce energy consumption. For an increase of 0.1 for the normalized difference vegetation index (NDVI) in the most critical areas, there would be a 15% increase in green areas, a decrease in the land surface temperature of 2.7 °C and energy savings of approximately 14 GWh/year, with a reduction in GHG emissions of about 2840 ton CO$_2$.

However, the assessment of greening effects in urban areas is a complex task [6], as detailed in the study of the Santa Rosa district in the Mediterranean city of Lecce, located in Southern Italy. Lecce is a medium-sized city of 96,534 inhabitants, representative of Mediterranean cities in terms of architectural design and climate. In the Köppen–Geiger classification, Lecce belongs to the Warm Mediterranean Climate Csa class, with dry and hot summers due to the prevalence of subtropical high-pressure systems, and mild and wet winters with moderate and changeable temperatures. The greening effects considered in the study [6] were air quality, CO$_2$ storage and economic impacts. The calculation tools used included the i-Tree Canopy model and computational fluid dynamics (CFD) microclimate

model ENVI-met. The results showed errors associated with the simple i-Tree Canopy model in the computation of impacts if the interactions among the vegetation characteristics, meteorological conditions and urban geometry were neglected. The complexity of this kind of assessment is particularly true in the case of urban canopies of Mediterranean areas characterized by the presence of narrow streets canyons, where pollutants can accumulate due ineffective air exchange with the above atmosphere [2]. The district studied in the city of Lecce [6] is characterized by two street canyons, named "a" and "b", with aspect ratios of H/W = 0.6. Street canyon "a" is delimited by buildings on both sides and has two side rows of 20 *Quercus ilex* L. subsp. ilex (evergreen species) trees, while street canyon "b" is more open and characterized by a central row of Tilia sp. (deciduous species) trees. Due to the presence of trees in street canyon "a", the air pollutant concentration at pedestrian height was always higher due to the trapping effect of air pollutants emitted by vehicle exhausts. The conclusion was that the impact of vegetation on air quality was highly context-dependent, because it can improve urban air quality in some situations but can be ineffective or even unfavorable in others.

The presence of vegetation also modifies the complex interactions between the urban heat island (UHI) effect, local circulation and air quality, requiring new methods of analysis [7]. The multiple-scale nature of the UHI and its relationship with flow and pollutant dispersion in urban street canyons was studied by carrying out two field experimental campaigns, one in summer and one in winter, in two parallel urban street canyons in the city of Bologna (44°290 N, 11°200 E; Italy), with a different aspect ratio and a different presence of vegetation [7]. The presence of trees together with the different morphologies was shown to mitigate the UHI intensity of around 40% by comparing its value in the center of the city, which is free of vegetation, with a residential area. The temperatures measured in the two canyons indicated 2 °C higher temperatures on average in the tree-free street canyon with respect to the vegetated canyon. This finding indicated the presence of local UHIs inside the urban texture. Moreover, a robust relationship between the UHI strength and pollutant concentration was derived, indicating that the positive effects of greening solutions in terms of improving urban thermal comfort likely will also positively impact air pollution.

Until now, in this editorial only local effects have been considered, however phenomena at regional or national scales also play significant roles in determining pollutant concentrations because background contributions can be significant. A comparative study validated observations from the Moderate-Resolution Imaging Spectroradiometer (MODIS) of the National Aeronautics and Space Agency, USA, Aqua and Terra Collection 6.1; and Modern-ERA Retrospective Analysis for Research and Application (MERRA-2) Version 2 of aerosol optical depth (AOD) at 550 nm against Aerosol Robotic Network (AERONET) ground-based sunphotometer observations over Turkey [8]. AERONET AOD data were collected from three sites during the period between 2013 and 2017. Since AOD is related to aerosol loads in the atmosphere, it is a widely used parameter for studying and monitoring anthropogenic aerosols. Regression analysis showed that overall the seasonally and daily statistics for MODIS were better than MERRA-2, as assessed via the means of several statistics parameters. A clear annual cycle in AOD was detected by the three platforms. However, overall, MODIS and MERRA-2 tended to overestimate and underestimate AOD, respectively, in comparison with AERONET. Finally, MODIS showed higher efficiency in detecting extreme events than MERRA-2.

Air quality in urban areas can also depend on less studied specific emission sources than the most common sources, such as vehicular traffic, domestic heating, ship or air emissions, energy production and others. This is true for landfills, which are often present in the surrounding areas of many cities [9], and generally for the cycle of solid wastes [10].

Landfills are sources of fugitive volatile organic carbon (VOC) emissions, including halogenated VOCs (halocarbons), which are highly volatile compounds that produce negative effects on human health and contribute to the greenhouse effect. A hazardous waste landfill located in Turin, Italy, was used as a case study [9], with the aim of evaluating

the contributions of halogenated VOCs to the health risks associated with the exposure of workers operating in the landfill and residents living in the nearby areas. A cumulative health risk analysis was conducted by applying a Monte-Carlo method. The results showed that the contribution of halocarbons to the total risk was significant but lower than those of benzene and ethylbenzene. Moreover, some waste typologies that are possibly responsible for halocarbon emissions were individuated, particularly sludge coming from wastewater treatment plants.

The correlation between air quality and waste cycle management was also discussed in a review [10]. Urban agglomerations and rural ecosystems in the Mediterranean region and globally are interlinked through the flows of resources, nutrients and wastes. Contributing to balancing these cycles, the review [10] advocated standardized biochar as a soil amendment, produced from Mediterranean suitable biowaste, in order to close the nutrient loop in agriculture and achieve parallel greenhouse gas reductions, enhancing air quality in urban agglomerations and mitigating climate change. Mediterranean-type suitable feedstocks (biowaste) to produce biochar, in accordance with biomass feedstocks approved for use in producing biochar by the European Biochar Certificate, were screened [10]. Data form large-scale and long-period field experiments were considered. With respect to air quality, the findings showed the following: pyrolysis does not release carbon dioxide to the atmosphere, contributing positively to the balance of carbon dioxide emissions to the atmosphere, with carbon uptake by plant photosynthesis; biochar stores carbon in soils, counterbalancing the effects of climate change by sequestering carbon.

Finally, it is necessary to discuss the tools to be used to monitor the effects of intervention policies aimed at achieving sustainable urban development. Several specific indicators have been selected to evaluate the transition towards a new development model [1]. Among them are:

- Exposure to air pollution in cities (with reference to the solutions able to mitigate the impacts);
- Premature mortality from ambient air pollution by sector (with reference to the solutions able to mitigate the impacts);
- Sustainable and healthy transport (with reference to the solutions able to mitigate the impacts).

In conclusion, increases in diseases due to increases in pollutants in the air cause economic and financial damage (in terms of health care expenditure, absence from work and reduced productivity) and social damage (in terms of reduced perception of safety). At the same time, a decrease in the attractiveness of a city due to high pollution rates can lead to economic and financial damage related to reductions in attractiveness for business activities or tourism or even reductions in real estate values [1].

Therefore, the application of the principles of sustainable development in urban areas is mandatory and time cannot be wasted. The application of sustainable development is more advanced in cities in Northern Europe (London, Amsterdam, Rotterdam, Brussels and Paris [1]) than in the Mediterranean area. The administrators and population of Mediterranean urban agglomerates must act rapidly to close this gap.

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