Editorial of Special Issue “Health Impact Assessment of Air Pollution”

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It is well recognized that air pollution affects health. The rapidly increasing body of scientific evidence is regularly reviewed confirming and strengthening conclusions on causal effects of selected components of air pollution (fine particulate matter, nitrogen dioxide, ozone) on specific health indicators, such as cardiovascular or respiratory mortality [1–3]. An important part of this evidence comes from epidemiological studies providing estimates of the extent of the increase in risk of certain health events with growing exposure. Recently conducted joint analysis of data from hundreds of cities [4] or systematic review and meta-analysis of all studies on selected exposures and health outcomes [5–7] increase precision of these estimates. This knowledge can be extrapolated to wider populations, and also to those where epidemiological studies have not been performed or are not feasible, to quantify the damage to health due to the exposure they experience, using health risk assessment (HRA) approaches [8]. HRA plays an increasing role in informing people on the risks posed by the exposure as well as of the impacts of changes in the exposure on health, helping in the definition of effective policies addressing the risks at global, regional, national, and local levels. One of the spectacular applications of the HRA approaches is the Global Burden of Disease project, where the burden of disease due to air pollution has been compared with that of 86 other environmental, behavioural, and metabolic risk factors [9]. This, repeated periodically since 2010, assessment shows that air pollution was the fourth leading risk factor for early death worldwide in 2019, surpassed only by high blood pressure, tobacco use, and poor diet, contributing to 6.67 million deaths. HRA methods have been also used to assess global and regional benefits of reducing population exposure to air pollution from the current levels to those recommended by WHO [10].

Such global assessments would not be possible without developments of methodology of exposure assessment or of synthesis of epidemiological studies covering global populations. Two of the articles included in this special issue refer to these topics [11,12].

Precise location and time specific estimates of population exposure to air pollution are essential inputs to the health risk assessment. Shaddick et al. [11] presents the modelling approach to estimate exposure of the global population to fine particulate matter (PM$_{2.5}$) in situations where air quality monitoring data is still scarce, or sometimes non-existent, in many regions of the world (https://whoairquality.shinyapps.io/AmbientAirQualityDatabase/). The initial versions of the Data Integration Model for Air Quality (DIMAQ), which combines the available information from ground measurements with that from other sources such as atmospheric chemical transport models and estimates from remote sensing satellites, have been used earlier to generate exposure estimates in the Global Burden of Disease project [13]. In the current paper, the authors use this approach together with the estimates provided by the most advanced Copernicus Atmosphere Monitoring Service Re-Analysis (CAMSRA) of atmospheric composition. They demonstrate that the agreement between the model estimates and concentrations from ground measurements improves significantly as compared to the “raw” CAMSRA estimates, reaching determination coefficients of about 0.9 for most regions of the world. As noted by the authors, “using DIMAQ with products such as CAMSRA offers great potential for future assessments of the health impacts of
individual sources of pollution and for informing potential mitigation policies by identifying the contributions from anthropogenic and non-anthropogenic sources”. Due to the high spatial resolution of this global approach, such analyses may be conducted also on a national (or even sub-national) level, providing an important tool for policy making.

The key step in health risk assessment procedure is the combination of the estimate of the target population exposure with the estimate of relative risk of specific health outcome associated with this exposure level. Burnett and Cohen [12] present an evolution of the concentration–response functions used in global burden of disease studies based on the growing number of cohort studies determining the association of mortality with concentration of fine particulate matter. The main challenge in global health risk assessment has been the discrepancy of the concentration range observed in the epidemiological studies, conducted predominantly in relatively clean environments of high-income countries, with the particulate matter concentration in many parts of the world where air pollution is often much higher. The initial solution to this challenge was the combination of evidence from epidemiological studies on effects of ambient and household air pollution with risk estimates emerging from studies on exposure to fine particulate matter from sources other than ambient air, namely second-hand and active tobacco smoking. Only in the recent years, cohort studies from China, with high air pollution levels, become available. Integration of evidence from all available studies required development of new methods of concentration–response function (CRF) estimation and resulted in changes in burden estimates. Burnett and Cohen discussed the issues related to the application of these evolving CRFs in health risk assessment and uncertainty of the estimates.

Though global estimates of the burden of disease due to air pollution have been crucial to raising awareness of the air pollution risk on global and national levels, they are less applicable to motivate, and guide, local administration and society to actions on a local level. In this special issue, Pascal et al. [14] present an application of health risk assessment to support risk communication and planning of pollution reduction in a small community in the south of France. The authors emphasize the value of transparency in the applied approaches, full communication of uncertainties and sensitivity of the analysis results to the assumptions made. Integration of the health risk assessment in the plan to protect the atmosphere allowed focussing the actions on those optimally preventing impacts of pollution on local population health.

Besides fine particulate matter considered as an indicator of exposure in many health risk assessment studies, the knowledge of the health effects of other air pollutants can be used to quantify health damage in populations exposed to these pollutants. In this special issue, Baek et al. [15] summarise such analysis focussed on several hazardous air pollutants (HAP) in an industrial city in Korea. The analysis covers volatile organic compounds (VOCs), carbonyls, polycyclic aromatic hydrocarbons (PAHs), phthalates, and heavy metals (HMs). Markedly higher cancer risk due to HAP was found in industrial than in residential areas of the city. The analysis also allowed identification of the substances increasing the risk the most, providing important support to the health-based air quality management.

In the recent years, various agencies developed tools to support implementation of health impact assessment. Their comparison is the subject of two of the papers included in this special issue. Lethomaki et al. [16] applied the ALPHA RiskPoll (ARP), Economic Valuation of Air Pollution (EVA), and the software developed at the Finnish Institute for Health and Welfare (ISTE) tools to estimate premature deaths attributable to annual ambient PM$_{2.5}$, NO$_2$, and O$_3$ concentrations in 2015 in the Nordic countries using the same exposure data source in the tools. The differences in baseline mortality data used as input by various tools resulted in significant disparities of air pollution impact estimates. Major differences in estimates resulted also from the application of various concentration–response functions. The analysis has also indicated that, when spatial exposure models are used, sufficiently high resolution is necessary to avoid underestimation of exposures and
health effects, especially for pollutants with concentrations that are strongly affected by local pollution sources, such as NO\textsubscript{2} or primary particulate matter.

Sacks et al. [17] focuses on comparison of two popular, open access health risk assessment tools: AirQ+ and Environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP—CE). Using common input data sets, the authors present all steps of the analysis performed with each of the tools, including sensitivity analysis using alternative sets of input parameters. The analysis demonstrated that BenMAP—CE and AirQ+ produce similar results in the process of estimating the public health impact of poor air quality. The analyses confirm that the underlying methodology used by each tool is consistent and that each tool can be used with confidence to estimate the public health impacts attributed to air pollution. However, different strengths and weaknesses of each of the tools, discussed in the paper, may be used as a guide to choosing one of them for application in a given practical situation and by different user groups. Special features of each of the tools may also determine the preference of users in deciding on their application for a particular analysis. The paper written by Sacks et al. [17] helps in making such a choice.

Besides quantifying impacts of air pollution on a population health, methods of health risk assessment have been used to develop tools facilitating prevention of these impacts. In a project presented in the paper by Olstrup [18], included in this special issue, an air quality health index (AQHI) has been developed to identify the short-term effects of a combination of urban air pollutants (PM\textsubscript{10}, NO\textsubscript{2}, and O\textsubscript{3}) on a range of health outcomes affecting various population groups. The analysis, using data from Stockholm, has demonstrated that values of daily indexes for various health outcomes are highly correlated, so the construction of all of them might not be justified. However, the magnitude of the individual health outcomes risk increase might be used to construct a risk-weighted index, better reflecting the overall hazardousness of the pollution for a city population.

The collection of the papers in this special issue demonstrates continuous development of the methods and applications of health risk assessment of air pollution. Further development is, to a large extent, determined by the progress in research disciplines generating scientific bases of the assessments, and by the expansion of routine air pollution and health monitoring essential for the generation of input data for analysis. Exposure assessment, providing more and more precise space- and time-specific estimates of exposure of populations and allowing its attribution to specific source categories or policy interventions, is the key to health risk assessment but still needs strengthening, especially in the regions with scarce air quality monitoring and poor data on pollution sources. Epidemiological studies have established robust concentration–response functions for mortality, but further studies on many non-fatal health outcomes are needed to expand health risk assessment to these less severe, though more common, effects of the exposure. Availability and quality of the baseline health data remains a limiting factor for implementation of the assessments in many specific populations around the world. Those needs are especially prominent in the less developed regions of the world, suffering from high pollution levels and poor infrastructure. Broadly available tools for health risk assessment, presented in this special issue, should encourage generation of the input data and assure the analysis directly supports policy development also, or in particular, in those less developed regions.

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References

1. U.S. EPA. *Integrated Science Assessment for Particulate Matter;* EPA/600/R-19/188; U.S. Environmental Protection Agency: Research Triangle Park, NC, USA, 2019.

2. U.S. EPA. *Integrated Science Assessment for Oxides of Nitrogen—Health Criteria;* EPA/600/R-15/068; U.S. Environmental Protection Agency: Research Triangle Park, NC, USA, 2016.

3. U.S. EPA. *Integrated Science Assessment for Ozone and Related Photochemical Oxidants;* EPA/600/R-20/012; U.S. Environmental Protection Agency: Research Triangle Park, NC, USA, 2020.

4. Liu, C.; Chen, R.; Sera, F.; Vicedo-Cabrera, A.M.; Guo, Y.; Tong, S.; Coelho, M.S.Z.S.; Saldiva, P.H.N.; Lavigne, E.; Matus, P.; et al. Ambient particulate air pollution and daily mortality in 652 cities. *N. Engl. J. Med.* 2019, 381, 705–715. [CrossRef]

5. Orellano, P.; Reynoso, J.; Quaranta, N.; Bardach, A.; Ciapponi, A. Short-term exposure to particulate matter (PM_{10} and PM_{2.5}), nitrogen dioxide (NO_{2}), and ozone (O_{3}) and all-cause and cause-specific mortality: Systematic review and meta-analysis. *Environ. Int.* 2020, 142, 105876. [CrossRef] [PubMed]

6. Chen, J.; Hoek, G. Long-term exposure to PM and all-cause and cause-specific mortality: A systematic review and meta-analysis. *Environ. Int.* 2020, 143, 105974. [CrossRef] [PubMed]

7. Huangfu, P.; Atkinson, R. Long-term exposure to NO_{2} and O_{3} and all-cause and respiratory mortality: A systematic review and meta-analysis. *Environ. Int.* 2020, 143, 105998. [CrossRef] [PubMed]

8. WHO. *Health Risk Assessment of Air Pollution—General Principles;* WHO Regional Office for Europe: Copenhagen, Denmark, 2016.

9. GBD Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020, 396, 1223–1249. [CrossRef]

10. Evangelopoulos, D.; Perez-Velasco, R.; Walton, H.; Gumy, S.; Williams, M.; Kelly, F.J.; Künzli, N. The role of burden of disease assessment in tracking progress towards achieving WHO global air quality guidelines. *Int. J. Public Health* 2020, 65, 1455–1465. [CrossRef] [PubMed]

11. Shaddick, G.; Salter, J.M.; Peuch, V.-H.; Ruggeri, G.; Thomas, M.L.; Mudu, P.; Tarasova, O.; Baklanov, A.; Gumy, S. Global Air Quality: An Inter-Disciplinary Approach to Exposure Assessment for Burden of Disease Analyses. *Atmosphere* 2021, 12, 48. [CrossRef]

12. Burnett, R.; Cohen, A. Relative risk functions for estimating excess mortality attributable to outdoor PM_{2.5} air pollution: Evolution and state-of-the-art. *Atmosphere* 2020, 11, 589. [CrossRef]

13. Shaddick, G.; Thomas, M.L.; Amini, H.; Broday, D.; Cohen, A.; Frostad, J.; Green, A.; Gumy, S.; Liu, Y.; Martin, R.V.; et al. Data integration for the assessment of population exposure to ambient air pollution for global burden of disease assessment. *Environ. Sci. Technol.* 2018, 52, 9069–9078. [CrossRef]

14. Pascal, M.; Yvon, J.-M.; Corso, M.; Blanchard, M.; De Crouy-Chanel, P.; Medina, S. Conditions for a meaningful health impact assessment for local stakeholders: The example of the Arve valley in France. *Atmosphere* 2020, 11, 566. [CrossRef]

15. Baek, K.-M.; Kim, M.-J.; Seo, Y.-K.; Kang, B.-W.; Kim, J.-H.; Baek, S.-O. Spatiotemporal variations and health implications of hazardous air pollutants in Ulsan, a multi-industrial city in Korea. *Atmosphere* 2020, 11, 547. [CrossRef]

16. Lehtomäki, H.; Geels, C.; Brandt, J.; Rao, S.; Yaramenka, K.; Åström, S.; Andersen, M.S.; Frohn, L.M.; Im, U.; Hänninen, O. Deaths attributable to air pollution in Nordic countries: Disparities in the estimates. *Atmosphere* 2020, 11, 467. [CrossRef]

17. Sacks, J.D.; Fann, N.; Gumy, S.; Kim, I.; Ruggeri, G.; Mudu, P. Quantifying the public health benefits of reducing air pollution: Critically assessing the features and capabilities of WHO’s AirQ+ and U.S. EPA’s Environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP—CE). *Atmosphere* 2020, 11, 516. [CrossRef] [PubMed]

18. Olstrup, H. An Air Quality Health Index (AQHI) with different health outcomes based on the air pollution concentrations in Stockholm during the period of 2015–2017. *Atmosphere* 2020, 11, 192. [CrossRef]