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# Toward Better and Healthier Air Quality

## Implementation of WHO 2021 Global Air Quality Guidelines in Asia

Huiling Ouyang, Xu Tang, Rajesh Kumar, Renhe Zhang, Guy Brasseur, Ben Churchill, Mozaharul Alam, Haidong Kan, Hong Liao, Tong Zhu, Emily Ying Yang Chan, Ranjeet Sokhi, Jiacan Yuan, Alexander Baklanov, Jianmin Chen, and Maria Katherina Patdu

**ABSTRACT:** Air pollution is estimated to contribute to approximately 7 million premature deaths, of which around 4.5 million deaths are linked to ambient (outdoor) air pollution. The deaths attributed to air pollution rank the highest in the Asian region, and thus, the implementation of the stricter World Health Organization (WHO) Global Air Quality Guidelines (AQGs) released on 22 September 2021 will generate the greatest health benefits in the Asian region. Here we present some key messages and recommendations at national, regional, and global levels to promote the strategies for implementation of the ambitious WHO 2021 AQGs in the Asian region.

**KEYWORDS:** Asia; Air pollution; Air quality and health

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Corresponding author: Xu Tang, tangxu@fudan.edu.cn; Rajesh Kumar, rkumar@ucar.edu
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**AFFILIATIONS: Ouyang, Tang, Zhang, Kan, Yuan, and Chen**—Asian Office Shanghai of Monitoring, Analysis, and Prediction of Air Quality, and Integrated Research on Disaster Risk International Centre of Excellence on Risk Interconnectivity and Governance on Weather/Climate Extremes Impact and Public Health, Department of Atmospheric and Oceanic Sciences and Institute of Atmospheric Sciences, Fudan University, Shanghai, China; **Kumar**—Research Applications Laboratory, National Center for Atmospheric Research, Boulder, Colorado; **Brasseur**—Max Planck Institute for Meteorology, Hamburg, Germany; **Churchill**—Regional Office for Asia and the South-West Pacific, World Meteorological Organization, Singapore; **Alam and Patdu**—Asia and the Pacific Office, United Nations Environment Programme, Bangkok, Thailand; **Liao**—Jiangsu Key Laboratory of Atmospheric Environment Monitoring and Pollution Control, Jiangsu Collaborative Innovation Center of Atmospheric Environment and Equipment Technology, School of Environmental Science and Engineering, Nanjing University of Information Science and Technology, Nanjing, China; **Zhu**—College of Environmental Sciences and Engineering, Peking University, Beijing, China; **Chan**—Collaborating Centre for Oxford University and CUHK for Disaster and Medical Humanitarian Response, Chinese University of Hong Kong, Hong Kong, China; **Sokhi**—Centre for Climate Change, and Centre for Atmospheric and Climate Physics, School of Physics, Engineering and Computer Science, University of Hertfordshire, Hatfield, United Kingdom; **Baklanov**—Science and Innovation Department, World Meteorological Organization, Geneva, Switzerland

On 22 September 2021, the World Health Organization (WHO) launched new Global Air Quality Guidelines (AQGs) to address this worldwide issue (WHO 2021a). Except for $SO_2$, all the other 2021 AQGs are considerably stricter than the 2005 WHO AQGs and several new indices have also been developed (Table 1). Recent advances in epidemiological and cohort studies have provided strong evidence that the adverse effects of air pollution can be observed not only at high exposure concentrations but also at very low concentration levels. As a result, after a systematic review of the accumulated evidence over the past 15 years, WHO substantially lowered AQGs to encourage further investment by countries in air quality management with the goal of minimizing the exposure of humans to air pollution. Estimates show that approximately 80% of the deaths attributed to ambient fine particulate matter ($PM_{2.5}$) exposure worldwide could be avoided if the new annual $PM_{2.5}$ level can be met by all countries (WHO 2021b).

At present, air pollution is most severe in developing countries, which accounted for 91% of the global premature deaths attributable to ambient air pollution (WHO 2021c). According to the estimation provided by Global Burden of Disease Study 2019, the deaths attributed to air pollution ranked the highest in the Asian Region (Fig. 1). More than two-thirds of these deaths occur in Asia alone (Murray et al. 2020). Ambient air-pollution-related deaths are dominated by $PM_{2.5}$, while ambient ozone pollution only accounted for about 8% of the global deaths (Murray et al. 2020). The top 10 cities with the

**Table 1. Comparison between WHO 2005 and 2021 Air Quality Guidelines (AQGs) (source: WHO 2021b).**

| Pollutant | Averaging time | 2005 AQGs | 2021 AQGs | Note |
|---|---|---|---|---|
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | Annual | 10 | 5 | Lower |
| | 24 h | 25 | 15 | Lower |
| $PM_{10}$ ($\mu g\ m^{-3}$) | Annual | 20 | 15 | Lower |
| | 24 h | 50 | 45 | Lower |
| $O_3$ ($\mu g\ m^{-3}$) | Peak season | — | 60 | New |
| | 8 h | 100 | 100 | Same |
| $NO_2$ ($\mu g\ m^{-3}$) | Annual | 40 | 10 | Lower |
| | 24 h | — | 25 | New |
| $SO_2$ ($\mu g\ m^{-3}$) | 24 h | 20 | 40 | Higher |
| CO ($mg\ m^{-3}$) | 24 h | — | 4 | New |

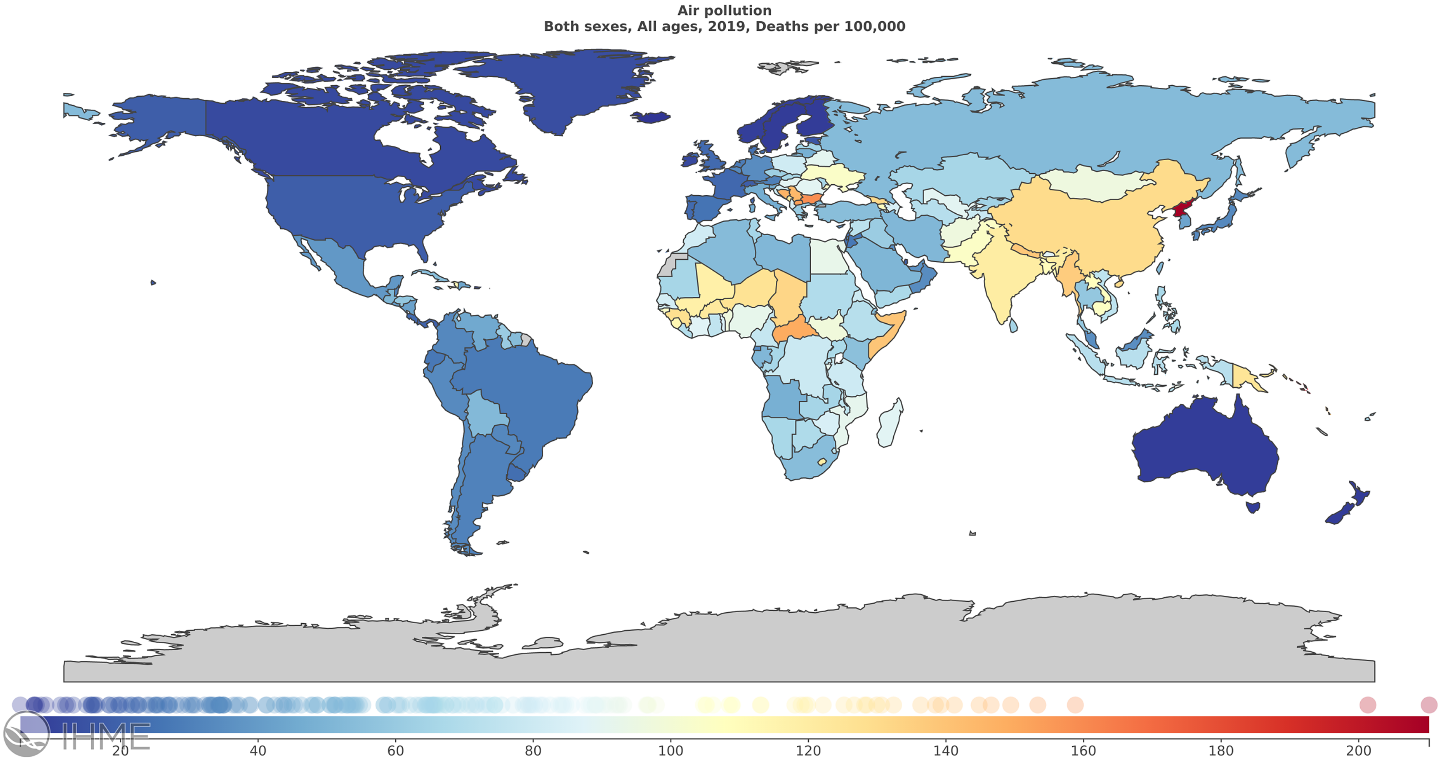


**Fig. 1. Deaths attributed to air pollution in different countries and regions in 2019, according to the Global Burden of Disease Study 2019 (Murray et al. 2020). Picture was captured from https://vizhub.healthdata.org/gbd-compare/ by selecting "air pollution" as the "risk" and "deaths" as the "measure."**

highest ambient $PM_{2.5}$ concentration are located in Asia (IQAir 2021). Thus, health benefits of improving air quality in Asia would be the greatest.

The implementation of the WHO 2021 AQGs toward a better and healthier air quality requires joint efforts and endeavors at multiple levels. Here we present some key messages and recommendations from experts in epidemiology, public health, atmospheric sciences, climatology, environmental sciences, and policy development, to promote the implementation of the ambitious WHO 2021 AQGs, specifically in the Asian region (Fig. 2). Although these recommendations are intended for the Asian region, they also apply to other parts of the world.

## Take immediate action to reduce health burden

While not legally binding, the WHO AQGs are an evidence-informed tool to guide legislation and policies to improve air quality and reduce the burden of disease from exposure to air pollution. At the moment, no country at the global level meets all of the WHO 2021 AQGs, when national averages are considered. Therefore, all countries need to make additional efforts to achieve the 2021 AQGs. A recent review of air quality legislation by the United Nations Environment Programme (UNEP) showed that, globally, 31% of the countries are yet to set up their National Ambient Air Quality Standards (NAAQS) (UNEP 2021). For countries that have already set up NAAQS, we urge a reassessment of the current NAAQS for a possible revision to align with the WHO 2021 AQGs. A comparison of NAAQS in major Asian countries including China, Japan, India, and South Korea with the WHO 2021 AQGs suggests there is still much effort to be made to improve air quality (Fig. 3). For those countries that have not adopted any NAAQS yet, we urge an assessment of the current air pollution conditions and the associated health impacts; we encourage these countries to set up a process for adoption of their own NAAQS as soon as possible, and we urge them to promote air pollution control through legislation.

A comparison of annual average $PM_{2.5}$ concentration in 2021 across countries is shown in Fig. 4. It must be noted that achieving the stricter WHO 2021 AQGs is considerably more

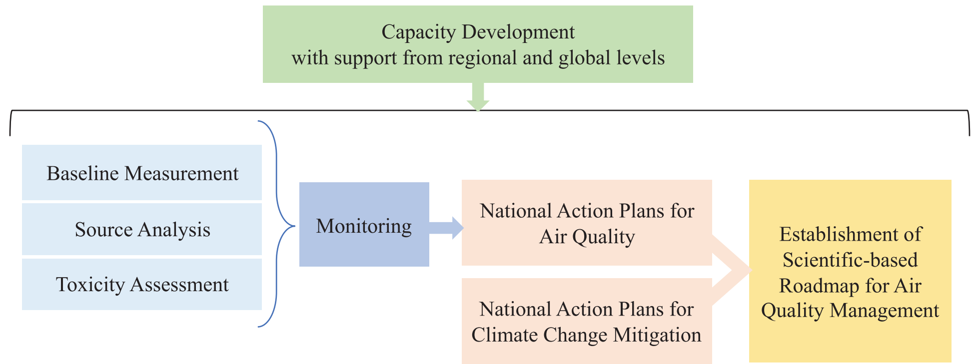


**Fig. 2. Schematic map for the implementation of WHO 2021 Air Quality Guidelines, as suggested by the present study.**

challenging for developing countries, especially those in Asia and Africa, as they are still attempting to improve the overall quality of lives for their citizens and are struggling to meet even the 2005 AQGs. An ideal experimental result obtained during COVID-19 period indicates that even with an unprecedented lockdown (i.e., dramatic reduction in emissions), most cities still struggled to achieve AQGs for several pollutants including $PM_{2.5}$, $O_3$, and sometimes $NO_2$ (WMO 2021a). For example, during lockdown periods in China, although there were reductions in concentrations of $PM_{2.5}$, $PM_{10}$, $NO_2$, $SO_2$, and CO, almost all the concentrations remained higher than the WHO AQGs as listed in Table 1, and the observed concentrations of $PM_{2.5}$ and $O_3$ even increased around Beijing (Wang and Zhang 2020). It should be noted that in addition to the high air pollution emissions, the heavy ambient air pollution over Asia is also attributed to the local meteorological conditions, such as weakened surface wind speed, declined vertical wind shear between the lower and upper troposphere, increased potential temperature difference between 850 and 1,000 hPa, enhanced humidity, and a weakened Asian monsoon (Zhang et al. 2014; Li et al. 2016; Wang and Zhang 2020). This suggests that achieving AQGs in those countries and regions in the near future will be extremely challenging. Therefore, developing countries need to adopt a stepwise approach by utilizing the interim targets of WHO AQGs as stepping stones. Every effort should be taken to achieve a lower level of air pollution to gain health benefits and save lives. For instance, 0.37 million premature deaths in China were avoided with the decrease of national $PM_{2.5}$ level from 61.8 $\mu$g $m^{-3}$ in 2013 to

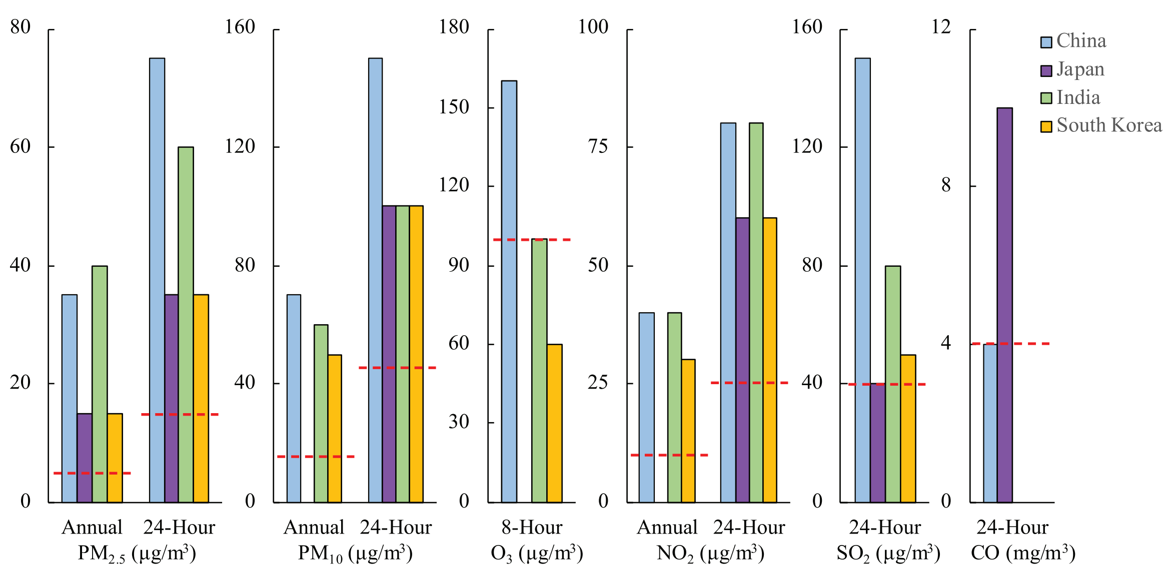


**Fig. 3. Comparison of National Ambient Air Quality Standards of China (blue), Japan (purple), India (green), and South Korea (yellow) with the WHO 2021 Air Quality Guidelines (red line).**

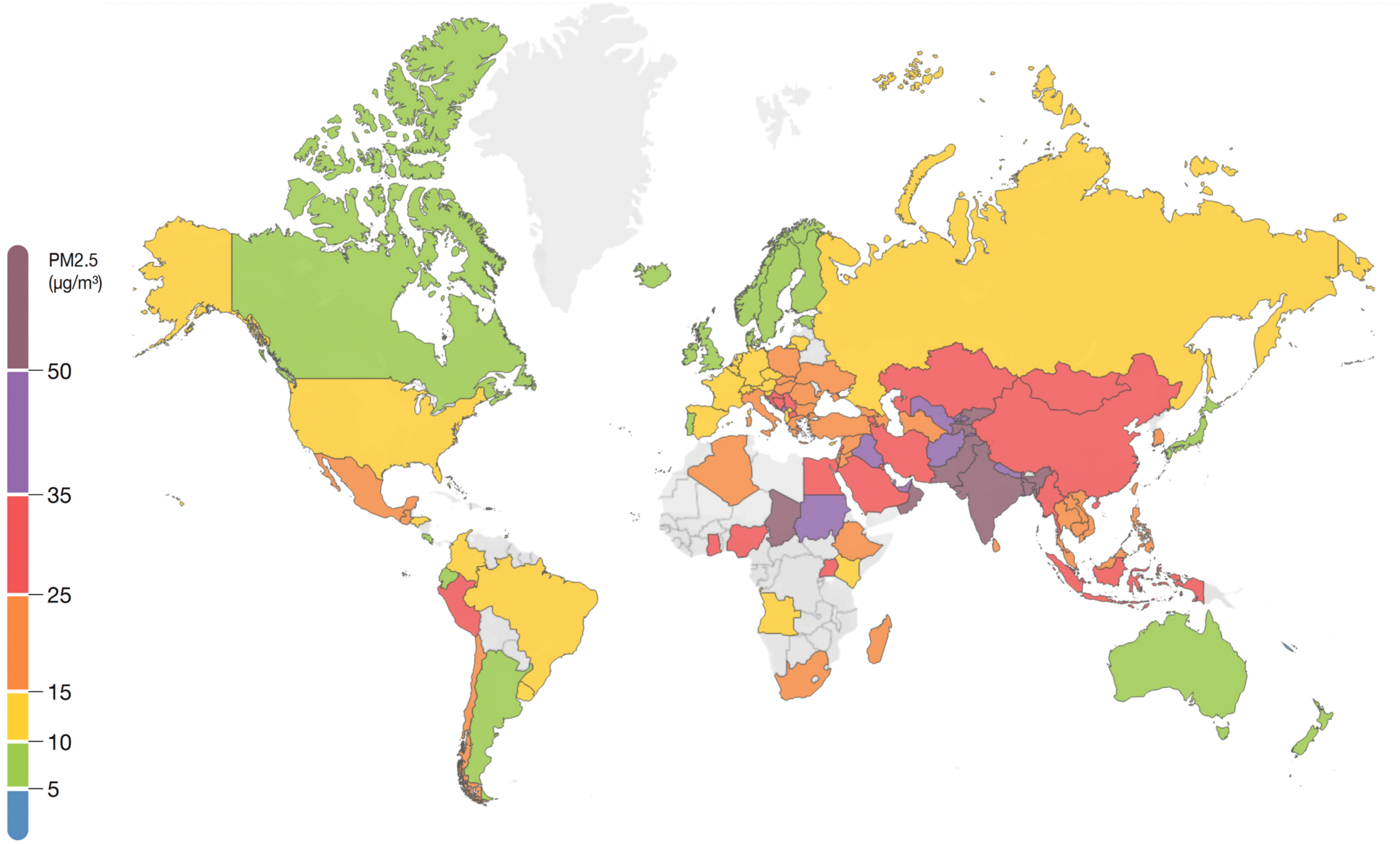


**Fig. 4. Spatial distribution of countrywise annual average $PM_{2.5}$ levels in 2021. Some countries are in gray due to lack of sufficient monitoring data. Picture is captured from www.iqair.cn/cn/world-air-quality-report.**

42.0 $\mu$g m$^{-3}$ in 2017, owing to the toughest-ever clean air policy (Zhang et al. 2019). More importantly, action should be taken now, as early as possible, instead of later.

## Policy integration with climate actions toward cohealth benefits

We have stepped into a climate-emergency era in which rapid actions to mitigate climate warming threats have become a top priority for governments around the world. Climate change and air pollution are interconnected and are exerting a combined effect on public health (Zhang et al. 2022). Evidence suggests that climate change may deteriorate air quality through altering emissions, reactions, and transport of chemical species as well as stagnant weather conditions, which play an important role in driving air pollution events (Zhang 2017). It is also well understood that climate actions including reducing fossil fuels consumption and a shift to clean energy would not only contribute to mitigation of climate change, but will also significantly improve air quality (WHO 2021b). A recent study shows that, if China achieves carbon neutrality by 2060, the average annual $PM_{2.5}$ could be reduced from 34.7 $\mu$g m$^{-3}$ (2020) to 8 $\mu$g m$^{-3}$ (2060) (Cheng et al. 2021). Climate actions to achieve carbon neutrality will therefore provide an excellent opportunity to reduce air pollution levels. The holistic integration of air quality control goals with climate actions will significantly reduce health burdens and should be considered as a whole by policy-makers to maximize health benefits.

## A step forward: Health-impact-based governance for the control of particulate matter

While other pollutants are single compounds, PM is composed of numerous components including sulfate, nitrate, ammonium, black carbon, organic carbon, dust, sea salt, and may also attach virus, bacteria, and bioallergens. Many studies have shown that the health impact of the same mass concentration of PM may vary significantly due to the differences in the particle composition, toxicity, weather, and mixing (Li et al. 2019; Daellenbach et al. 2020; Vermeulen et al. 2020). Therefore, deep investigation is required to support the shift from concentration-based governance to targeted health-impact-based governance for PM control, with the development of a new operable metric that is more targeted. This is particularly important in light of the 2021 AQGs because several regions (e.g., in the Middle East, northwestern parts of India and China) might never be able to achieve an annual average $PM_{2.5}$ mass concentration of 5 $\mu$g $m^{-3}$ due to high natural abundance of dust aerosols.

Understanding the composition of the PM is essential for health impact assessment. Thus, the monitoring infrastructure should include not only concentration measurements, but also provide information on the composition and the toxicity of the PM. Moreover, it is important to have a full understanding of the sources of the pollutants and their related toxicity. In addition to anthropogenic contributions, natural sources including natural dust, sea salt, and a fraction of biomass burning are also responsible for air pollution. Only if the contributions from different sources are well quantified, it will be possible to identify, optimize, and implement cost-effective policies for reducing the health impacts.

## Efforts toward the implementation of AQGs

The disparity in air quality levels across the world is significant. In some regions, for example, the background concentration of PM from natural sources (e.g., from wildfires, sea salt, or sand/dust storms) is already higher than the 2021 AQGs levels, making it challenging for these regions to achieve the guideline levels. For example, the background $PM_{2.5}$ level at Mumbai, India, was found to be 33 ± 7 $\mu$g $m^{-3}$ (Beig et al. 2020), which is 6.6 times higher than the 2021 AQGs. The background $PM_{2.5}$ level at Beijing, China, was found to be 30.6 $\mu$g $m^{-3}$ (CMA 2021), which is 6 times higher than the 2021 AQGs. Further investigation is necessary to assess and understand the relevant background conditions at national and regional levels. WMO and partners are working in this direction within the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) (WMO 2021b) and Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System (VFSP-WAS) (Baklanov et al. 2021) research projects for Asia and Pacific in particular.

While the WHO 2021 AQGs is meant to guide the wide community internationally, localization of AQGs for different regions to guide regional legislation, considering the differences in surface environment and background levels, may be more meaningful. Therefore, we recommend that WHO and UNEP work together with other regional organizations through their regional offices to lead the development of regional guidance, for a better and smooth implementation of AQGs. International and regional groups, such as the WMO Global Atmosphere Watch Urban Research Meteorology and Environment (GURME) and Monitoring, Analysis, and Prediction of Air Quality (MAP-AQ) communities, should be involved as hubs of expertise in support of the implementation of AQGs. In this direction, it is also important to consider urban cross-cutting foci to support the realization of effective urban air quality forecasting and information systems (Sokhi et al. 2022) and integrate urban weather, climate and environmental systems and services (IUS) (Baklanov et al. 2018; Grimmond et al. 2020) in an effort to promote for environment and climate smart cities.

## Make sure no one is left behind for a fairer world

The disparity in the air quality and related health burden between developed countries and least developed countries (LDCs) should be addressed. Support to the LDCs that are severely affected by air pollution are urgently needed to create a more equal, fair, and healthier world. The vulnerable groups including children, women, elderly people, and those who have suffered basic health problems should also be supported so that their health can be improved.

Observations represent the fundamental basis for all the evaluation. Without accurate observational data, there is no reliable and convincing information on the level of air pollution and its impacts, which is a prerequisite for developing any improvement strategy. Monitoring facilities are still lacking in large parts of the world, especially the measurements of components of PM in less-developed regions. In some countries, although monitoring facilities are available, the accuracy, sharing, and consistency of the data remain a concern. This paper calls for increased investments and funding to support the development of fundamental monitoring infrastructure. The aim must be to develop a global air quality monitoring network so that no one is left behind (Kumar et al. 2018; WMO 2017).

In addition, capacity development of the associated technical staff and research scientists is crucial for the implementation of science-based policy-making. This includes, but is not limited to, training for data quality control, chemical analytic methods, particle composition analysis, health impact evaluation, air quality forecasting, source attribution modeling, and approaches to policy decision-making. Strengthened international cooperation and collaboration between multiple stakeholders including academia, universities/institutes, government agencies, international organizations, donors, and enterprises is required to ensure better air quality.

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**Data availability statement.** All the data used in this manuscript are publicly available as stated in the text or in the references.

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