

KEY POINTS

- More than 90% of cities in Asia are experiencing unhealthy levels of air pollution, adversely affecting the environment, health, and quality of life of 92% of the Asia and Pacific region's population.
- Globally, air pollution is creating a significant economic burden, by 2060, air pollution could be responsible for a reduction in global annual economic output of 1% of global gross domestic product, \$330 per person, while global annual health-care costs could increase to \$176 billion.
- An ADB-supported program assessed air quality management (AQM) efforts in four cities and countries in Asia; and identified challenges and potential solutions to address urban air pollution.
- While each country and city had specific challenges unique to its context, common challenges requiring attention were insufficient air quality information, limited technical capacity, leniency of national air quality standards, poor coordination, weak enforcement, insufficient financial resources and incentive schemes, and a lack of mainstreaming of air quality issues in urban development.
- Integrated AQM consists of assessment activities that enable the setting of air quality objectives and implementing measures to achieve those objectives and thereby reduce the environmental and health impacts of urban air pollution.
- Once the extent and causes of the air pollution problem a country or a city faces are understood, a range of sectors—including urban development, energy, transport, industry, health, and finance—must work together to develop and deliver on clean air action plans.

Making Urban Asia's Air Cleaner

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INTRODUCTION

Between 2018 and 2050, the proportion of the global population living in urban areas will increase from 55% to 68%.¹ The United Nations estimates that well over 2.2 billion people in Asia will live in cities by 2026, and this will grow to more than 3.3 billion people by 2050 (footnote 1). However, strong economic growth driven by rapid urbanization and growing energy consumption in many developing countries in Asia has already led to urban air pollution levels having adverse health outcomes much more severe than in developed countries. Urban air pollution also puts pressure on the environment, food security, water security, and climate change, thereby undermining the human right to a standard of living adequate for the health and well-being of oneself and family.² The 2030 Agenda for Sustainable Development adopted in 2015 set out a specific agenda for sustainable cities and communities (Sustainable Development Goal [SDG] 11) requiring committed countries to make their cities and human settlements inclusive, safe, resilient, and sustainable with one target specifically related to addressing the impact of cities on air quality.

While cities in Asia are currently home to 54% of the world's urban population (footnote 1), less than 8% of Asia's population breathes air that meets the World Health Organization Air Quality Guideline (WHO AQG) for fine particulate matter less than 2.5 microns in diameter (PM_{2.5}) of 10 micrograms per cubic meter (µg/m³) as an annual

¹ United Nations Department of Economic and Social Affairs. 2018. *The 2018 Revision of World Urbanization Prospects*. <https://population.un.org/wup/>.

² Universal Declaration of Human Rights, Article 25.

average, specified as a level that does not pose a significant risk to health.³ In a program supported by ADB,⁴ Clean Air Asia assessed the air quality situation of 419 cities in Asia for the period 2007–2017 and found that the PM_{2.5} concentrations of 98% of the cities exceed the WHO AQG, with 55% of the cities exceeding even the WHO Interim Target-1 (IT-1) (Figure 1).⁵ Out of the 1.37 billion people living in the People's Republic of China (PRC), 83% live in areas where the PM_{2.5} concentration exceeds the PRC's ambient air quality standard of 35 µg/m³ annual average, which is 3.5 times higher (more lenient) than the WHO AQG.⁶

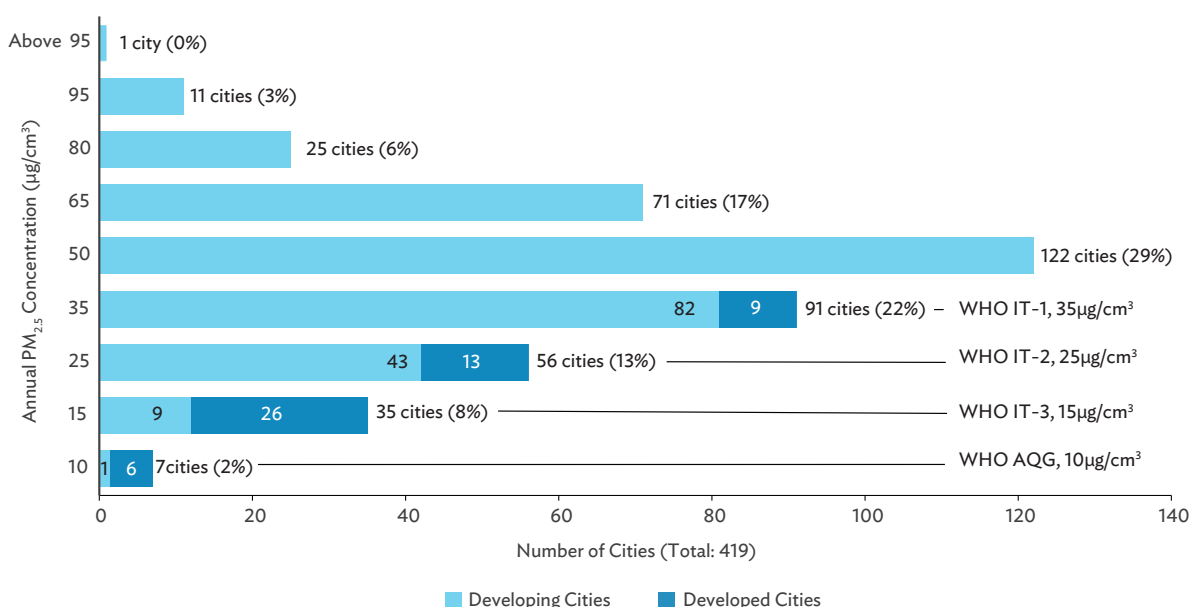
Urban air pollution is a multisector, environmental, social, and economic development issue. Managing and improving urban air quality is complex, but experience in Asia and beyond shows that

improving air quality is achievable through streamlined solutions in air quality monitoring; the enforcement of ambient air quality and emissions standards; strengthened technical capacity; incentive mechanisms; and coordinated efforts in planning, mainstreaming, and implementing AQM measures.

HIGH COST OF URBAN AIR POLLUTION

Coupled with growing urban migration and population density, high levels of indoor and outdoor air pollution already result in over 4.9 million people from the region dying prematurely each year, including 1.2 million in the PRC and 1.2 million in India.⁷ This is attributed primarily to exposure to PM_{2.5}, which is one of the dominating risk factors for early death through health impacts such

Figure 1: PM_{2.5} Levels in Cities in Asia



µg/m³ = microgram per cubic meter, AQG = air quality guideline, IT = interim target, PM_{2.5} = fine particulate matter less than 2.5 microns in diameter, WHO = World Health Organization.

Source: Clean Air Asia. 2018. *Air Quality in Asia Status and Trends 2018*.

³ World Health Organization. 2005. *Air Quality Guidelines –Global Update 2005*. <https://www.who.int/airpollution/publications/aqg2005/en/>; United Nations Environment Programme, Asia Pacific Clean Air Partnership and Climate and Clean Air Coalition. 2018. *Air Pollution in Asia and the Pacific: Science-based Solutions*. <https://ccacoalition.org/en/resources/air-pollution-asia-and-pacific-science-based-solutions-summary-full-report>.

⁴ ADB. 2014. *Mainstreaming Air Quality in Urban Development through South–South Twinning*. <https://www.adb.org/sites/default/files/project-document/149268/46250-001-tar.pdf>.

⁵ Under the Sustainable Urban Mobility in Asia (SUMA) program supported by ADB and the Swedish International Development Cooperation Agency (Sida), Clean Air Asia developed the Microsoft Excel-based Clean Air Scorecard Tool (CAST) that assesses (i) air pollution and health, (ii) clean air management capacity, and (iii) clean air policies and actions. For the ADB-supported program, Clean Air Asia used the Air Pollution and Health Index (APHI) of CAST to assess the air quality status of more than 400 cities in Asia.

⁶ Y. Jin and S. Zhang. 2018. An Economic Evaluation of the Health Effects of Reducing Fine Particulate Pollution in Chinese Cities. *Asian Development Review*. 35 (2). pp. 58–84. https://doi.org/10.1162/adev_a_00114.

⁷ Health Effects Institute. 2019. *State of Global Air 2019, A Special Report on Global Exposure to Air Pollution and its Disease Burden*. https://www.stateofglobalair.org/sites/default/files/soga_2019_report.pdf.

as respiratory infection, heart disease, stroke, chronic lung disease, and lung cancer.

Air pollution disproportionately affects the poorest and the most marginalized people in Asia. Already suffering from poor nutrition with little or no access to health care, they are also more likely to live and work in polluted environments. Children, older people, and the infirm are particularly vulnerable to its effects. Miscarriage, premature birth, low birth weight, neurological development delays in children, and dementia in older people have all been linked to air pollution. A 2010 study by the Stockholm Environment Institute estimated that about 18% of all preterm births globally—or 2.7 million preterm births per year—were associated with outdoor exposure to PM_{2.5}.⁸

Urban air pollution not only poses health risks, but also imposes a high burden on national economies. In addition to the financial burden to individuals due to the cost of health services and health-care needs, air pollution also creates a massive economic burden for governments by increasing public health-care and social welfare costs, and causing a loss of productive labor, thereby reducing output and incomes. The annual labor income losses from premature deaths of working-age men and women are estimated to amount to 0.8% of the gross domestic product (GDP) in South Asia and 0.25% in East Asia and the Pacific.⁹ The Organisation for Economic Co-operation and Development (OECD) predicts that air pollution could be responsible for reduction in global annual economic output of 1% of global GDP, \$330 per person, and a global increase in annual health-care costs of \$176 billion by 2060.¹⁰ The World Bank estimates that the annual air pollution costs to the global economy are some \$5.11 trillion in welfare losses. In terms of magnitude, welfare losses in Asia and the Pacific are estimated to be equivalent to 7.5% of regional GDP (footnote 9).

MAKING ASIA'S CITIES MORE LIVABLE

Making cities in Asia more livable is one of ADB's seven key operational priorities.¹¹ Through its TA projects, ADB aims to contribute to enhancing the capacity of cities to manage urban air pollution and work toward the increased application of knowledge and understanding of AQM by city governments.

Under an ADB-supported program (Regional Capacity Development Technical Assistance 8751: Mainstreaming Air

Quality in Urban Development through South-South Twinning) (footnote 4), the AQM efforts of four cities in Asia (Chengdu and Xiangtan in the PRC, Kathmandu in Nepal, and Metro Manila in the Philippines), and four countries (Nepal, the Philippines, the PRC, and Thailand) were assessed, and challenges and potential solutions to address urban air pollution were identified.¹²

A TALE OF FOUR CITIES

Unprecedented urbanization, motorization, and industrialization were main drivers of urban air pollution in many Asian cities in the four countries studied, and specifically, in the four densely populated and urban concentrated cities of Chengdu, Kathmandu, Metro Manila, and Xiangtan (Figure 2). Despite the existing legal and policy frameworks and pollution control measures in place, urban air pollution remains a critical issue in these four cities, and air pollutants remain above the respective national air quality standards.

Of the countries studied, the PRC was the largest emitter of major air pollutants (sulfur dioxide [SO₂], nitrogen oxides [NO_x], particulate matter [PM], volatile organic compounds [VOCs], and ammonia [NH₃]) with total SO₂ emissions at 17.5 million tons and NO_x emissions at 17.8 million tons in 2016. Emission inventories were estimated at approximately 12 million tons per year for PM_{2.5} and 30 million tons per year for VOCs. Rapid economic growth and emerging manufacturing hubs deeply dependent on heavy industries, such as iron, steel, cement, chemicals, and nonmetal mineral production have contributed to persistently high emissions of major pollutants at the city and subnational levels. Industrially induced urban air pollution is heavily concentrated in the Beijing–Tianjin–Hebei (BTH) region of the PRC, where an ADB technical assistance (TA) project supported formulation of the BTH regional air pollution prevention and control mechanism and measures and capacity building in AQM.¹³

Chengdu is a large city and the capital of Sichuan province in the southwest of the PRC, with a population of more than 7 million, whereas Xiangtan is in the central part of Hunan province in the southeast of the PRC, with a population of around 1.032 million.¹⁴ In Chengdu and Xiangtan, industrial processes, coal-fired thermal power plants, and increasing numbers of light- and heavy-duty vehicles are the main sources of urban air pollution. Additional sources of Chengdu's particulate matter less than 10 microns in diameter (PM₁₀)

⁸ C. Malley et al. 2017. Preterm Birth Associated with Maternal Fine Particulate Matter Exposure: A Global, Regional and National Assessment. *Environment International*. Volume 101. April 2017. pp. 173–182. <https://www.sciencedirect.com/science/article/pii/S0160412016305992>.

⁹ World Bank and Institute for Health Metrics and Evaluation. 2016. *Cost of Air Pollution: Strengthening the Economic Case for Action*.

¹⁰ OECD. 2016. *The Economic Consequences of Outdoor Air Pollution*. Paris: OECD Publishing. <https://www.oecd.org/environment/indicators-modelling-outlooks/Policy-Highlights-Economic-consequences-of-outdoor-air-pollution-web.pdf>.

¹¹ ADB. 2018. *Strategy 2030*. <https://www.adb.org/sites/default/files/institutional-document/435391/strategy-2030-main-document.pdf>.

¹² Clean Air Asia. 2018. *Mainstreaming Air Quality in Urban Development of Asia: Lessons and Recommendations from Selected Country and City Studies*. Regional Capacity Development Technical Assistance (R-CDTA) 8751: Mainstreaming Air Quality in Urban Development through South–South Twinning. <https://www.adb.org/sites/default/files/project-documents/46250/46250-001-tacr-en.pdf>.

¹³ ADB. 2017. *China, People's Republic of: Preparing Air Quality Improvement Program (2017–2019) in the Greater Beijing–Tianjin–Hebei Region*. <https://www.adb.org/projects/51004-002/main>.

¹⁴ United Nations, Department of Economic and Social Affairs, Population Division. 2016. *The World's Cities in 2016 – Data Booklet*.

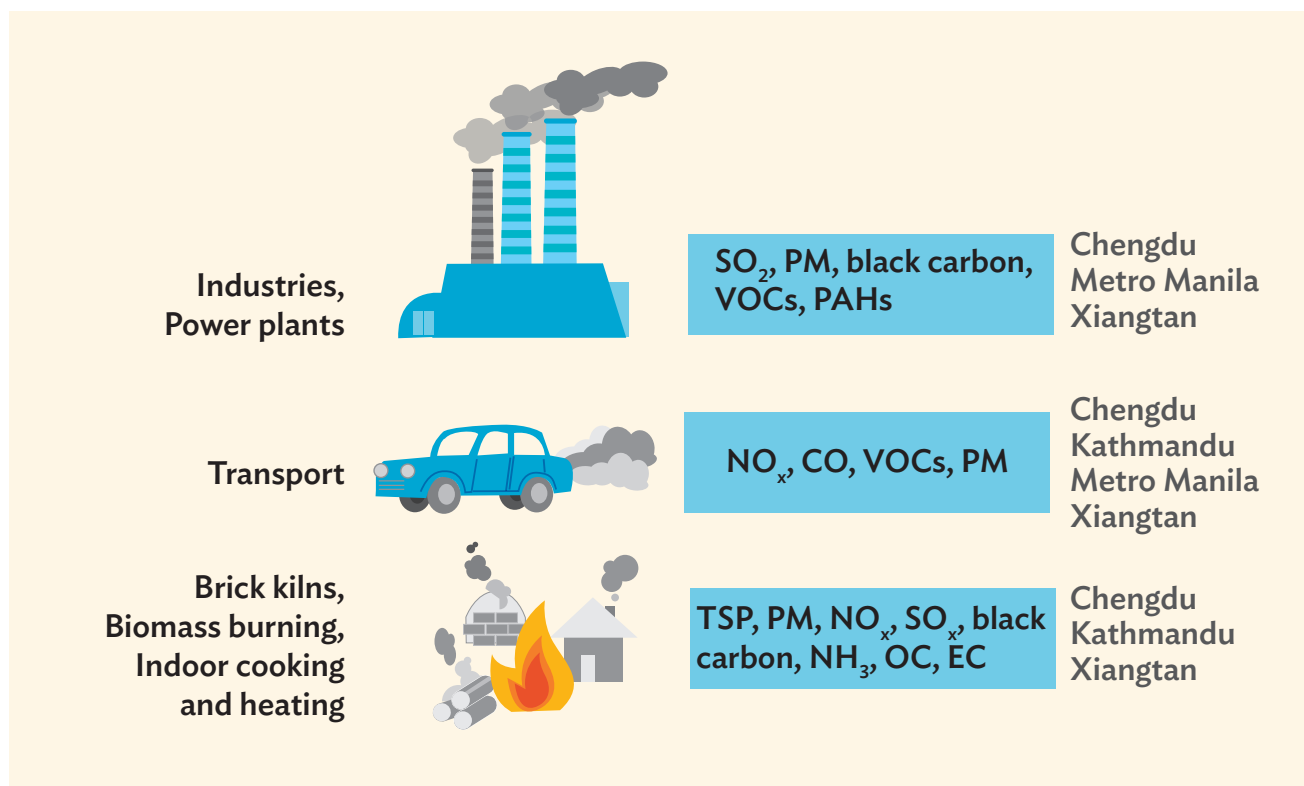
and PM_{2.5} include dust storms and soil erosion, whereas indoor and outdoor cooking are also significant sources in Xiangtan.

Metro Manila, the capital of the Philippines, has grown to be one of the most densely populated cities in Asia, where transport is the most significant source of urban air pollution. The iconic diesel engine jeepneys have been the primary source among road vehicles, followed by resuspended dust, burning of solid wastes, agricultural wastes, and industrial activities. A limited car-centric road network and the absence of a reliable mass transit system, combined with increasing private vehicle ownership, have contributed to more traffic congestion to accommodate

2.79 million registered motor vehicles in 2018.¹⁵ Mobile sources alone contribute to 88% of air pollution in Metro Manila in 2015.¹⁶

In Kathmandu, the capital city of Nepal, smoke from hundreds of brick kilns, agricultural biomass burning, indoor cooking and heating, and a growing number of motor vehicles pollutes the air. In Province 3 (formerly the Bagmati zone), which hosts Kathmandu, the number of vehicles increased ninefold in the last 2 decades, reaching 922,900 vehicles in 2015 and more than 1.1 million in 2018. In addition, transboundary air pollution is a major concern in Nepal, especially during the dry season when air pollution from the south and the west affects its air quality.

Figure 2: Sources of Urban Air Pollution in the Four Cities



CO = carbon monoxide, EC = elemental carbon, NH₃ = ammonia, NO_x = nitrogen oxides, OC = organic carbon, PAHs = polycyclic aromatic hydrocarbons, PM = particulate matter, SO₂ = sulfur dioxide, SO_x = sulfur oxides, TSP = total suspended particles, VOCs = volatile organic compounds.

Source: Clean Air Asia. 2018. *Mainstreaming Air Quality in Urban Development of Asia: Lessons and Recommendations from Selected Country and City Studies*. Regional Capacity Development Technical Assistance (R-CDTA) 8751: Mainstreaming Air Quality in Urban Development through South-South Twinning.

¹⁵ Government of the Philippines, Land Transportation Office. 2018. *Annual Report*. <https://www.lto.gov.ph/transparency-seal/annual-reports/file/634-annual-report-2018.html>.

¹⁶ Environmental Management Bureau, the Philippines. 2018. *Annual Report Calendar Year (CY) 2018*. <https://emb.gov.ph/wp-content/uploads/2019/04/EMB-ANNUAL-REPORT-FOR-CY-2018.pdf>.

COMMON CHALLENGES FOR CITIES









The table illustrates the basic socioeconomic, emission, and air quality monitoring-related information of the four cities. Yet, despite the air quality monitoring networks and implementation of pollution control measures, emissions remain high and air pollutant concentrations continue to exceed national air quality standards in these cities. The small number of monitoring stations means that data on the actual air pollution situation is limited in terms of spatial coverage and pollutants monitored.

The cities recognize several key challenges, including a lack of enforcement of existing air quality and other standards; complexity of the air pollution problems because of multiple, different sources; and incomplete and inaccurate emissions inventories

and inadequate control measures. At a technical level, there is a lack of knowledge and skills at national and local levels to develop emissions inventories, carry out receptor and dispersion modeling, impact assessments, and to assess the contribution of transboundary and regional air pollution. The cities lack clean air action plans (CAAPs) with clearly indicated roles of sector agencies, private sector, and other stakeholders, and links into sector plans for transport, energy, and land use. Countries and cities have also not fully developed financial and investment plans showing the cost of implementing measures in CAAPs that do exist.

Like Chengdu, Kathmandu, Metro Manila, and Xiangtan, many Asian cities struggle to achieve better air quality. While each city faces challenges unique to their national or local context, the ADB-supported program found that all share common challenges in varying

Table: Air Pollution Drivers and Situations in Selected Cities

	CHENGDU People's Republic of China	XIANGTAN People's Republic of China	KATHMANDU Nepal	METRO MANILA Philippines
 Population (million)	8.8	1.1	1.3	13.5
 GDP growth (%)	8.1%	8.3%	–	6.1%
 Main energy source	Coal	Coal	Coal, oil, biomass	Coal, oil
 Number of vehicles (million)	4.67 (2016)	0.61 (2015)	1.1 (2018)	2.79 (2018)
 Main Pollutants	PM _{2.5} , O ₃ , (AQ improving)	PM _{2.5} , O ₃ , (AQ improving)	PM ₁₀ , NO ₂	PM ₁₀
 Major emission sources	Traffic, TPP, SMEs	Large industry, TPP, Traffic, OB	Traffic, brick kilns, OB, cooking	Traffic, industry, MSW, OB
 Number of AQ monitoring stations	33	6	8	34
 AQ information dissemination	Real time (Website)	Website	Real time (Website)	Real time (Website, social, media, etc.)

AQ = air quality, GDP = gross domestic product, MSW = municipal solid waste, NO₂ = nitrogen dioxide, O₃ = ozone, OB = open burning, PM = particulate matter, PM_{2.5} = fine particulate matter less than 2.5 microns in diameter, SMEs = small and medium-sized enterprises, SO₂ = sulfur dioxide, TPP = thermal power plants.

Sources: Clean Air Asia. 2018. *Mainstreaming Air Quality in Urban Development of Asia: Lessons and Recommendations from Selected Country and City Studies*. Regional Capacity Development Technical Assistance (R-CDTA) 8751: Mainstreaming Air Quality in Urban Development through South-South Twinning; United Nations, Department of Economic and Social Affairs, Population Division. 2018. *The World's Cities in 2018 – Data Booklet*; Hong Kong Trade Development Council Research. 2019. *Xiangtan (Hunan) City Information and Chengdu (Sichuan) City Information*; Philippine Statistics Authority. 2017. *Special Release: Regional Economy of the National Capital Region in 2017*. http://rssoncr.psa.gov.ph/sites/default/files/2018%20%20GRDP_SR.pdf; The Himalayan Times. 2018. Traffic Management Turns Daunting as Vehicles Exceed 1.1 Mil Mark: News release on November 3, 2018; Government of the Philippines, Land Transportation Office. 2018. *Annual Report*. <https://www.lto.gov.ph/transparency-seal/annual-reports/file/634-annual-report-2018.html>.

degrees in implementing integrated AQM. These are (i) insufficient air quality information to inform policies, plans, and programs; (ii) limited technical capacity; (iii) lack of coordination among stakeholders in AQM; (iv) leniency of national air quality standards; (v) weak enforcement of ambient air quality standards and emission standards; (vi) insufficient financial mechanisms and incentive schemes to promote and scale up solutions and technologies; and (vii) lack of mainstreaming AQM issues in urban planning and development. This led to cities finding remedial approaches for urban air pollution issues, rather than preventive solutions.

BRIDGING THE GAP: WHAT CITIES CAN DO

Effective AQM requires

- assessment of the existing state of air exposure;
- capability and capacity to develop reliable emissions inventories, dispersion modeling, assessment of the impacts of air pollution on human health and environment, identification of appropriate control measures and their costs, and evaluation of the benefits of the planned action;
- ability to develop city-specific CAAPs; and
- close coordination among government agencies and all relevant stakeholders involved in the implementation and enforcement of action plans.

The experiences of the European Union (EU) and the United States (US) lead the way in achievement of significant improvements in air quality. Good practices involved

- promulgation, implementation, and enforcement of international, national, and local air quality regulations;
- development of “best” environmental practices and “best” available technologies for stationary and mobile sources;
- enforcement of cleaner fuels and vehicles for transportation;
- comprehensive CAAPs in the EU and state implementation plans in the US;
- sufficient funding for the implementation and enforcement of the plans; and
- active participation of relevant stakeholders.

The following recommendations on how to address the existing common challenges in cities in Asia were developed, built on good AQM practices from the US, Germany, Singapore, and Thailand, as well as from the experiences of Asian cities (Bangkok in Thailand; Hong Kong, China; Kawasaki in Japan; Chengdu; Kathmandu; Metro Manila; and Xiangtan).

EIGHT RECOMMENDATIONS FOR ASIAN CITIES

1. Develop a clean air action plan with clear objectives, roles, and accountability

Integrated, comprehensive, and evidence-based CAAPs are required to address urban air quality issues in Asian cities. CAAPs (or clean air implementation plans [CAIPs]) can set clear air quality objectives or goals for all sectors and stakeholders; clarify



Smog in the People's Republic of China. Industrial processes, coal-fired thermal power plants, and increasing numbers of light- and heavy-duty vehicles are the main sources of urban air pollution.

roles while facilitating collaboration; define accountability, reporting, and monitoring; and should be backed by a financial and investment plan. CAAPs can also establish requisite coordination mechanisms among responsible ministries, government agencies, and all other stakeholders.

Many cities in Indonesia, the Philippines, Thailand, and Viet Nam have embarked on multi stakeholder development of CAAPs. In the PRC, 305 cities developed CAAPs in line with the national government's extensive efforts to reduce emissions. For example, as a result of the implementation of the Comprehensive Action Plan for Air Pollution Prevention and Control in 2013, the level of PM_{2.5} in the Greater Beijing area declined by around 40% by 2017. Furthermore, with these improvements in air quality, the estimated number of deaths attributable to ambient PM_{2.5} in Greater Beijing decreased by 10%—from around 95,000 to 85,000—in the same period.¹⁷ The approval by Mongolia's Prime Minister in 2017 of the National Action Program on Reducing Air Pollution paved the way for improving air quality in Mongolia. In addition to being a milestone document, it is now the source document for all future air quality efforts in Mongolia and represents a turning point in the country's national air quality management.

Effective implementation of CAAPs is important and ADB implemented this approach through its projects supporting the BTH region in the PRC,¹⁸ and in Ulaanbaatar, Mongolia.¹⁹ An ADB TA project is now helping other Asian cities in Bangladesh, Mongolia, Pakistan, the Philippines, and Viet Nam to (i) develop CAAP and associated investment estimates for immediate, medium-term, and long-term actions; (ii) conduct economic and financial analyses of proposed CAAP investments; (iii) design an incentive and financing mechanism to promote air quality improvement technologies; and (iv) identify potential domestic and international resources, including private sector funding.

2. Tighten ambient air quality standards

Each country sets air quality standards to protect public health and, as such, are an enforceable and important component of national environmental and risk management policies. National standards vary depending on each country's approach to balancing health risks, technological feasibility, economic considerations, and other political, cultural, and social factors. The World Health Organization recommends adopting targeted levels of ambient air quality standards to deliver improvements in air quality over time

Integrated, comprehensive, and evidence-based clean air action plans are required to address urban air quality issues in Asian cities.

and notes that national governments should make efforts to align their national standards with the WHO AQGs which are set at a level that does not pose a significant risk to health.²⁰ At present, some countries do not cover all the critical pollutants (e.g., PM_{2.5}) in their ambient air quality standards.

Measures to prevent and control emissions from different air pollutant sources will then be needed to contribute to achieving the national ambient air quality standards and any city-level air quality targets that are set. These include optimizing the composition and growth of industrial plants and using stringent emissions standards and caps, especially for thermal (coal) power plants, and promoting a shift to cleaner fuels for transportation, cooking, and heating.

3. Raise political and public awareness of the impacts and costs of air pollution

Making people recognize and understand the impacts of urban air pollution is crucial to generate political action, spurred by public demand, to implement and invest in AQM. Providing policy makers and legislators with scientific and economic analyses that highlight the benefits of AQM will help informed decision-making, particularly in prioritizing actions to reduce air pollution-related environmental and health impacts and to mobilize the necessary resources to address the sources of urban air pollution at country and city levels. Hong Kong, China adopted an Air Quality Health Index system that uses information from local hospital admissions data for air pollution-related illnesses tracking multiple air pollutants.²¹ Thailand provides real-time information on the state of air quality to mobilize citizens and protect their health. For example, it established the "Air4Thai" mobile phone application that reports hourly data on Thailand's air quality index to disseminate information to the general public.²²

¹⁷ J. Huang et al. 2018. Health Impact of China's Air Pollution Prevention and Control Action Plan: An Analysis of National Air Quality Monitoring and Mortality Data. *The Lancet*. 2 (7). E313–E323.

¹⁸ ADB. 2015. China, People's Republic of: Beijing–Tianjin–Hebei Air Quality Improvement—Hebei Policy Reforms Program. <https://www.adb.org/projects/49232-001/main>.

¹⁹ ADB. 2018. Mongolia: Ulaanbaatar Air Quality Improvement Program. <https://www.adb.org/projects/51199-001/main>.

²⁰ World Health Organization. 2006. WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide: Global Update 2005 (Summary of Risk Assessment).

²¹ Air Quality Health Index, Hong Kong, China. <http://www.aqhi.gov.hk/en/what-is-aqhi/about-aqhie469.html?showall=&start=1>.

²² Thailand Air Quality and Situational Reports. <http://air4thai.pcd.go.th/webV2/>.

4. Enhance technical capacity in air quality monitoring, data management, source emission control, and impact assessment

Good air quality information is essential to set policy and identify priorities for action. The lack of data from air quality monitoring and emissions inventories, combined with limited understanding of the magnitude of the urban air pollution problem hampers the effectiveness of policies and programs. In addition, there is a strong need to improve technical understanding and skills related to air quality monitoring (especially on the use of online instruments), data management and analysis (focusing on statistical analyses, visualization, and interpretation), source emission control (especially of fugitive and area sources), and impact assessment (covering health damage and economic loss). Choosing and adopting suitable and affordable new clean technologies and air pollution control equipment can also be challenging for decision makers in many developing cities in Asia.

In the PRC, a monitoring network covering all prefecture-level cities and the installation and operation of continuous emission monitoring systems were established in all provinces. Capacity building complemented by monitoring and laboratory infrastructure can improve enforcement and compliance. AQM training in the PRC is organized by the Ministry of Ecology and Environment, provincial environmental protection departments, and environmental protection bureaus, with support from nongovernment organizations from time to time. Annual workshops on total emission control are focused on technical topics, industry sectors, and policy instruments.

5. Prioritize emission prevention and control, and use of economic instruments to address air pollution

Economic instruments such as taxes, levies, penalties, differential pricing of fuels and energy sources, and incentives for greener options or investments are rarely used by Asian cities to manage air pollution. However, an emission permits system is widely used in the US and EU to regulate the emissions activity of stationary sources. The US operating permit program streamlines the way federal, state, tribal, and local authorities regulate air pollution by consolidating all air pollution control requirements into a single, comprehensive “operating permit” that covers all aspects of a source’s year-to-year air pollution activities. Taxing polluting vehicles, restricting the importation of second-hand motor vehicles, providing subsidies to electric and hybrid vehicles, and imposing stricter penalties for emission violations are good examples for reducing air pollution emissions from mobile sources. In Hong Kong, China, practical emissions abatement actions include implementation of emissions caps and permitting emissions trading, retrofitting existing coal-fired power plants with flue gas desulfurization, wider use of natural gas in power plants, and promotion of renewable energy facilities. In 2006,

Mongolia introduced a waiver of excise taxes on imported hybrid, liquefied petroleum gas-fueled and electric vehicles to encourage their use. As a result, the number of hybrid cars in Ulaanbaatar grew dramatically from 4,360 in 2011 to 75,532 in 2016, or almost 17 times. Today, one in four vehicles on Ulaanbaatar’s roads is a hybrid car.²³

6. Integrate air quality management into sector policies, plans, and programs

Air quality is impacted by the policies, plans, and programs of different stakeholders and sectors, particularly due to emissions from transport, energy production, and industries. Land-use planning, through its influence on demography, topography, and economic and social concerns, and interlinked with the transportation, construction, and industry sectors, can greatly influence air quality in the long term. Land-use planning for air quality control includes zoning codes and performance standards, land-use controls, housing and land development, and land-use planning policies.

Strategic environmental assessment (SEA) of existing or future development policies, programs, and plans can be an entry point to integrated AQM in urban development. An SEA can provide a systematic framework within which to assess the environmental impacts of development at a strategic level on urban air pollution. In Hong Kong, China, an SEA is applied to major development plans such as territorial development, waste, and energy. Decision makers provide key information on potential impacts of air pollution from proposed developments within these development plans, allowing air pollution prevention and control to be incorporated upfront in the planning process.

In the transport sector, sustainable urban mobility plans (SUMP) are used by city authorities to reduce air pollution emissions, along with improved safety and quality of life, while supporting economic development. SUMP include important measures such as integrated planning, urban logistics, collective transport, clean fuel and vehicles, intelligent transport systems, safety and security, and mobility demand management. To measure emissions from transport and urban mobility, Transport Emissions Evaluation Models for Projects (TEEMP) is widely used to evaluate greenhouse gases, air pollution, and other impacts of different transport options.

Air quality is impacted by the policies, plans, and programs of different stakeholders, particularly the transport, energy production, and industry sectors.

²³ B. Tsevegjav. *Presentation on Policies of Reduction of Air Pollution in Ulaanbaatar and its Co-Benefits*. November 2017. Beijing, PRC.



Bus Rapid Transit in the People's Republic of China. Air quality can be improved by the policies, plans, and programs of the transport sector.

In the energy sector, the promotion of renewable energy, energy efficiency and conservation, power import and export, and environmental concerns are reflected in the long-term national energy sector policies and plans. There is a strong need to take account of environmental and social impacts and costs in energy planning, choice of technology, and location of thermal power plants. City authorities have used sustainable energy action plans to take an integrated approach in achieving emission reductions in residential, industrial, and transport sector energy use.

Extensive and intensive use of materials and energy have resulted in increased pressure on the environment and urban air pollution, and there is demand for more sustainable industrial development. The pollution prevention approach in the industry sector focuses directly on the application of best available technologies with respect to processes, practices, materials, and energy use that can improve emissions to air and costs. Highlighting the economic and environmental benefits and costs of urban air pollution reduction in industry sector policies, plans, and programs may help in incorporating air pollution prevention in the design of industrial processes.

7. Enforce air quality laws and regulations

Enforcement of air pollution laws, standards, and regulations needs to be strengthened in developing Asian countries and cities using innovative methods and proven procedures. Enforcement of emission control regulations is needed to ensure industries, thermal power

plants, motor vehicles, and other sources meet the emissions limits set in standards. As an immediate course of action, national and city-level agencies should be properly resourced (in terms of staffing, but also technical capacity) so these can enforce existing laws.

A range of methods are available to monitor compliance from different sectors. The traditional methods for government to monitor industry compliance with emissions standards include stack monitoring, requiring industry to report their emissions, and mandating the set-up of continuous emissions monitoring systems. Innovative methods of compliance monitoring include the use of infrared cameras and drones carrying them. Since 2012, the Visible Infrared Imaging Radiometer Suite onboard the Suomi National Polar-Orbiting Partnership satellite has detected fires with higher resolution images of the Earth's surface.²⁴ In countries that ban or limit fires during certain seasons, government and law enforcement officials will have more accurate information for identifying where prohibited fires start burning.

To measure an in-use vehicle's real driving exhaust emissions, two different approaches are used: onboard emission measurement by portable emission measurement systems (PEMS) and remote sensing device (RSD) systems. PEMS measure emissions in large detail over a whole driving cycle or a route, and were used to detect defeat devices on late-model diesel passenger cars (cars corresponding to the Euro-5 emission standard). RSD systems provide a snapshot (of less than a second) of a vehicle's emissions and can be employed to measure the momentary emissions of

²⁴ E. Sziszar et al. 2012. Active Fires from the Suomi NPP Visible Infrared Imaging Radiometer Suite: Product Status and First Evaluation Results. *Journal of Geophysics Research: Atmosphere*. 119 (2). i–v. January 2012. pp. 363–1096.

thousands of cars per day. However, because of certain challenges with remote sensing, it is best used at this time as an adjunct to annual or biennial inspections and PEMS diagnostics.

8. Secure adequate, sustainable funding for integrated air quality management

Unless sustainable financing mechanisms supported by policy frameworks and the right investment climate are in place, infrastructure, capacity, and resources to implement and enforce air pollution prevention and control in Asia's cities will continue to be deficient. This requires national governments to allocate the appropriate level of funding for AQM, implement the polluter pays principle, and enforce emissions fees for air pollution. With the growing pressure on air pollution, the PRC allocates \$1.4 trillion annually for its AQM activities at national and local levels. The Government of Nepal allocated around \$74 million for programs related to environmental conservation, including installation of air quality monitoring stations. The Philippines established an AQM Fund under the Clean Air Act and the Special Vehicle Pollution Control Fund to support air pollution reduction initiatives, but disbursement issues related to lack of clear guidelines remain.

To support government investment through budget allocation, public–private partnership models, green bonds, and financing through climate funds may be optional solutions. One example is the energy savings performance contract financing model between an energy savings company and a government agency or institution. One other key source of financing for air pollution is climate funds given the co-benefits of addressing air pollution of climate change mitigation, and that some air pollutants are also short-lived climate pollutants.

WAY FORWARD

Improving air quality in Asia's cities is a complex, but not impossible challenge. Other cities in the region and around the world have shown that with the right mix of strategies, policies, market reforms, financial instruments, and mechanisms, better air quality can be achieved. Once the extent and causes of the air pollution problem faced by a country or city are understood, a range of sectors—including urban development, energy, transport, and health—must work together to develop and deliver on CAAPs.

When better AQM is mainstreamed in land use, transport, energy, industry, and other sector policies, plans, and programs, along with a clear investment road map, the prospects for Asian cities to achieve cleaner air, livable environments, and healthier residents are much better. Such an approach has been adopted by ADB projects in Ulaanbaatar and the BTH region. It now needs to be

With the right mix of strategies, policies, market reforms, financial instruments, and mechanisms, better air quality can be achieved.

transferred to other cities in Asia to enable them to become livable, in accordance with ADB's seventh operational priority, as showcased by an ADB TA project.²⁵

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