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Asian Development Bank

Mainstreaming Air Quality in Urban Development in 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

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List of Abbreviations

ADB	Asian Development Bank
APHI	Air Pollution and Health Index
AQ	air quality
AQG	air quality guideline/s
AQI	air quality index
AQM	air quality management
AQNMP	Air Quality and Noise Management Action Plan
BaP	Benzo(α)pyrene
BC	black carbon
BMA	Bangkok Metropolitan Authority (Thailand)
BMR	Bangkok Metropolitan Region
CAA	Clean Air Asia
CAAP	Clean Air Action Plan
CAIP	Clean Air Implementation Plan
CAST	Clean Air Scorecard Tool
CEMS	continuous emission monitoring systems
DENR	Department of Environment and Natural Resources (Philippines)
EC	European Commission
EI	emissions inventory
EIA	Environmental Impact Assessment
EMB	Environmental Management Bureau (Philippines)
ENRO	Environment and Natural Resources Office/r
EPA	Environmental Protection Agency
ERP	electronic road pricing
ESCo	Energy Saving/s Company
EU	European Union
FEPA	Federal Exposure Protection Act
FYP/s	five-year plan/s
GHG/s	greenhouse gas/es
IASS	Institute for Advanced Sustainability Studies
ICIMOD	International Centre for Integrated Mountain Development
LPG	liquefied petroleum gas
MEP	Ministry of Environmental Protection (People’s Republic of China)
MODIS	moderate resolution imaging spectroradiometer
MoPE	Ministry of Population and Environment (Nepal)
NAAQS	national ambient air quality standard
NGO/s	nongovernment organization/s
NMVOC/s	non-methane volatile organic compound/s
OECD	Organization for Economic Co-operation and Development
PAH	polycyclic aromatic hydrocarbon
PCD	Pollution Control Department
PEMS	portable emission measurement system/s
PRC	People’s Republic of China
PRD	Pearl River Delta
QA	quality assurance
QC	quality control
RSD	remote sensing device (system)
SDG	Sustainable Development Goal/s
SEA	Strategic Environmental Assessment
SEAPs	Sustainable Energy Action Plans
SIP	State Implementation Plan
SLCP	short-lived climate pollutants
SUMP	Sustainable Urban Mobility Plans
SusKat	Sustainable Kathmandu
TA	technical assistance
TI Air	Technical Instructions for Air Quality

TSP	total suspended particulates
UN	United Nations
UNDESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
US	United States
US EPA	United States Environmental Protection Agency
VIIRS	Visible Infrared Imaging Radiometer Suite
VOC/s	volatile organic compound/s
WHO	World Health Organization

Preface

This report is a knowledge product for the Asian Development Bank's (ADB) Regional Capacity Development Technical Assistance (R-CDTA) 8751: Mainstreaming Air Quality in Urban Development through South-South Twinning.

Through this TA, ADB aimed to contribute to enhancing the capacity of cities to manage urban air pollution and worked towards the increased application of knowledge and understanding of air quality management (AQM) by city governments. The TA promotes evidence-based long-term planning in AQM through South-South shared learning. Clean Air Asia, a nongovernment organization with more than 15 years of experience in air quality management in Asia, implemented the TA.

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Executive Summary

AIR POLLUTION AND HEALTH

The World Health Organization estimates that ambient and household air pollution causes 7 million premature deaths worldwide. This is attributed primarily to exposure to fine particulate matter ($PM_{2.5}$), which ranks as the 6th highest risk factor for early death through respiratory infections, heart disease, stroke, chronic lung disease and lung cancer (Health Effects Institute [HEI], 2018). Majority (91%) of populations exposed, and thus experiencing this burden of disease, are people in low- and middle-income countries in the WHO Western Pacific and Southeast Asia regions (World Health Organization [WHO], 2018b). Ambient air pollution also contributes to climate change with emissions of short-lived climate pollutants (SCLPs) like black carbon (BC) due to combustion of diesel and agricultural residue.

AIR POLLUTION AND ECONOMIC IMPACTS

The annual labor income losses from premature deaths of working-age men and women are equivalent of 0.8% of the gross domestic product (GDP) in South Asia and 0.25% in East Asia and the Pacific. The Organization for Economic Cooperation and Development (OECD) predicts that by 2060, air pollution could be responsible for a reduction in global economic output of $330 per person with annual healthcare costs increasing from $21 billion in 2015 to $176 billion.

AIR POLLUTION AND SUSTAINABLE DEVELOPMENT GOALS

Addressing air pollution is now incorporated into the targets and indicators of the United Nations' Sustainable Development Goals (SDGs) such as Health (Goal 3) and Sustainable Cities (Goal 11). Other SDGs that directly or indirectly contribute to improving global air quality include: SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure) and SDG 12 (Responsible Consumption and Production).

IMPORTANCE OF MAINSTREAMING AIR QUALITY MANAGEMENT IN ASIAN CITIES

In 2015, 2.11 billion people in Asia lived in urban areas, which accounts for 53% of the world's urban population. Between 2016 and 2030, the number of cities in Asia with 500,000 inhabitants or more is expected to grow by 30%. It is crucial that cities meet national ambient air quality standards (NAAQS) and WHO's health-based air quality guidelines. Unfortunately, most cities in Asia do not comply with the latter. To achieve compliance and mitigate the adverse impacts, it is imperative that air pollution be integrated into country and city development planning. This requires the mainstreaming of air quality considerations in urban sector plans (e.g., power and energy, transportation, urban development). A clean air action plan (CAAP), which evolves following an integrated AQM framework with sectoral mainstreaming (e.g., sustainable energy action plans, sustainable urban mobility plans, land-use plans), is the way forward. Integrated AQM comprises of activities that enable the setting of an air quality objective and reduce the health and environmental impacts of air pollution.

FOCUS OF THE TECHNICAL ASSISTANCE (TA)

The focus of TA 8751 is on *Mainstreaming Air Quality in Urban Development through South-South Learning. The TA* was designed to create opportunities to promote sharing of experiences and knowledge on good practices in AQM from and within the region.

SCOPE OF THE TA

The TA assessed the strengths and improvements needed in AQM in four cities – Chengdu, Kathmandu, Metro Manila, and Xiangtan – and four countries – Nepal, Philippines, People's Republic of China, and Thailand. It identified challenges and potential solutions to address the issue of urban air pollution.

METHODOLOGY

The following methodology was used in the TA:

- Application of the Clean Air Scorecard Tool (CAST) across several cities in Asia to shortlist the cities and countries for which AQM assessments were conducted;
- Air quality management assessments of selected cities and countries based on secondary data complemented by stakeholder consultations and expert review of the assessment results, to identify common challenges in implementing integrated AQM; and
- Regional dialogue for knowledge exchange of good practices in AQM to address the common challenges, including recommendations for strengthening integrated AQM and mainstreaming of air quality in urban development.

COMMON CHALLENGES TO IMPLEMENTING INTEGRATED AQM FRAMEWORK

While each country and city has specific challenges unique to its context, the assessment identified the following common challenges in implementing integrated AQM:

- insufficient air quality information to inform policies, plans, and programs;
- limited technical capacity;
- lack of coordination among stakeholders in AQM;
- leniency of national air quality standards;
- weak enforcement of air quality standards;
- insufficient financial resources and incentive schemes; and
- lack of mainstreaming of air quality concerns in urban development.

RECOMMENDATIONS TO STRENGTHEN INTEGRATED AQM AND MAINSTREAM AIR QUALITY IN URBAN DEVELOPMENT

Based on the results of the assessment, identification of common challenges, and a rapid review of successful practices from selected cities and countries in implementing integrated AQM, the following recommendations were developed:

- Develop CAAPs with clear objectives, roles, and accountability;
- Tighten ambient air quality standards;
- Increase political and public awareness on air pollution impacts;
- Enhance technical capacity in key aspects of integrated AQM;
- Strengthen emission prevention and control and use of economic instruments;
- Integrate air pollution prevention and control into sectoral policies, plans, and programs;
- Enforce air quality laws and regulations; and
- Secure adequate financial resources.

Recommendations were also provided to address specific urban air quality issues faced by cities and countries.

While national and local governments in selected Asian countries and cities have developed strategies to address the deterioration of urban air quality, their scope and effectiveness vary. Progress has been made in implementing key aspects of an integrated AQM system, however, further action is required to see significant improvements in air quality in developing Asia and contribute to the implementation of the SDGs and the Paris Climate Agreement. In particular, there is potential to exploit air and climate co-benefits and address SLCP emissions.

DEVELOP CAAP WITH CLEAR OBJECTIVES, ROLES AND ACCOUNTABILITY

Clean air action plans need to be developed at the city level, mainstreaming of air quality concerns in urban development. A CAAP provides an overarching document that sets clear air quality objectives or goals for all sectors and stakeholders. It clarifies roles of different sectoral agencies and stakeholders; facilitates collaboration; defines accountability, reporting, and monitoring and is backed by a financial and investment plan. Since air pollution is not limited to administrative boundaries, a regional or airshed-based approach is also needed. There is relatively less experience in Asia on the preparation of regional CAAPs, unlike in the United States and Europe where they prepare CAAPs at the State level. Whether an airshed, city, region, or state approach is to be taken will be dependent on the source and type of pollution and level of cooperation between agencies and stakeholders. There is a need to prepare model CAAPs on this basis and build capacities at urban, regional, and state levels.

TIGHTEN AMBIENT AIR QUALITY STANDARDS

There is a variance in the adoption of ambient air quality standards across Asian countries. National governments should make efforts to align national standards with WHO guidelines or standards based on international good practice. However, when formulating policy targets, governments should consider their own local circumstances, especially the infrastructure and institutional capacities before adopting WHO guidelines or standards.

INCREASE POLITICAL AND PUBLIC AWARENESS OF AIR POLLUTION IMPACTS

Increasing political and public awareness is necessary to change attitudes, foster behavioral change, encourage action to address poor air quality and mobilize financial resources. These are important to ensure that air pollution-related health and environmental impacts are not neglected. Costs of inaction on air pollution abatement need to be estimated and communicated to the public to get the needed political support.

ENHANCE TECHNICAL CAPACITY IN KEY ASPECTS OF INTEGRATED AQM

There are several aspects where strengthening of the technical capacity of key institutions is needed. There is a dire need to improve technical understanding and skills related to air quality monitoring (especially on the use of on-line 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). This is where national training institutions and academia could take the lead. Capacity building complemented by monitoring and laboratory infrastructure will improve enforcement and compliance. It is also important to promote participatory monitoring and democratization of air quality data where people, especially children and youth, are involved. Advances in and availability of sensor technologies allow for low-cost air quality monitors to be provided to citizens to get them involved, after necessary checks and quality control. This will help build a large and dense database on city air quality that can be shared.

STRENGTHEN EMISSION PREVENTION AND CONTROL AND USE OF ECONOMIC INSTRUMENTS

Economic instruments, such as taxes and levies, differential pricing of fuels and energy sources, and incentives for greener options or investments are rarely used by Asian cities to manage air pollution. Building a tool box of economic instruments, gathering application of experience, contextualizing the tools, and piloting their application in some of the highly polluted cities in Asia contribute to achieving air quality targets and implementing CAAPs.

INTEGRATE AIR QUALITY INTO SECTORAL POLICIES, PLANS, AND PROGRAMS

For Asian cities to be able to meet their air quality goals, they should integrate air pollution issues into sectoral planning. Policies, plans, and programs of different agencies and sectors such as transport, power and energy, and industry can influence urban air quality. The sector policy cycle typically involves steps such as agenda setting, consultations, formulation, legitimation, implementation, assessment and re-formulation/ expansion (Koojo Amooti, 2006) and each stage offers an opportunity for integrating air quality considerations. In the transport sector, for instance, demand management, use of cleaner fuels, and transport planning play crucial roles. Other examples include increasing renewable energy sources in cities (e.g., rooftop solar systems) and applying land-use planning tools considering air quality (e.g., zoning) for housing development. One approach to ensure air quality becomes part of urban development is to apply Strategic Environmental Assessment (SEA) to PPPs. Such assessments can be used to develop a systematic, rigorous, and participatory framework that can integrate air pollution.

ENFORCE AIR QUALITY LAWS AND REGULATIONS

Enforcement of air pollution laws, standards, and regulations needs to be strengthened in developing Asian cities and countries using innovative methods and proven procedures.

SECURE ADEQUATE FINANCIAL RESOURCES FOR INTEGRATED AQM AND CLEAN AIR ACTION PLAN IMPLEMENTATION

Having adequate financial resources to implement the different components of an integrated AQM system is essential. This requires national governments to recognize that air pollution is a priority and allocate the appropriate resources, implement the polluter-pays principle, and allocate collected emission fees, fines and penalties to air pollution prevention and control. Special funds could be set up by the government to finance air pollution control projects. Public-private partnerships also have the potential to provide funding for projects that help improve air quality. An example of such partnership is the energy savings performance contract financing model between an Energy Savings Company (ESCO) and a government agency or institution. Other sources of funding could be international donors that provide grants and loan financing facilities.

Introduction

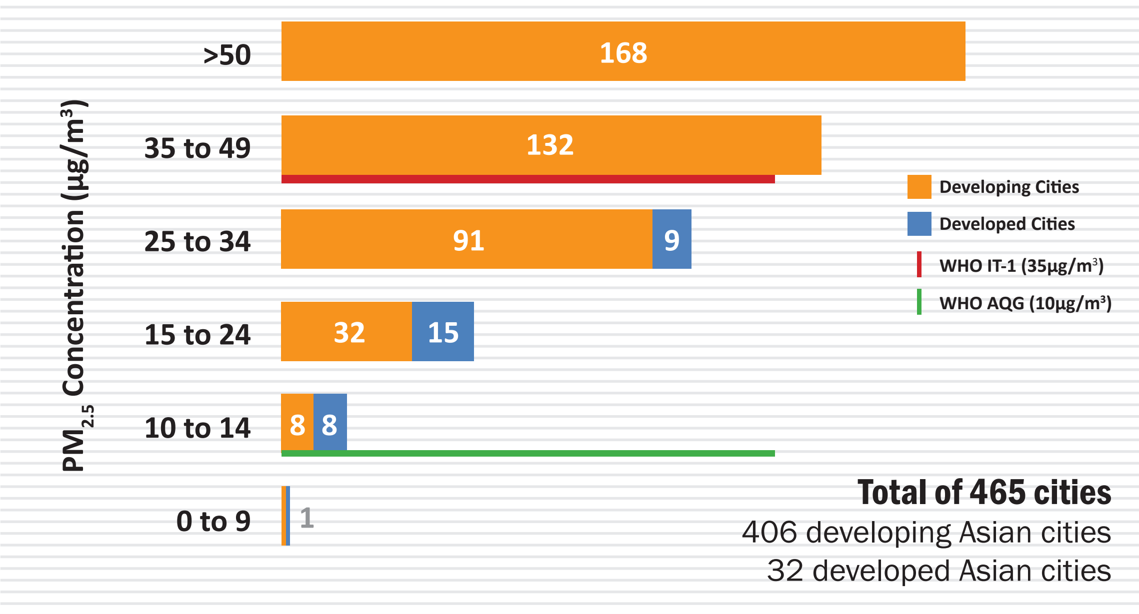
AIR POLLUTION THREATENS THE HEALTH, WELLBEING, PRODUCTIVITY AND ECONOMIC DEVELOPMENT OF A SIGNIFICANT NUMBER OF ASIAN CITIES. It causes illnesses and premature deaths, reduces labor and agricultural productivity, and makes cities unattractive and unhealthy places to live in.

In densely populated and highly motorized cities, diesel-fueled transport, open-waste burning, coal-fired power stations, construction sites, and dirty fuels are sources of harmful air pollutants such as particulate matter (PM) and nitrogen oxides (NO_x) which are harmful to human health (Appendix I). In addition, transboundary pollution from forest fires , agricultural open burning as well as dust storms can influence air quality.

The World Health Organization estimates that ambient and household air pollution causes 7 million premature deaths worldwide. This is attributed primarily to exposure to fine particulate matter ($PM_{2.5}$), which ranks as the 6th highest risk factor for early death through respiratory infections, heart disease, stroke, chronic lung disease and lung cancer (Health Effects Institute [HEI], 2018). Majority (91%) of populations exposed, and thus experiencing this burden of disease, are people in low- and middle-income countries in the WHO Western Pacific and Southeast Asia regions (World Health Organization [WHO], 2018b). More than 90% of cities in Asia are experiencing unhealthy levels of particulate pollution (Figure 1. Clean Air Asia, 2017). Ambient air pollution not only adversely affects health, environment, and quality of life but also contributes to climate change with the emissions of short-lived climate pollutants (SLCPs) such as black carbon (BC) from diesel.

A large rise in mortality rates is expected in India, the People's Republic of China (PRC), South Korea, and Central Asian countries (e.g., Uzbekistan), where expanding populations and congested cities mean more people are exposed to power plant and vehicle emissions. Premature death rates are

Figure 1: Air Quality in Asian Cities



Data collected from publicly available sources compiled by WHO and CAA.
Data for the last available year in the period 2012-2016
Clean Air Asia, 2017

forecast to be up to three times higher in 2060 than in 2010 in PRC and up to four times higher in India (Organization of Economic Co-operation and Development [OECD], 2016).

While an improvement in air quality is already being realized in high-income Asian cities, the challenge is to move all Asian cities to levels of compliance with their national air quality standards and then to levels not exceeding WHO guideline values.

Air pollution also has economic impacts, with annual labor income losses from premature deaths of working-age men and women costing the equivalent of 0.8% of gross domestic product (GDP) in South Asia and 0.25% in East Asia and the Pacific (World Bank and Institute for Health Metrics and Evaluation, 2016). The OECD (2016) predicts that by 2060, air pollution could be responsible for a reduction in global economic output of $330 per person with annual healthcare costs increasing from $21 billion in 2015 to $176 billion in 2060.

In 2015, 2.11 billion people in Asia lived in urban areas, accounting for 53% of the world's urban population (World Bank and Institute for Health Metrics and Evaluation, 2016). Between 2016 and 2030, the number of Asian cities with 500,000 inhabitants or more is expected to grow by 30% (United Nations of Economic and Social Affairs [UNDESA], 2016). It is, therefore, crucial that cities meet National Ambient Air Quality Standards (NAAQs) as well as the health-based WHO air quality guidelines.

Decisions about a city's development can determine whether or not it takes a low emission, energy efficient and sustainable pathway. Energy use, cost of living, provision of services and quality of life vary between cities with similar income levels depending on past infrastructure and planning decisions. Land development decisions are infrastructural - once made, they are difficult and expensive to undo. Costs of traditional development can result in higher financial and welfare costs related to traffic congestion, socio-economic costs of air pollution, inefficient energy consumption, and failure to account for the higher costs of providing public infrastructure in sprawling cities. However, through the implementation of land use and infrastructure good practices, cities can shape better outcomes for their citizens (Clean Air Asia Cities for Clean Air Certification).[1]

The UN-Habitat's New Urban Agenda acknowledges the challenges of an increasingly urban world and sets out a roadmap for building cities that can serve as engines of prosperity and centers of cultural and social well-being while protecting the environment. It is an extension of the UN 2030 Agenda for Sustainable Development that outlined 17 Sustainable Development Goals (SDGs) needed to make the transition towards a low carbon society.

Although air pollution is included in both the New Urban Agenda and the SDGs, it is not prominent enough. The SDGs incorporate air pollution into the targets and indicators on Health (Goal 3) and Sustainable Cities (Goal 11). Other SDGs that directly or indirectly contribute to improving global air quality include SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure) and SDG 12 (Responsible Consumption and Production).

Mainstreaming the management of air quality in urban sector plans (e.g., transport, power and energy, urban development) can contribute to the SDGs, and the New Urban Agenda by reducing air pollution impacts on health, promoting air pollution prevention, adopting clean technologies, and exploiting air and climate co-benefits.

Many city-level actions such as reducing emissions from municipal solid waste can improve urban air quality and reduce greenhouse gases (GHGs) and SLCPs. These contribute to meeting the goals set out in the Paris Climate Accord to combat climate change and deliver multiple social, environmental and economic co-benefits (WHO, 2015).

The main recommendation of the Lancet's Commission on Pollution and Health (2017) was for environmental pollution, including air pollution, to be integrated into country and city planning, particularly development planning (Landrigan, et al., 2017). A clean air action plan (CAAP) based on sound scientific evidence and adheres to an integrated air quality management (AQM) approach[2] is a means of mainstreaming air quality concerns in urban development.

Learning from successful strategies, policies and approaches adopted in other Asian cities can help lead the way to achieving better air quality in Asia and more sustainable and low carbon cities (Chan and Solheim, 2017).

It is in this context that the Asian Development Bank (ADB) Technical Assistance (TA) 8751 on Mainstreaming Air Quality in Urban Development through South-South Learning was developed. The TA promotes evidence-based long-term planning in AQM through South-South shared-learning. It was designed to create opportunities to promote sharing of AQM experience and knowledge in the region through city and country AQM assessments, stakeholder consultations and regional dialogue.

[1] *Clean Air Asia, 2017. Cities for Clean Air Certification Program. www.cleanairasia.org/certification*

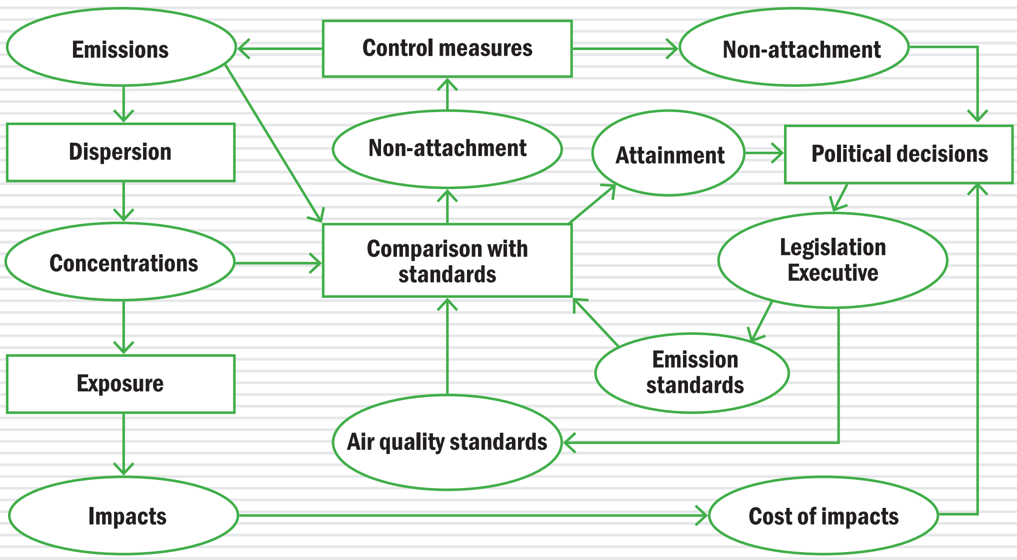
[2] *Clean Air Asia, 2016. Guidance Framework for Better Air Quality in Asian Cities.*

1.1 Integrated Air Quality Management

The Guidance Framework for Better Air Quality in Asian Cities (Clean Air Asia, 2016) outlines an integrated AQM approach. It comprises of activities that enable the setting of an air quality objective and reduce the health and environmental impacts of air pollution. Integrated AQM ensures key components that contribute to identifying, monitoring, assessing, preventing, and/or mitigating pollutant air emissions are in place and work effectively.

This involves implementing key AQM activities on a regular basis: air quality monitoring, emissions inventories, dispersion modeling, assessment and quantification of air pollution impacts, and measures to ensure validity of the information generated (Schwela and Goelzer, 1997; International Labour Organization [ILO], 2017). The benefits of avoided and monetized health impacts should be compared with the costs of implementing the control measures. All this information feed into the development of CAAPs or clean air implementation plans (CAIPs) and contribute to an integrated AQM system. Developing Asian cities require assistance to strengthen their capacity to implement this integrated AQM system (Clean Air Asia, 2016; Figure 2).

Figure 2: Air Quality Management System



Source: Adapted from Clean Air Asia (2016)

1.2 Methodological Approach

The methodology used in the study is as follows:

Application of the Clean Air Scorecard Tool (CAST) in Selecting Cities and Countries. The Air Pollution and Health Index (APHI) of CAST was used to assess the air quality status of almost 500 cities in 17 Asian countries (Box 1). As part of data pre-processing, the list was narrowed down to include only cities that have at least 3 years of annual average data for PM_{10}, $PM_{2.5}$, sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) from 2011 to 2013 or from 2012 to 2014. The availability of the 3-year dataset is used as an indication that the city has an operational AQM system in place.

The analysis showed that cities often report or publish PM_{10} data more than other pollutants due to its direct effect on public health. PM_{10} data from 214 cities was analyzed in the shortlisting process. Cities with high and low APHI results for each population category (i.e., large, medium, small) were then evaluated based on city selection criteria.

These criteria are important to identify and select cities for sharing and learning. The approach was to identify cities with air pollution levels exceeding WHO guideline values but have demonstrated some level of AQM capacity. This process resulted in the selection of Xiangtan and Chengdu (PRC); Kathmandu (Nepal); and Metro Manila (Philippines) as the focus of the city assessments and learning activities for the project.

As for the countries in this study, these were selected based on the following criteria: (1) those with the highest number of cities with critical to very poor APHI scores; (2) those with a large proportion of cities with air quality monitoring data (vis-a-vis total number of cities); and (3) those able to demonstrate initiatives in AQM. The shortlist comprised of India, Indonesia, Mongolia, Nepal, the Philippines, PRC, Sri Lanka, Thailand, and Viet Nam. Of these countries, four sent commitment letters agreeing to participate in country assessments on AQM – Nepal, Philippines, PRC and Thailand.

City and Country Assessments. City and country assessments were undertaken for the selected Asian cities and countries using peer review surveys and grey literature, secondary data and consultations, and city and country profiles to assess state of air quality and its impacts and challenges of, and recommendations for AQM. These are reflected in assessment reports validated by technical experts at the national and local levels in each of the countries and cities.

Assessments of air quality in the selected countries and cities were undertaken covering the key pollutants $PM_{2.5}$, PM_{10}, NO_2, SO_2, and ozone (O_3) using secondary data and data from city and national government agencies. Reference materials included national air quality status reports, AQM plans and progress reports, journal articles, and other documents with information on the state of the air at national and/or city levels. These provided a complete picture of the state of the air, progress in terms of air quality improvement, and challenges that need to be addressed in a given geographic area.

Stakeholder consultations were undertaken to review and validate the assessments conducted. These comprised of consultation meetings with focal ministries and other concerned agencies and focus group discussions. The focus group discussions brought together focal agency/ministry representatives and other relevant stakeholders to identify the AQM solutions that are aligned with national and/or local programs and strategies. These meetings served to validate, update, and correct findings generated through secondary data research and solicit inputs on the applicability and soundness of recommendations put forth in the reports vis-à-vis national and local contexts.

Regional and international AQM experts provided inputs and ensured the technical and scientific soundness of the recommendations in the city and country assessments.

BOX 1

The Clean Air Scorecard Tool

The Clean Air Scorecard Tool (CAST) is an Excel-based tool incorporating three indices: (i) Air Pollution and Health, (ii) Clean Air Management Capacity, and (iii) Clean Air Policies and Actions. Clean Air Asia under the Sustainable Urban Mobility in Asia (SUMA) program developed the CAST with support from Asian Development Bank and the Swedish International Development Cooperation Agency (SIDA) to help cities gain a comprehensive understanding of the status of their AQM. The tool builds on experiences from past benchmarking studies and assessment tools. These past studies include a Benchmarking Study on Air Quality Management (Study) in the early 1990s by the World Health Organization (WHO)/UNEP–GEMS Project in 20 Asian cities conducted by Clean Air Asia, Korea Environment Institute, Stockholm Environment Institute, and United National Environment Program (UNEP) in 2006; the assessment covered four components: AQM capacity, data assessment and availability, emissions inventory (EI), and AQM enabling capacity. The Study made use of a questionnaire survey developed.

For this ADB-supported study, the Air Pollution and Health Index (APHI) of CAST was used to assess the air quality status of almost 500 cities in 17 Asian countries–Bangladesh, Bhutan, Brunei Darussalam, Cambodia, India, Indonesia, Japan, Republic of Korea, Mongolia, Nepal, Pakistan, the Philippines, People’s Republic of China (PRC), Singapore, Sri Lanka, Thailand, and Viet Nam.

The APHI follows the general calculation approach in converting pollutant concentration into an index value based on US EPA, 2012 Technical Assistance Document for the Reporting of Daily Air Quality – the Air Quality Index). This is also the index calculation approach used in most Asian countries, but with different breakpoints based on national air quality standards. The APHI assesses air quality levels of cities relative to the WHO Air Quality Guideline (AQG) values and Interim Targets (i.e., a “good air” day in this index is in relation to WHO AQG rather than the national ambient air quality standards which are generally less stringent). While the index includes seven pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO and lead [Pb]), a city is required to have, at a minimum, monitoring data for PM_{10} to be shortlisted.

Since its development in 2010, CAST has been applied in 24 Asian cities from 9 countries. These are: Bac Ninh, Viet Nam; Bangkok, Thailand; Cagayan de Oro, Philippines; Can Tho, Viet Nam; Changchun, PRC; Chiang Mai, Thailand; Colombo, Sri Lanka; Dalian, PRC; Foshan, PRC; Guangzhou, PRC; Hangzhou, PRC; Hanoi, Viet Nam; Harbin, PRC; Iloilo, Philippines; Jakarta, Indonesia; Jiangyin, PRC; Jinan, PRC; Kathmandu, Nepal; Korat, Thailand; Manila, Philippines; Quetta, Pakistan; Tongxiang, PRC; Visakhapatnam, India; and Zhaoqiang, PRC. The implementation of CAST was supported by ADB, Energy Foundation, Rockefeller Brothers Fund, German International Cooperation (GIZ), Integrated Programme for Better Air Quality in Asia (IBAQ Programme), and Fredskorpset Norway.

Based on an analysis of the city and country assessments, common challenges in AQM were identified as areas for learning. The cities of Kawasaki, Japan, Hong Kong, China, and Bangkok, Thailand, and Singapore were then requested to share AQM good practices.

International Case Study Reports. An assessment of the development of AQM policy in the US and Germany and its effectiveness in reducing pollutant air emissions was undertaken to identify different approaches in addressing poor air quality.

Regional Workshop. A regional workshop was organized on 9-12 October 2017 in Bangkok, Thailand and convened representatives from the four countries and cities, development partners, and AQM experts. Participants from Bangladesh, Mongolia, Pakistan, Sri Lanka, Thailand, and Viet Nam attended the workshop to share their experiences in AQM. Together they identified solutions to address knowledge and capacity gaps in AQM and discussed ways of mainstreaming air quality in urban development plans.

1.3 Limitations of the Approach

In-depth analyses of AQM in the selected countries and cities were undertaken using secondary data. Information obtained were verified with national and city focal points and with other studies, where available. Additional information from the countries and cities that participated in the Bangkok worshop were included in the analysis. However, no new emission inventory studies or modeling were undertaken as part of the assessment.

1.4 Focus and Structure

This report provides a summary of lessons learned from the ADB-supported TA 8751. It outlines the evidence on AQM gathered from – Nepal, Philippines, PRC, and Thailand – and the cities – Xiangtan and Chengdu, PRC, Kathmandu, Nepal, and Metro Manila, Philippines. It describes the persistent and emerging AQM issues and proposes measures Asian cities and countries can adopt to strengthen integrated AQM and mainstream them into urban development. Specifically, it aims to:

- provide an overview of the state of air quality, conditions that drive air pollution at the national and local levels, and regulatory and institutional frameworks shaping AQM actions;
- explain existing initiatives and current technical and management capacity to address challenges in AQM;
- identify factors that facilitate and/or hinder the effective implementation of proposed measures and/or plans; and
- recommend ways to mainstream air quality in urban development plans and programs.

This report is divided into five chapters, including the introduction. Chapter 2 presents the results of the assessments in the selected countries and cities. Chapter 3 identifies common challenges in addressing deteriorating air quality and implementing an integrated AQM. Chapter 4 presents case studies of good practice in AQM. Finally, Chapter 5 outlines actions to be taken to fill the gaps in AQM and provides recommendations and possible mechanisms that could be developed to achieve better air quality in Asia.

The report will be of interest to policy makers, implementers, and key AQM stakeholders in Asian countries and cities, and it is hoped that the recommendations provide a way forward to address the challenge of poor air quality in Asia.

Air Quality Management in Selected Asian Countries and Cities

The study analyzed air quality levels in selected Asian countries and cities using the Air Pollution Health Index of the Clean Air Scorecard Tool to identify which cities will be included in more in-depth AQM assessments and participate in the knowledge exchange facilitated through the TA. Country AQM assessments for Nepal, Philippines, PRC, and Thailand and city assessments for Chengdu, Kathmandu, Metro Manila, and Xiangtan were conducted to expand the understanding of AQM processes, issues, and opportunities. The in-depth assessments provided information and insights on the sources of air pollution, state of air quality, legal framework, and stakeholders, and highlighted the unique challenges of addressing deteriorating air quality in each of the cities and countries.

2.1 Air Pollution and Health Index Analysis of Asian Cities

The annual average air quality levels (i.e., annual average PM_{10}, $PM_{2.5}$, SO_2 and NO_2) of almost 500 cities in Asia from 2011 to 2014 were analyzed using the APHI. The cities were categorized into small, medium, and large cities.[3] The APHI assesses air quality levels of cities relative to WHO's Air Quality Guideline (AQG) values and Interim Targets (i.e., a "good air" day in this index is in relation to WHO AQG rather than the national ambient air quality standards which are generally less stringent). While the index includes six pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO and Pb), a city was required to have, at a minimum, monitoring data for PM_{10} to be included in the analysis. The WHO AQG and Interim Target 3 were considered as bases for the highest category. Succeeding categories were based on Interim Targets 1 and 2 as well as annual average concentration levels of air pollutants. For example, *excellent*, is based on WHO guideline of 20 µg/m^3 and Interim Target 3 of 30 µg/m^3. *Good* and *moderate* categories are based on the Interim Target 2 of 50 µg/m^3 and the Interim Target 1 of 70 µg/m^3, respectively (Table 1). *Poor* and *very poor* categories are based on annual average PM_{10} of 101.23 µg/m^3 in 180 cities in Asia with a standard deviation of 50 µg/m^3.

Of 214 cities[4] in Asia with complete 3-year data between 2010 and 2014 for PM_{10}, 59% fall under *moderate to excellent* APHI while 41% are classified within the *poor to critical* category. Disaggregated by size, results showed that more than half of the large-sized cities (61%) and medium-sized cities (52%) have APHI results in the *poor* to *critical* categories. Worthwhile to note is that 68% of small-sized cities had APHI results within the *excellent* to *moderate* category (Figure 3).

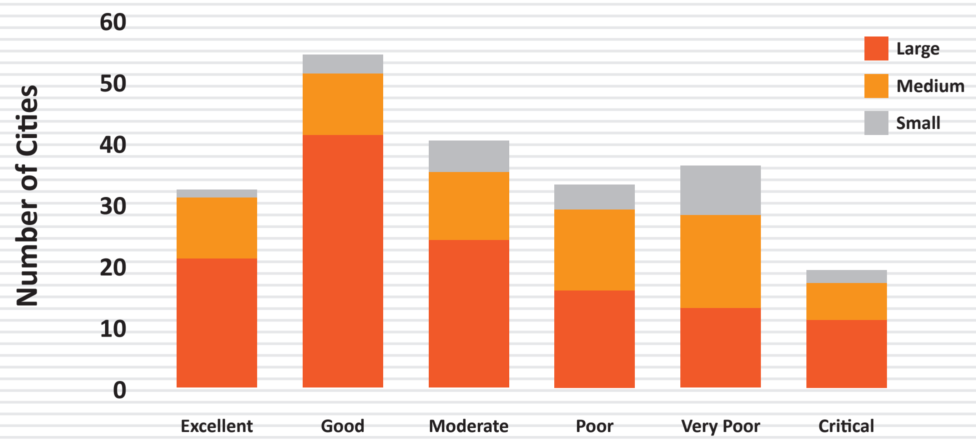
[3] In the TA, a city is classified as small-sized if its population is equal to or less than 1 million, medium-sized if greater than 1 million but equal to or less than 5 million, and large-sized if greater than 5 million. These assumptions were based on UNDESA's (2014) World Urbanization Prospects. Population data at the city level were derived primarily from the UNDESA's (2014) World Urbanization Prospects and published population census

[4] Cities are from Bangladesh, Brunei Darussalam, India, Indonesia, Japan, Mongolia, Philippines, PRC, Republic of Korea, Singapore, Thailand, and Viet Nam.

Table 1: Description of Air Pollution and Health Index Categories

Category	Description
Excellent	Low levels of pollution within WHO-prescribed guidelines. Public health implications for pollutants monitored are limited and hardly noticeable.
Good	Relatively low levels of air pollution but considerable impacts to sensitive groups.
Moderate	Elevated levels of air pollution with aggravated symptoms for sensitive groups and contributing to onset of risks for exposed healthy individuals.
Poor	High levels of pollution with significant health effects to vulnerable populations and contributing to increased risks for exposed healthy individuals.
Very Poor	Extremely high levels of pollution affecting large share of population.
Critical	Critical levels of air pollution resulting in adverse health effects to public in general.

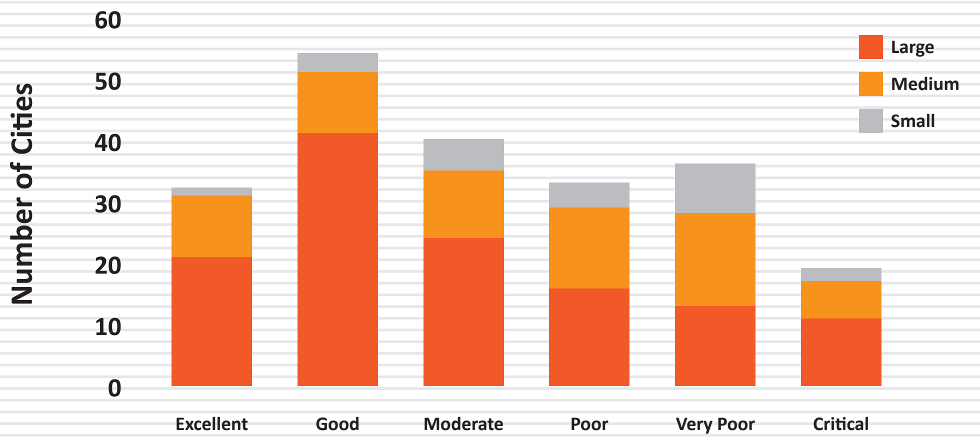
Figure 3: Distribution of 214 Asian Cities Based on APHI Results and Population Size



Source: Based on analysis done by the TA (2016)

When developed cities in Japan and Republic of Korea (ROK) are excluded from the analysis, there is a decline in the number and percentage of cities with *moderate* to *excellent* APHI, at 44% and corresponding increase in the percentage of cities that fall within the *poor* to *critical* APHI categories, at 56% (Figure 4). Of the large developing cities, 64% fall within the *poor* to *critical* APHI categories. For the medium-sized developing cities, 72% had *poor* to *critical* APHI. Of the small-sized developing cities, 51% had *poor* to *critical* APHI.

Figure 4: Distribution of 158 Asian Cities based on APHI Results and Population Size (excluding Developed Cities from Japan and ROK)



Source: Based on analysis done by the TA (2016)

2.2 Sources of Air Pollution

Unprecedented urbanization, motorization, and industrialization have been the main drivers of air pollution in the Asian cities of Chengdu, Kathmandu, Metro Manila, and Xiangtan, having high population density and concentrated economic activities. Yet despite the implementation of pollution control measures, emissions remain high and air pollutant concentrations continue to exceed national air quality standards.

The People's Republic of China (PRC) is one of the fastest-growing economies in the world and is a global manufacturing hub with a strong dependence on heavy industries (e.g., iron, steel, and cement). These heavy industries are the main sources of air pollution at the city and sub-national levels, followed by transport. The rapid expansion of economic activities that characterize development in PRC accounts for the persistently high levels of emissions of major pollutants (i.e., SO_2, NO_x, PM, volatile organic compounds or VOCs, and ammonia or NH_3).

Air pollutant emissions are concentrated in the eastern part of the country and in the Beijing-Tianjin-Hebei (BTH) Region, where the most polluted cities and provinces are located relative to the regions of the Pearl River Delta (PRD) and the Yangtze River Delta (YRD).

In Chengdu and Xiangtan, industrial processes are the main sources of SO_2, PM_{10}, $PM_{2.5}$, black carbon (BC), organic carbon (OC), VOCs and polycyclic aromatic hydrocarbons (PAH). Coal-fired thermal power plants emit major amounts of SO_2, NO_x, BC, and OC. The increasing number of light-duty and heavy-duty vehicles are the sources of NO_x, CO, VOCs, and resuspended dust (PM_{10}, $PM_{2.5}$). Additional sources of PM_{10} and $PM_{2.5}$ in Chengdu include dust storms and soil erosion, while in Xiangtan, indoor and outdoor cooking is a significant source of PM. Agriculture appears to be a relevant source of NH_3 in Chengdu.

In contrast, transport is the major source of NO_x, CO and VOCs in the Philippines with industry being a main source of sulfur oxides (SO_x) while open biomass burning (e.g., from crops and forests) is a main source of PM.

Information on air pollution emissions sources for the whole of Nepal is unavailable. This is due to limited technical and financial capacity to undertake AQM processes. National EI and air quality monitoring activities have been intermittent and have been funded externally by development agencies (e.g. World Bank's URBAIR project in 1993 and DANIDA's Environment Sector Programme Support project in 2003) and undertaken by external consultants.

From the limited data on emission sources in Nepal, it is possible to deduce that transport is the main contributor to PM_{10} emissions followed by agricultural biomass burning and brick kilns, particularly in the Kathmandu Valley. Transboundary air pollution is a major concern in Nepal and should be tracked, especially during the dry season when it comes from the south and west.

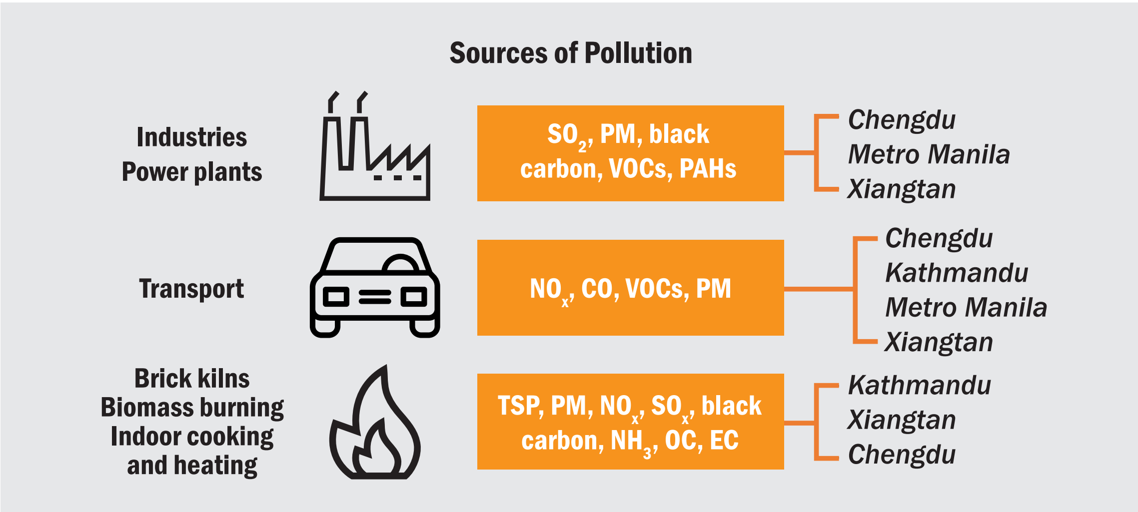
In Kathmandu as in Metro Manila, vehicles are the most relevant sources of NO_x, CO, VOCs, PM_{10}, and $PM_{2.5}$. Kathmandu also rates emissions of BC, OC, EC, VOCs, PAHs, and other air toxics emitted from vehicles as contributing to poor air quality. Resuspended road dust and fugitive soil and construction dust (total suspended particulate matter, PM_{10}, $PM_{2.5}$) are common in both cities.

During the period 1980–2010, approximately 1.18 million vehicles were registered in Nepal, 48% of which are found in the Bagmati zone. From 2000 to 2013, there has been a 52% average growth in vehicles, and in the Bagmati zone alone, the number of vehicles has increased nine-fold in the last 2 decades with a total of 922,900 vehicles in 2014/15.

Other emission sources in Kathmandu include brick kilns, biomass/garbage burning, agriculture, and indoor cooking and heating, especially in rural areas. Kathmandu has no fossil fuel-driven power plants as hydropower plants produce all of its required energy.

In Thailand, industry is a main source of SO_2, transport is a key contributor to NO_x and CO emissions, fugitive emission and industry is a main source of non-methane volatile organic compounds (NMVOCs), and biomass burning of PM emissions. In 2015, the total number of registered vehicles in Thailand was 36.73 million, with the fleet population growing rapidly between 2007 and 2015 with an average annual growth rate of 4.5% (Thailand Department of Land Transport, 2016). From 2010 to 2013, there was a rapid growth in the number of registered vehicles in Thailand because of the reduced tax of the 'first car' policy implemented in 2011 (DLT, 2016). During this period, motorcycles dominated on-road traffic fleets at 55%, followed by light commercial vehicles at 20%, and passenger cars at 18%. In 2015, the total number of registered vehicles in the Bangkok Metropolitan Region (BMR) alone was over 8.5 million units with an annual average growth rate of 5.5%.

In Metro Manila, power plants, food manufacturing, paper and packaging products manufacturing, and small-scale chemical manufacturing all contribute to emissions of PM_{10}, $PM_{2.5}$, SO_x, NO_x, CO and VOCs. In addition, there are approximately 2.3 million registered motor vehicles, 27% of the country's total in 2012.



2.3 Air Quality Monitoring

Air quality monitoring networks and systems are in place in all four countries (Table 2) and cities but these could still be further optimized in scope and coverage, frequency of data collection, technologies, particularly with respect to quality assurance and quality control (QA/QC). PRC's extensive air quality monitoring network of 1,436 stations in 338 cities and more than 100 regional and background monitoring stations managed by the national government, more than 3,000 monitoring stations operated at provincial and municipal levels, guarantees that all its primary and secondary cities will have sufficient spatially representative air quality data.

Chengdu and Xiangtan monitor the key pollutants $PM_{2.5}$, PM_{10}, NO_2, SO_2, O_3 and CO at 33 and six automatic stations, respectively. Both cities follow strict QA/QC procedures and protocols to obtain concentration data of known quality. Both cities report hourly concentration data for the key pollutants and produce daily reports. In addition, Chengdu produces daily forecast reports for up to 72 hours, while Xiangtan reports 24-hour changes of hourly concentrations and of individual air quality indexes.

Table 2: Number of Monitoring Stations in the Four Countries

Compound	China	Nepal	Philippines	Thailand
sulfur dioxide, SO_2	4536		25	70
nitrogen dioxide/ nitrogen oxides NO_2/NO_x	4536		25	70
ozone, O_3	4536	2	25	70
carbon monoxide, CO	4536		25	70
volatile organic compounds, VOC			25	18
PM_{10}	4536	12	27, 27m	70
$PM_{2.5}$	4536	12	27	33
total suspended particulates, TSP			22m	70m

Note: Monitoring stations are manual where indicated by m, otherwise they are automatic; PM_{10} particulate matter less than 10 µm; $PM_{2.5}$ particulate matter less than 2.5 µm.
Source: Compiled from Country Air Quality Management Reports developed under the TA

In 2016 annual concentrations of NO_2, PM_{10}, and $PM_{2.5}$ in Chengdu did not comply with national ambient air quality standards. The annual concentrations of PM_{10} and $PM_{2.5}$ are a factor of five to six above WHO guideline values. Ozone (O_3) annual means are almost a factor of two above WHO's 8-hour guideline value, indicating that 8-hour concentrations will be even higher than a factor of two above the WHO guideline value.

Nevertheless, compared to 2013 levels, air pollution in Chengdu has declined in 2014 and 2015. Measures such as clean energy transformation, industrial structure optimization, industrial waste gas treatment, vehicle exhaust gas treatment, and agricultural source control contributed to this improvement.

In the Kathmandu Metropolitan Region, there are seven Department of Environment (DoE) and International Centre for Integrated Mountain Development (ICIMOD) stations that deliver and report real-time concentration data for $PM_{2.5}$ and PM_{10} and two US Embassy/ ICIMOD stations that yield and report hourly data for $PM_{2.5}$.

However, air pollution has not improved in Kathmandu during the 2 decades in which AQM efforts have been attempted. Concentrations of PM_{10} are 2 to 4.5 times above the national standard. In addition, daily concentrations of $PM_{2.5}$ were three to five times higher than the national standard while daily NO_2 concentrations were 12 times higher than the national standard. Daily concentrations of PM_{10} and $PM_{2.5}$ are a factor of four to ten above WHO guideline values, and O_3 annual mean concentrations are almost a factor of 1.5 above the WHO 8-hour guideline value. Annual TSP concentrations are two times above the WHO guideline value of 60 to 90 µg/m^3 (WHO, 1972). Annual total PAH concentrations are 150 times above the BaP concentration.

The EI and air quality monitoring efforts conducted in Nepal focused only on Kathmandu Valley, resulting in sparse information on the state of air quality outside the country's capital/region. The air pollution situation in Kathmandu Valley substantially changed after the earthquake in spring 2015 that damaged more than 500,000 buildings, 7,000 schools and 1,000 health facilities in the country. 95% of brick kilns in the Kathmandu Valley needed repairing. This event led to increased demand for bricks in reconstruction work that led to increased dust emissions.

Rebuilding after the earthquake presented an opportunity to "build back better" through the incorporation of better technology when rebuilding destroyed kilns, which would directly reduce emissions and air pollution. It was also a chance to set standard kiln design guidelines and to introduce earthquake resistant chimneys.

Air quality monitoring activities in the Philippines focused primarily on TSP. While there has been an expansion which included PM_{10}, monitoring this remains limited and only urbanized regions and cities include SO_2, NO_2, and O_3 in their monitoring activities. Since the 1990s, a National Air Quality Status Report (NAQSR) has been produced biannually. However, these reports (latest of which is DENR, 2014. NAQSR 2012-2013) could be further enhanced with comparative analyses based on past and most recent EI to determine trends, demonstrate progress, or identify persisting and/or emerging pollutants of concern. There are limited studies to provide policy-makers with a reliable estimate on the exposure to and impacts of air pollution for areas other than from major urban cities.

The key pollutants monitored in Metro Manila are TSP, PM_{10}, $PM_{2.5}$, SO_x, NO_x, O_3, CO. There are 27 automatic stations that assess PM_{10}, $PM_{2.5}$, NO_2, SO_2, O_3, and CO. Twenty-two manual monitors measure TSP levels and determine its lead content, and 27 manual monitors measure PM_{10}. In addition, $PM_{2.5}$ is monitored at four automatic stations provided by the European Union and in four stations provided by the Makati Rotary Club.

Progress has been made in reducing SO_2, NO_2, and O_3 but TSP remains a problem.

Metro Manila reports online hourly real-time concentration data for key pollutants from several automatic stations. AQI values for TSP, PM_{10}, SO_2, O_3, CO, and nitrogen oxides (NO_x) are reported as averages over 24-hours, 8-hours, and 1-hour periods, respectively. Data from the EU-provided stations are reported as real-time Air Quality Index (AQI) values and those from the Rotary Club station as real $PM_{2.5}$ concentrations.

Annual TSP concentrations in Metro Manila have not complied with the air quality standard of 90µg/m^3 since 2004. However, annual concentrations of PM_{10} exceed the national standard at a smaller number of stations. Annual $PM_{2.5}$ concentrations are a factor of two to five above the WHO AQG value. However, SO_2, NO_2, O_3 concentrations are well within the respective air quality standards.

Building back better brick kilns

After the earthquake in the spring of 2015, the CCAC carried out a rebuilding project in close collaboration with the Nepalese Government, which has invited CCAC partner - the International Centre for Integrated Mountain Development (ICIMOD) - to be part of a committee to revise the brick kiln emission standard. The Department of Industry has since issued a notice that all brick kilns should be structurally safe and earthquake resistant. Requests have been flooding in from entrepreneurs who are rebuilding kilns as news has spread about how adopting the new design reduces coal and improves brick quality. Nine kilns have been rebuilt according to the new designs and other kilns have adopted the brick stacking and firing techniques. Emissions measured from these kilns showed a 60% decrease in particulate matter. Coal consumption was reduced by 40-50%. Only 70gm of coal is now needed to bake one brick whereas around 90-100 gm was required previously. Due to the efficient moving of fire, the number of bricks produced has also doubled. 'A' grade bricks has also increased by 90%. Workers are also experiencing less exposure to dust and pollution. Total rebuilding costs is estimated to be around $100,000, which the entrepreneurs paid for themselves. The payback period for investing in rebuilding a kiln is expected to be less than two years. The kiln redesign has been a win-win situation. Entrepreneurs are benefiting from coal saving and better brick quality. The kilns are structurally sound, earthquake resistant, energy efficient and provides safer and healthier working conditions for workers.

More details can be found at http://www.ccacoalition.org/en/news/bricks-success-story-nepal-building-back-better

2.4 Air Quality Impacts

In the Kathmandu Valley, only limited information from scientific studies is available. One study observed elevated respiratory health burden in schoolchildren during wintertime operation of brick kilns. Another study reported reduced lung function in traffic police officers due to exposure to elevated levels of $PM_{2.5}$.

More assessments of air pollution impacts needed to mobilize stakeholders

Although some scientific evidence on the impact of air pollution on health and crops in Thailand exist, comprehensive assessments of air pollution are needed to mobilize stakeholders to act. For example, studies on the impact on farmer's health and commuter health For reference, such information exists in the international literature, e.g., Adler, 2010; Kumar & Joshi, 2013 for crop burning in India.

In the Philippines, limited information on the impacts of air pollution on health is available from three scientific studies. About 600,000 cases of acute respiratory infection, acute lower respiratory tract infection and pneumonia, bronchitis, and heart diseases were attributed to air pollution (DENR, 2012). The Philippine Cancer Society attributed to air pollution more than 9,000 premature deaths from all medical causes (DENR, 2012). The total cost of air pollutant impacts in Metro Manila was estimated to amount to USD 15.2 million for years 2004 and 2007 combined (Estanislao, et al., 2011).

2.5 Legal Basis

Each of the four countries - Nepal, Philippines, PRC, and Thailand - has an environmental protection law that sets out air quality guidelines, emission standards, addresses issues of accountability and compliance, and designates dedicated environmental bodies.

Greater provincial and local accountability for air quality compliance in PRC.

The 2015 amendment to PRC's 2000 Air Pollution Prevention and Control included greater provincial and local government accountability for air quality compliance. As part of the State Council air pollution action plan, each province has been assigned a target to reduce PM (PM_{10} or $PM_{2.5}$). Provincial and municipal governments in PRC are mandated to achieve the objectives for cleaner air formulated in Five-Year Plans (FYPs). These plans address certain aspects of air quality at the time of the formulation of a FYP. The Eleventh (11^{th}) FYP (2006-2010) addressed the reduction of NO_x as a precursor of O_3 and mandated provinces and cities to meet the air quality standards.

No direct laws to address air pollution exist in Nepal

The Twelfth (12th) FYP for 2011-2015 mandated cities to lower the annual average concentrations of PM_{10} and $PM_{2.5}$ by 25% and 20%, respectively in 2017 compared to 2013 levels. It also ordered cities to strengthen source control and improve supervision, management, and enforcement by including air pollution prevention and control in municipal government work. As a response, Chengdu and Xiangtan established an institution to coordinate the different departments involved in AQM. Chengdu, in particular, set up an AQM Office.

The 1997 Environmental Protection Act mandated the protection of a clean and healthy environment in Nepal. Climate change policy (2011) aimed at employing low carbon development that provides co-benefits in corresponding air pollutant reduction.

In Kathmandu, the responsibility for AQM is shared by three ministries – Ministry of Population and Environment (MoPE), Ministry of Industry, Commerce and Supplies (MoICS), and the Ministry of Physical Infrastructure and Transport (MoPIT), with MoPE responsible for the overall implementation and oversight of environmental protection including climate change mitigation and adaptation. Under the MoPE, the Department of Environment (DoE) is responsible for AQM.

Few local clean air action plans in Thailand.

In Thailand, the main overarching legislation for AQM is the 1992 Enhancement and Conservation of National Environmental Quality Act. Existing laws and policies are sufficient to ensure close coordination at the national and provincial levels; however, discrepancies in existing national and city level EI results are hampering the development of CAAPs or CAIPs as reliable instruments for policy intervention.

In the Philippines, the 1999 Clean Air Act sets out a national program of integrated air pollution management, which focuses primarily on pollution control and prevention. The cities and local governments forming part of Metro Manila are mandated to strengthen policymaking, planning, monitoring, and evaluation of capacities to implement the functions, programs, and projects devolved by national legislation; provide technical assistance packages to develop technical capabilities; enforce pollution control and environmental protection laws, rules, and regulations; and implement cease and desist orders issued by the Pollution and Adjudication Board, among others.

2.6 Governance

In Nepal, most of the legislation and regulations are set at the national level and implemented by national authorities. However, the 1999 Local Self- Governance Act indicates that municipalities are primarily responsible for urban environmental management and mandates for environmental protection. In 1998, the Kathmandu Metropolitan City Office established the Environment Department and an Urban Environment Section for Kathmandu Metropolitan City Office to raise air pollution awareness.

The Environment Department and an Urban Environment Section of the Kathmandu Metropolitan City Office have developed five approaches to reduce air pollution: vehicular exhaust emissions monitoring; air quality monitoring; city greening; encouraging the use of electric vehicles; and raising awareness among citizens with the long-term goals of changing people's behavior. These approaches have, however, not been fully implemented. Kathmandu Metropolitan area also created the Kathmandu Sustainable Urban Transport Project (KSUTP) and an approach for a Sustainable Kathmandu (SusKat) (Government of Nepal, 2017; IASS, 2017). KSUTP is to ensure more efficient, safe, and sustainable urban transport systems by (i) improving and upgrading public transport (using electric of low emission vehicles on two pilot bus routes), (ii) improving transport management (traffic flow on 25 junctions and constructing two bridges), (iii) improving walkability in the city center, and (iv) enhancing air quality monitoring. By these measures it is hoped to improve the quality of urban life, including air quality. The objective of SusKat is to understand the dynamics of air pollution and to transcend scientific understanding into implementation of mitigation measures, engaging local stakeholders. The Urban Environment Section was also active in collaborating with various nongovernment organizations (NGOs) in forming the Citizens Monitoring Group that campaigned against diesel-operated three-wheelers, which the Government finally banned from circulating in the Valley in 1999.

Although approaches to improving air quality have been outlined, these have not been implemented in practice

In 2017, the Kathmandu government prepared the Air Quality Management Action Plan for Kathmandu Valley. The action plan proposes an Integrated Urban Air Quality Management Framework to control air pollution in Kathmandu Valley and a separate strategy on assessing the impacts of air pollution on human health, the environment and the economy (Kathmandu Post, 2017). The action plan will include short-, medium-, and long-term plans to tackle air pollution in the Kathmandu Valley. It also includes recommendations for hospitals, industries, and brick kilns to reduce waste and emissions.

The PRC has effective air quality measures in place but is still encountering air pollution challenges; an integrated AQM approach still needs to be undertaken. Despite initiatives and measures that have reduced air pollutant emissions, SO_2, NO_x, and $PM_{2.5}$ remain high and still exceed national air quality standards. SO_2 and NO_x emissions were reduced by 18%, a significantly higher gain than the five-year target of 8% and 10%, respectively, as indicated in its 12th Five-Year Plan for 2011-2015. Existing air quality measures do not consider or are ineffective at addressing emerging air pollution issues such as VOCs, and secondary pollutants (O_3 and secondary $PM_{2.5}$ from the chemical reaction of gases).

Due to the severe air pollution condition in recent years, the Chengdu and Xiangtan municipal governments took a series of initiatives to improve their AQM capacity. Notable responses to air pollution in Chengdu include the Action Plan for Air Pollution Prevention and Control (2014-2017) that includes a performance assessment, the Plan for Emergency Response to Heavily Polluted Weather, the Municipal Regulation on the Management of Fireworks, and the Regulation on Construction Waste Management.

Another plan developed in Xiangtan include the Xiangtan Implementation Program for the Air Pollution Prevention and Control Action Plan. The Plan emphasizes the appraisal of AQM performance and the 2016 Xiangtan Implementation Program for Integrated Air Pollution Prevention and Control. The latter assessed the integration of air pollution control measures with different sectoral approaches. Other regulations in Xiangtan include: the ban on high-polluting fuels and the program promoting and enforcing the application of alternative energy-fueled vehicles.

Plans and regulations in these two cities strengthen the overarching AQM systems and ensure transparent management. Both cities emphasize the importance of stakeholder involvement and participation; the city of Xiangtan set up a 'Xiangtan Environmental Protection Association' to institutionalize stakeholder involvement.

Common Challenges

THE SEVERITY OF AIR POLLUTION IN SEVERAL DEVELOPING ASIAN CITIES REFLECTS THE LEVEL AND SPEED OF THEIR ECONOMIC DEVELOPMENT AND THE EFFECTIVENESS OF PAST AND CURRENT AQM EFFORTS. Each country and city is unique in its physical, economic, and social characteristics, which influence spatial and temporal patterns of emission sources and air pollution concerns.

Today, many Asian countries and cities struggle to achieve better air quality. The approaches, strategies, and measures taken to monitor, assess, and reduce pollutant emissions vary. Some actions have been successful in achieving a demonstrable improvement in air quality while others have been less effective due to a number of factors.

Challenges in AQM stem from the low priority given to air pollution versus competing social and economic objectives by national and local governments. Often, governance is a barrier to developing appropriate action to address urban air pollution and allocating sufficient financial resources. Unless a sustainable financing mechanism is in place, adequate infrastructure, capacity and resources to implement and enforce air pollution prevention and control will continue to be deficient.

Based on the country and city assessments, and the results of the regional dialogue workshop held in October 2017 in Bangkok, it is possible to identify a number of key gaps that the focus countries and cities face in managing air quality.

Among the key challenges identified were the availability, or lack of, air quality data for evidence-based policy-making, the technical capacity to undertake key aspects of AQM (e.g., modelling and emission inventories), and enforcement of existing air quality standards and limits. In addition, access to financial resources and appropriate policy measures to support the implementation of an integrated AQM are also often lacking.

3.1 Insufficient Air Quality Information to Inform Policies, Plans and Programs

While air quality monitoring networks exist in all the countries and cities included in the assessment, these are often sparse and insufficient. A small number of air quality monitoring stations means that data on the actual air pollution situation is limited in terms of spatial coverage and pollutants monitored. For example, there is a lack of continuous monitoring of $PM_{2.5}$, VOCs and semi-VOCs due to insufficient resources.[5]

In Nepal, air quality monitoring is undertaken in using 7 stations in Kathmandu, one in Kathmandu Valley, one each in Kavre, Chitwan, and Rupendehi, and three in Pokhara. Adherence to QA/QC protocols to ensure the validity of air quality monitoring needs to be assessed as in the case of Metro Manila.

Among the countries covered, PRC has the most extensive coverage of its air quality monitoring network at the city and national levels. However, some key pollutants (e.g., VOCs and O_3) are not monitored on a regular basis. Despite technological advancements and significant air quality improvements, some key pollutants still exceed standards.

[5]Semi-VOCs are a subgroup of VOCs that tend to have a higher molecular weight and boiling point temperature. The WHO distinguishes between very volatile (gaseous) organic compounds with a boiling point range between 0°C and (50 -100)°C, volatile organic compounds (VOCs) with a boiling point range between (50 -100)°C and (240 -260)°C, and semi-volatile compounds (SVOCs) with a boiling point range between (240 -260)°C and (380-400)°C (WHO, 1989). SVOCs include pesticides (DDT, chlordane, plasticizers [phthalates], and fire retardants [PCBs, PBB]). The US EPA has adopted WHO's classification in its regulatory definition of VOCs that impact photochemical oxidation in outdoor air (US EPA, 2017a).

Coverage of air quality monitoring networks remains a challenge for many Asian cities. For example, Nepal has 12 monitoring stations, which is too low for achieving spatial representativeness in the country. Table 3 shows the minimum number of sampling points required if the EU air quality monitoring requirements are applied to Nepal. Similarly, Metro Manila, Chinese and Thai cities and municipalities would need more sampling points than they currently have (Table 4, Table 5, and Table 6).

Table 3: Minimum Number of Sampling Points in Nepal Based on EU Guidelines

City/ Municipality	Population (2011)	Number of Sampling Points[a]		
		Pollutants Except PM and O_3	PM[b] (Sum of PM_{10} and $PM_{2.5}$)	O_3
Bhaktapur	301,720	2	3	1
Chitwan		1	2	1
Dhulikhel		1	2	1
Kathmandu Metropolitan Area	1,780,148	5	7	3
Lalitpur	463,532	2	3	1
Langtang		1	2	1
Lumbini		1	2	1
Pokhara	313,841	2	3	1
Total		15	24	10

[a] Monitoring stations for PM, NO_2, CO and C_6H_6 (if monitored at all) should include at least one urban background monitoring station and one traffic-oriented station (without increasing the number of sampling points). It should be noted that a sampling point is not necessarily a station. A sampling station refers strictly to a stationary/fixed monitoring site, while a sampling point may refer to a location where air quality data is collected. A sampling station can also be considered as a sampling point.

[b] Where PM_{10} and $PM_{2.5}$ are measured at the same monitoring station, these shall count as two separate sampling points.

Table 4: Minimum Number of Sampling Points in Metro Manila Based on EU Guidelines

City/ Municipality	Population (2015)	Number of Sampling Points[c]		
		Pollutants Except PM and O_3	PM[d] (sum of PM_{10} and $PM_{2.5}$)	O_3
Caloocan	1,583,978	5	7	3
Las Piñas	588,894	2	3	1
Makati	582,602	2	3	1
Malabon	365,525	2	3	1
Mandaluyong	386,276	2	3	1
Manila	1,780,148	5	7	3
Marikina	450,741	2	3	1
Muntinlupa	504,509	2	3	2
Navotas	249,463	1	2	0
Parañaque	664,822	2	3	2
Pasay	416,522	2	3	1
Pasig	755,300	3	4	2
Pateros	63,840	1	2	0
Quezon City	2,936,116	7	10	5
San Juan	122,180	1	2	0
Taguig	804,915	3	4	2
Valenzuela	620,422	2	3	2
Total	12,877,253	44	65	26

[c] Monitoring stations for PM, NO_2, CO and and C_6H_6 (if monitored at all) should include at least one urban background monitoring station and one traffic-oriented station (without increasing the number of sampling points). It should be noted that a sampling point is not necessarily a station. A sampling station refers strictly to a stationary/fixed monitoring site, while a sampling point may refer to a location where air quality data is collected. A sampling station can also be considered as a sampling point.

[d] In monitoring stations where PM_{10} and $PM_{2.5}$ are both measured, these shall count as two separate sampling points.

Table 5: Minimum Number of Sampling Points in Xiangtan and Chengdu Based on EU Guidelines

City	Population[g]	Number of Sampling Points[e]*		
		Pollutants Except PM and O3	PM[f] (sum of PM_{10} and $PM_{2.5}$)	O_3
Chengdu	8,077,000	10	15	7
Xiangtan	2,748,552	6	8	4

[e] Monitoring stations for PM, NO_2, CO and and C_6H_6 (if monitored at all) should include at least one urban background monitoring station and one traffic-oriented station (without increasing the number of sampling points). It should be noted that a sampling point is not necessarily a station. A sampling station refers strictly to a stationary/fixed monitoring site, while a sampling point may refer to a location where air quality data is collected. A sampling station can also be considered as a sampling point.
[f] Where PM_{10} and $PM_{2.5}$ are measured at the same monitoring station, these shall count as two separate sampling points.
[g] Population data for Chengdu: 2017; for Xiangtan: 2010

Table 6: Minimum Number of Sampling Points in Thailand Based on EU Guidelines

City or Municipality	Population (2017)	Number of Sampling Points[h]		
		Pollutants except PM and O_3	PM[i] (sum of PM_{10} and $PM_{2.5}$)	O_3
Bangkok	5,104,476	9	13	7
Chiang Mai	200,952	1	2	1
Chonburi	219,164	1	2	1
Khon Kaen	147,579	1	2	1
Lampang	156,139	1	2	1
Nakhon Ratchasima	208,781	1	2	1
Nonthaburi	291,555	2	3	1
Rayong	106,737	1	2	1
Samut Prakam	388,920	2	3	1
Samut Sakorn	313,841	2	3	1
19 cities	< 250,000	19	38	19
Total		40	72	35

[h] Monitoring stations for PM, NO_2, CO and and C_6H_6 (if monitored at all) should include at least one urban background monitoring station and one traffic-oriented station (without increasing the number of sampling points). It should be noted that a sampling point is not necessarily a station. A sampling station refers strictly to a stationary/fixed monitoring site, while a sampling point may refer to a location where air quality data is collected. A sampling station can also be considered as a sampling point.
[i] Where PM_{10} and $PM_{2.5}$ are measured at the same monitoring station, these shall count as two separate sampling points.

In terms of capacities to identify emission sources, PRC, Nepal, Thailand, and the Philippines develop country EI based on one of the following:

- compiling data collected locally in a bottom-up approach (Philippines, PRC);
- estimations performed through the Intercontinental Chemical Transport Experiment-Phase-B (INTEX-B) project[6] (Nepal, Thailand); and
- satellite observations using Moderate Resolution Imaging Spectroradiometer (MODIS) (Nepal).

For Nepal, some measures need to be employed to gain better understanding of emission sources for the whole country. Existing EI in Kathmandu Metropolitan Area (KMA) and Kathmandu Valley need updating; more recent source apportionments by receptor modelling are only

[6]The INTEX-B project, conducted by NASA, estimated total Asian anthropogenic emissions in the year 2006. For the project, several detailed technology-based approaches, including a dynamic methodology representing rapid technology renewal, critical examination of energy statistics, and a new scheme of NMVOC speciation for model-ready emissions were employed. Source: https://www.atmos-chem-phys.net/9/5131/2009/acp-9-5131-2009.pdf

able to identify emissions from source types, and not individual sources.

One of the major constraints of a national EI is the limited availability of local emission factors (Philippines, PRC, Thailand). International EIs estimation of the overall emissions from countries also commonly use default emission factors and activity patterns from internationally published sources, which may not produce the same results as the country-based EI estimates. The use of default emission factors may both over- and under-estimate the results from national EIs as stated in the country report for Thailand. Applicability or uncertainty of default emission factors are not accounted for and may not provide reliable estimates. This is due to lack of consideration of local activity data.

In the Philippines, the major gap in national EI is the limited data on non-point or area sources. Typical area source emissions reported are the resuspended dust from roads or construction activities, open burning of solid wastes, agricultural wastes and by-products, and slash-and-burn farming. The 2015 National Air Quality Status Report cited PM as a major pollutant from area sources.

The Environment Statistics System developed in PRC needs to be improved to support the policymaking for $PM_{2.5}$ pollution control as there is a lack of information on precursors forming secondary PM such as VOCs and NH_3, non-road mobile sources and fugitive dust. The technical approach for emission estimation lacks QA/QC. Emissions inventories developed by other organizations (e.g., universities and institutes) provide complete coverage of pollutants and sources; estimates however, are not up-to-date due to limited data availability.

City-level EIs also suffer from similar shortcomings as the countries. For example, the Chengdu EI does not give estimates for benzopyrene (BaP) and lead although monitoring of these compounds is required by law, and a NAAQS exists.

A special challenge exists in Xiangtan, where, in view of the high correlation between the causes of air pollution in the three cities of Changsha, Zhuzhou and Xiangtan (the CZT triangle), it is necessary to clarify the main sources of pollutants in the whole CZT area to allow Xiangtan to derive political solutions on AQM in its municipal area.

The consideration of methane (CH_4) emissions from waste deposits is a shortcoming for all countries and cities with the exception of Thailand. In addition, the countries and cities do not sufficiently address the issue of emissions from non-road vehicles such as tractors, bulldozers, ships, planes, and equipment usually propelled by internal combustion engines such as farm and construction equipment, electricity generators and indoor air pollution.

In general, the lack of data from air quality monitoring and EI limits the understanding of the extent and magnitude of the air pollution problem. This can hamper the effectiveness of planned and existing policies and programs, and the ability of environment authorities to generate the political support for air quality programs. In PRC's case, this means that emerging air quality issues (e.g. reducing VOC emissions) are unaccounted for and unaddressed in several cities. Except for leading cities such as Beijing, Shanghai, and Shenzhen, most of the PRC cities need to improve knowledge and data on local VOC emissions to ensure that the VOC policies and measures in those cities have the scientific basis needed for these to be effective.

The lack of validated and regularly released air quality information limits the ability of the public to take action to protect themselves and their families by limiting their exposure to air pollution.

3.2 Limited Technical Capacity

A lack of technical capacity refers to insufficient technical knowledge and skills of personnel in relevant agencies to undertake key AQM activities. These include the capacity to conduct EI, receptor and dispersion modelling, impact assessments (e.g., human health, crops and environment), and to assess the the contribution of transboundary and regional air pollution to local and national air quality.

The following are several challenges faced by the four countries and cities:

In Nepal and Kathmandu Valley, air pollution was identified as a challenge as early as 1993, mainly due to emissions during winter from the Himal cement factory, and in the early 2000s from several hundreds of stationary and moveable brick kilns (Himal Southasian, 1987). Measures taken to reduce emissions from these sources included shutting down the Himal cement factory and moving it outside of the Valley in 2001, and banning Bull Trench kilns in 2003 and replacing them by Vertical Shaft Trench kilns. In addition, two-stroke spark ignition engines and diesel three-wheelers with compression ignition engines were relocated outside of the Valley. Currently, five sources of outdoor air pollution are dominant in the Kathmandu Valley: brick kilns (in winter),

pxhere.com/en/photo/500038

motor vehicles, fugitive soil dust, biomass/garbage burning, and indoor air pollution from cooking and heating (especially in winter).

To combat air pollution, the Nepal Air Pollution Control Task Force submitted simple and doable actions (period 2016-2018) to the National Planning Commission in 2016. Under the direction of the Good Governance Committee and the Prime Minister's Initiative, the Cabinet Secretariat prepared a comprehensive work plan to minimize air pollution in Kathmandu. The plan proposed the formation of a Strategy and Action Plan Implementation Coordination Committee and a Strategy and Action Plan Implementation Unit. Twenty-three government agencies are involved in reducing air pollution in Kathmandu. Three ministries (MoICS, MoPE, MoPIT) largely share the responsibility for AQM in the country. However, the implementation and enforcement of the envisaged actions will take longer to implement.

In the Philippines and Metro Manila, CAAP development in the Philippines is driven by initiatives that intend to support city AQM, such as the GIZ Clean Air for Smaller Cities project, which was implemented in Iloilo City and Cagayan de Oro City. Some elements of city AQM actions have reached other cities as well, but a key factor in implementing such actions is political will, which is only demonstrated by a limited number of cities. Smaller and medium-sized cities encounter planning and implementation issues because of economic and institutional constraints.

The underlying challenge here is to mainstream AQM so that all LGUs will have the capacity and resources to adequately plan and implement air quality improvement measures.

Another difficulty is that cities have limited capacity to collect data on urban transport mode. This information is essential in developing transport planning, policies and measures. For instance, unless the planners know the urban mode share, it is difficult to develop time-relevant policies that could lead to a more sustainable transport sector.

In the PRC cities of Chengdu and Xiangtan, lack of information on precursors forming secondary PM such as VOCs and NH_3 (as well as CH_4), non-road mobile sources and fugitive dust is a challenge. In addition, the technical approach for emission estimation is relatively rough and lack QA/QC.

Another challenge for implementing control measures is that the various air pollutants are not considered all at once but in a sequential manner. For example, SO_2 was addressed in the 11th Five-Year Plan, NO_x was added in the 12th Five-Year Plan, and PM in the 13th Five-Year Plan. As all pollutants are interacting with each other, especially with respect to O_3 formation, it is obligatory to consider all of them in integrated AQM and the development of a CAAP or CAIP.

Emission standards issued or revised by PRC in the past three to five years are very stringent and some of them even more stringent than in the EU. The revised emission standards authorize the Ministry of Environmental Protection and the provincial governments to enforce the special limitation for air pollutants in more polluted regions, so that the industries in these regions are required to emit concentrations even lower than the regular standards. In 2013, the Ministry of Environmental Protection announced that 47 cities should enforce the Special Limitation for air pollutants, and the provincial governments extended the list of cities when their implementation plans were developed.

In Thailand, oil refinery and natural gas production principally should have contributed significantly to the NMVOC emissions but no comprehensive EI work has been conducted for this source. This can lead to a failure to estimate O_3 concentration with the consequence of inefficient control actions. The discrepancies in the existing EI results for the country and the EI results at the city level also call for a more consistent and comprehensive EI at both national and city levels. The official EI by the Pollution Control Department (PCD) should be regularly updated to provide input for the AQM activities and to produce the emission trends to assess the impact of policy interventions.

3.3 Lack of Coordination of Stakeholders in Air Quality Management

Three countries, Nepal, Philippines, and Thailand, define stakeholders as international organizations and funding agencies, ministries and other governmental agencies, academe and research institutions, NGOs and the health sector. None of the countries mentions or describes a co-ordination mechanism between responsible ministries and governmental agencies and other stakeholders.

Nepal has started to acknowledge "a clear need to coordinate and, collaborate with different stakeholders, especially governmental agencies". For example, the Air Pollution Control Task Force, which is comprised of environmental experts, was called to develop doable actions for 2016-2018 to control air pollution in the Valley. Moreover, research, training, annd technical support are being conducted and provided by the academe.

While Thailand stresses the need for stakeholder information, involvement, and active participation, it needs to expand stakeholder involvement with respect to co-benefits of AQM and GHG mitigation, dissemination of haze events to prone and surrounding industrial areas, enforcement of the ban on open burning, and appraisal by commuters of mass transit.

Chengdu and Xiangtan list academe, local and external (but national) research organizations, and non-profit associations involved in environmental issues as stakeholders. Metro Manila names NGOs, research institutions and government agencies supporting the Department of Environment and Natural Resources (DENR) as stakeholders. The DENR is the lead agency responsible for air quality management in the Philippines.

In summary, cities do not have CAAPs that indicate the roles of sectoral agencies, the private sector, and other stakeholders. Air quality concerns are not integrated into city sectoral plans on transport, energy and land use planning. The cooperation, if any, between the health sector and the agencies responsible for AQM appears to be insufficient. The following observations in the city and country reports can be cited.[7]

Although various acts, regulations, and programs for AQM already exist in Kathmandu Valley, the "government has not been able to activate the existing acts and systems in place towards mitigation of air pollution." The Environment Protection Act, Local Governance Act, Transport Management Act, Solid Waste Management Act, and Public Health Regulation are rarely activated by the concerned ministries to regulate air pollution. The implementation of emission standards by the Ministry of Labor and Transport Management has "not been fully effective."

In the Philippines, Environment and Natural Resources Offices (ENROs) are "necessary to implement provisions of the Clean Air Act at the local level" towards improved AQM in a specific territorial jurisdiction. As the creation of Local Government ENROs is optional, not all LGUs have active ENROs in the country. In Metro Manila, more often than not, ENROs serve "as sanitation and/or solid waste management offices, with limited or no focus on air quality management issues in the city." The country and city reports are silent about the integration of AQM in land use planning, energy planning, or urban development planning. The Philippines joined the Climate and Clean Air Coalition to scale up its activities to address near-term climate change and air pollution through short-lived climate pollutant (SLCP) mitigation. Upon joining, the Philippines expressed a particular interest in reducing SLCP emissions from heavy duty vehicles and engines and municipal solid waste and to raise awareness about SLCPs throughout the country.[1]

In contrast, the Chengdu and Xiangtan city reports, and the PRC country report make the following suggestions: (1) "Clarifying the responsibilities of stakeholders and establish an incentive mechanism for delivering commitments;" (2) integrating AQM "with energy planning to promote efficient, clean and sustainable energy utilization;" and (3) "upgrading control policies on vehicles." Country and city reports are, however, silent about the integration of AQM in land use planning or urban development planning.

[7] Citations in quotation marks originate from the city and country reports prepared under the TA and completed in 30 October 2017
[1] http://www.ccacoalition.org/fr/partners/philippines

3.4 Leniency of National Air Quality Standards

Table 7 compares the promulgated standards of Nepal, Philippines, PRC, and Thailand with the WHO guideline values. It shows that air quality standards of the different countries vary, although all aim to protect human health.

Table 7: Air Quality: National Standards and WHO Guideline Values

Pollutant	Averaging Time	PRC Class 1[j]	PRC Class 2[j]	Nepal	Philippines[k]	Thailand[k]	WHO[l]
SO_2	Annual	20	60	50	86	114	-
	24 hours	50	150	70	200	343	20
	Hourly	150	500	-	-	858	-
NO_2	Annual	40	40	40	-	56	40
	24 hours	80	80	80	150	-	-
	Hourly	200	200	-	-	320	200
CO	24 hours	4,000	4,000	-	-	-	-
	8 hours			10,000	10,305	10,305	10,000
	Hourly	10,000	10,000	-	34,350	34,350	30,000
O_3	Daily, 8-hour maximum	100	160	157	60	140	100
	Hourly	160	200	-	-	200	-
TSP	Annual	80	200	-	90	100	60-90[1]
	24 hours	120	300	230	230	330	120[2]
PM_{10}	Annual	40	70	-	60	50	20
	24 hours	50	150	120	150	120	50
$PM_{2.5}$	Annual	15	35	-	25	25	10
	24 hours	35	75	40	50	50	25
Lead (Pb)	Annual	1	1	-	1	0.5	0.5
	Seasonal	1	1	-	1.5	-	-
	1 month	-	-	-	-	1.5	-
Benzopyrene (BaP)	Annual	0.001	0.001	-	-	-	**

[j] Class 1: Special regions such as national parks; Class 2: urban and industrial areas.
[k] Air quality standards for gases are regulated in ppm. Conversion factors used for this table:
SO_2: 1 ppm = 2,860 µg/m^3; NO_2: 1 ppm = 1,880 µg/m^3; O3: 1 ppm = 2,000 µg/m^3; CO: 1 ppm = 1,145 µg/m^3 (WHO, 1987).
[l]WHO, 1979. Sulfur oxides and suspended particulate matter. Environmental Health Criteria No. 8.
[l]WHO, 1987. Air Quality Guidelines for Europe. WHO Regional Publications, European Series No. 23. Regional Office for Europe, World Health Organization, Copenhagen.

Compared with WHO guideline values, it can be inferred that PRC's class 1 and class 2 air quality standards for SO_2 24-hour exposure are factors of 2.5 and 7.5, respectively, above the WHO guideline value. The SO_2 24-hour standards promulgated in Nepal, Philippines, and Thailand are factors of 3.5, 10, and 17, respectively, above WHO's guideline value.

The NO_2 annual standards of PRC (identical for classes 1 and 2) and Nepal are at the same level as the WHO annual guideline value. The Philippines has not set an annual standard for NO_2, and the standard in Thailand is above the WHO guideline value.

The daily, 8-hour O_3 class 1 standard for PRC is set at the same level as the WHO guideline value while class 2 is a factor of 1.6. The corresponding standards for Nepal and Thailand are also above the WHO guideline value, while the Philippine 8-hour O_3 standard is lower than the WHO guideline value.

PRC's annual PM_{10} class 1 and class 2 standards exceed the WHO guideline value. Its 24-hour PM_{10} class 1 standard is the same as the guideline value of WHO, while the class 2 standard is a factor of 3 above it. The annual PM_{10} standards for the Philippines and Thailand are factors of 3 and 2.5, respectively, above the WHO guideline value. Nepal has not promulgated an annual PM_{10} standard. The 24-hour PM_{10} standards of Nepal, Philippines, and Thailand exceed the WHO guideline value.

PRC's annual $PM_{2.5}$ class 1 and class 2 standards exceed the WHO guideline value by factors of 1.5 and 3.5, respectively. Only Thailand has also set an annual $PM_{2.5}$ standard, which is a factor of 2.5 above the WHO guideline value. Nepal lacks a $PM_{2.5}$ annual standard. PRC's 24-hour $PM_{2.5}$ class 1 and class 2 standards are above the WHO guideline value by factors of 1.4 and 3, respectively. The 24-hour $PM_{2.5}$ standards of Nepal, Philippines, and Thailand exceed the WHO guideline value by factors of 1.6, 2, and 2, respectively.

The annual standards for Pb in PRC is equal to the WHO guideline value, while annual standards for the Philippines is twice the value. Nepal has not set a standard for Pb.

The various other standards set by the governments of the four countries have no counterpart in the WHO guideline values. For example, WHO stopped setting annual and hourly guideline values of SO_2 because (a) an annual guideline value would have to be much smaller than the 24-hour guideline value, and there is little knowledge about the effects of SO_2 at concentration values close to the detection limit of 1-2 µg/m³ of monitoring devices; and (b) a 1-hour guideline value was never recommended by WHO. The setting of a 10-minute guideline value (WHO, 2000b) was not maintained by the global update 2005 (WHO, 2006), probably due to the fact that this short-term guideline value was derived from laboratory exposures of volunteers, which do not necessarily reflect real world exposures.

WHO also did not recommend 24-hour guideline values for NO_2 and CO because of inconsistency or lack of peer-reviewed papers addressing health effects of these two compounds for 24-hour exposures. As a consequence, a 24-hour standard for NO_2 is based on an interpolation between hourly and annual standards, which lacks the scientific basis provided by peer-reviewed studies. Similarly, a 24-hour standard for CO is an extrapolation from short-term standards and, therefore, not supported by scientific studies.

WHO has not set a 1-hour O_3 guideline value because of the observation that effects due to 1-hour O_3 exposure are strongly related to the effects due to 8-hour O_3 exposure, i.e., if concentrations comply with the 8-hour guideline value they also comply with a 1-hour guideline value.

As BaP is a strong human carcinogen, WHO applies the procedure of setting unit risk[8] values instead of guideline values. Exposure to high levels of BaP causes respiratory tract infection, damages the reproductive system, and poses genotoxic effects.

It can be stated in general that national standards in the four countries are in most cases more lenient than WHO guideline values.

Nepal has not promulgated standards for TSP, PM_{10}, or $PM_{2.5}$ long-term exposure. Exposure to $PM_{2.5}$ can have serious respiratory and cardiovascular impacts and result in increased premature mortality, hospital admissions, emergency room visits, and outpatient visits (Appendix I).

The Philippines has not set an annual standard for NO_2. In view of the long-term exposure effects of this compound, promulgation and compliance to NO_2 annual standard would help protect human health (WHO, 2013).

[8] The unit risk is defined as the "additional lifetime risk occurring in a hypothetical population in which all individuals are exposed continuously from birth throughout their lifetime to a concentration of 1 µg/m3 of the agent in the air they breathe" (WHO, 2000a).

3.5 Weak Enforcement of Air Quality Standards

All four countries recognize the challenge of enforcing existing air quality and other standards mainly due to the following:

- non-compliance of air pollutant concentrations with air quality standards;
- complexity of the air pollution problem because of multiple and different sources;
- incomplete and inaccurate emissions inventories and corresponding inadequate control measures, in particular for industrial area sources, waste deposits, open waste and biomass burning, emissions from surface aircrafts/airports, emissions from inland, and ocean shipping in ports;
- on-road emissions of in-use vehicles vastly differ from emission standards set for type approval, particularly for diesel vehicles;
- rapid increase of vehicle population offsets the tightened emission standards (especially in PRC);
- emission standards are set for new vehicles but are not complied with by in-use vehicles;
- emission standards and fuel specifications (ultra-low sulfur content) in the four countries lag behind those of developed countries in terms of stringency, e.g. only Euro 4 vehicles and fuels are mandated in Nepal, Philippines, Thailand;
- emission standards are not related to air quality standards;
- insufficient control for area sources;
- non-consideration of aviation emissions at airports and low altitudes (less than 1,000 m);
- non-consideration of ocean ship emissions at ports;
- agricultural waste burning and vegetation fires;
- long-range transport of air pollution;
- complicated chemical reactions in the atmosphere with regards to secondary particulate matter and O_3; and
- lack of control for off-road vehicles and construction machinery.

Nepal stresses that studies are needed to understand the high level of air pollution so that they can come up with viable solutions to reduce air pollution concentrations that comply with their air quality standards.

Similarly, emission standards in the Philippines are less stringent than those of other countries. It needs to strengthen emissions standards especially for coal-fired power plants - a sector which continues to pose detrimental health and environment risks to citizens. No emissions standards exist in all four countries for hazardous air pollutants, so called 'air toxics' such as PAHs (except for BaP in PRC), benzene (C_6H_6), perchloroethylene, methylene chloride, and heavy metals except lead.

3.6 Insufficient Financial Resources and Incentive Scheme

The lack of or limited financial resources and incentive schemes is a crosscutting challenge in AQM, which adversely affects the implementation of clean air action plans and enforcement.

Countries and cities appear to have not fully developed financial and investment plans showing the cost of implementing the measures in the CAAP or CAIP. It is likely that data on air quality and information on health and economic impacts of air pollution have not been sufficiently provided to decision-makers to convince them to allocate funds. Cost-benefit analyses that weigh control costs versus impacts costs to show the higher benefit of avoided impacts due to the implementation of the control measures must be performed in order to encourage and promote investments in air quality.

3.7 Specific Issues

Controlling emissions of fine particulate matter

$PM_{2.5}$ emissions remain high and exceed national air quality standards partly due to a lack of monitoring capacity and that $PM_{2.5}$ is not included in the list of monitored pollutants in some countries and cities.

The Philippines has initiated monitoring of PM_{10} and $PM_{2.5}$ in 27 automatic stations managed by the EMB and in the same number of stations with Differential Optical Absorption Spectroscopy (DOAS) equipment. In addition, PM_{10} is monitored at 27 manual stations. TSP has been monitored at 22 manual monitors since the introduction of emission inventories and air quality monitoring activities in the 1990s.

Historically, the policy focus in countries such as PRC has been on controlling SO_x and NO_2 emissions. Controlling PM emissions was only identified as a priority in its 12th Five-Year Plan for 2011-2015. PRC has tended to address air pollutants sequentially in different FYPs. In both instances, the Philippines and PRC will stand to gain not only from shifting to an integrated, multi-pollutant approach, but also in mainstreaming AQM in a broader and more holistic urban development framework.

Addressing emerging air quality issues

VOCs and O_3 are emerging air pollution issues as reductions in criteria pollutants (e.g. NO_2, SO_2, CO, and Pb) are being achieved. These criteria pollutants are emitted directly from a variety of sources. O_3 is not directly emitted but is formed when NO_x and VOCs react in the presence of sunlight. Particulate Matter can be directly emitted or can be formed when emissions of NO_x, SO_x, NH_3, organic compounds (including VOCs) and other gases react in the atmosphere.

In addition, non-road sources (e.g., tractors, locomotives, mowing and harvesting machines) are making significant contributions to total pollutant emissions. However, addressing these sources requires greater integration of clean air, sectoral, national economic and local development plans to address persistent and emerging air quality concerns.

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Exploiting clean air and climate co-benefits

There is limited progress seen in efforts to maximize air and GHG emissions co-benefits in air pollution policies, which are not integrated or considered in other sectoral plans. This leads to piecemeal results of emissions reduction efforts and limits the co-benefits potential that may be realized in targeting both air pollutant & GHG emissions.

PRC has a clear policy on targeting CO_2 emissions but the authority for climate change mitigation is the National Development and Reform Commission and not the MEP. Between Xiangtan and Chengdu, the former currently does not have the capacity to monitor GHGs while the latter hosts the first GHG monitoring station in the Sichuan Province albeit with limited human capacity.

In almost all countries in Asia, except for Bangladesh, relevant departments handling air quality and climate change are often two entities. Integrating climate change and air pollution has the advantage of consolidating and maximizing the potential of funding resources to mitigate the former and address the latter. It can also result in a cohesive approach to addressing both concerns and further exploiting their co-benefits.

Understanding the contribution of re-suspended road dust, construction sites, open burning, and fugitive emissions from mounds, heaps and slag heaps to air pollution

All four countries are grappling with the challenge of understanding the contribution these sources make to overall air pollution. This is due to the lack of information on the number (unpaved roads, of construction sites, open fires, mounds and heaps) and type (pollutants emitted, material burned, fire characteristics) of these sources and the availability of monitoring data.

Enforcement is also a challenge and imposition of sanctions can strengthen and ensure compliance with air quality standards and the implementation of emission reduction measures. This is demonstrated in the case of PRC's MEP and city-level Environmental Protection Boards.

Pressure is exerted by the PRC central government on provinces and cities, through the annual evaluation of emissions reduction achievement and air quality improvement. As a result, capacity is enhanced and significant objectives have been attained through:

- The establishment of a monitoring network covering all prefectural-level cities and the installation and operation of continuous emission monitoring systems (CEMS) in all states as well as in some provincial-level key emission sources, resulting in a significant improvement in the availability of air pollution information. Sub-prefectural-level cities will also need an air quality monitoring network.
- Many experts trained through workshops and training courses organized by MEP, provincial Environmental Protection Departments, and Environmental Protection Bureaus (EPBs), with support from NGOs from time to time. For example, training workshops on total emission control are organized every year, focused on different technical topics, industrial sectors, and policy instruments. Resource speakers from universities and experts from research institutes, as well as international experts from developed countries, are invited to train on source apportionment and emission inventory and to introduce the technical details. These trainings are very helpful for the local people to understand policies and improve operational skills. However, the trainings should always be considered as a continuous process.

3.8 Lack of Mainstreaming Air Quality in Urban Development

Many of the common challenges outlined here contribute to air quality issues not being considered in urban development planning (UNEP, 2013).[9] Political support and commitment and generating broad participation and enthusiasm from urban residents, as well as from elected officials and city staff, are essential components to addressing AQ challenges and priorities. Political support also includes good governance and the provision of sufficient funding for AQM. Participation of elected officials and city staff requires sufficient technical skills and capacities. Participation and enthusiasm of urban residents require continuous information exchange between government and the public.

The country report of Nepal notes the "absence of a coordinating platform among different institutions, lack of explicit definition of responsibilities among stakeholders, and lack of effective institutional framework". The report also emphasizes, that "Nepal needs emphasis on good governance, strengthening capacity of stakeholders for effective management, innovative regulations and simple effective policies applicable for local scenarios and public awareness."

Although there are specific roles for an environment unit and environment officers in all LGUs in the Philippines, these only exist on an ad hoc and temporary basis, seriously limiting their ability to effect significant changes. For example, the EMB needs to develop a sustainable "plan for expansion and network improvement" and "to more actively engage airshed members/concerned LGU staff". Moreover, to enhance capacities of LGU staff and increase "awareness of concerned decision-makers". Access to funds from AQMF and other funding sources needs to be improved. Another area of concern in the Philippines is the lack of technical skills and capacities of LGU staff and other officials as well as lack of sufficient equipment for AQM.

In PRC, the country report states that a "lack of coordination among departments has resulted in delayed replacement of coal by cleaner energy in rural areas, and control of fugitive dust in some provinces." In addition, an overarching responsible institution (Department of Air) would help motivate all stakeholders and design a stakeholder-motivation system to "facilitate the progress of AQM" and "more integrated and effective tools." Moreover, there is a need to "enhance the responsibility of other government agencies regarding AQM" and "improve the AQM system to better engage and involve emitters and the general public."

[9] *This report emphasizes three approaches to incorporate air quality (as part of the environment) into urban development planning or, as UNEP phrases it, city development strategies. These are:*

1. *participation, politics and political commitment;*
2. *harmonization and multi-level governance; and*
3. *identifying and overcoming gaps and challenges.*

Shared Learning in AQM

SHARING BEST PRACTICES CAN PRODUCE OPTIMAL RESULTS BY FOLLOWING AN ESTABLISHED OR PROPOSED STANDARD SUITABLE FOR WIDESPREAD ADOPTION (MERRIAM-WEBSTER, 2017). However, a practice rarely works in every situation (Ambler, 2005-2014). It is more appropriate to speak of 'good practice' or 'smart practice' (Bardach, 2011) instead.

Countries and cities differ in meteorology, location, topography, emission sources, population, growth trajectory, policies, stakeholder awareness, technical capacity, and financial resources. These factors need to be considered to ensure that lessons learned and activities undertaken or measures replicated from other countries or cities are applicable in the local context. In addition, best practice can be based on habit, which is the result of conditions that may no longer apply.

AQM plays an important role in shaping environmental policy in a country or city. However, the effectiveness of AQM depends on a number of factors including, but not limited to:

- assessment of the existing state of air pollution exposure;
- capability and capacity to
    - o develop reliable emissions inventories;
    - o perform dispersion modelling;
    - o assess the impacts of air pollution on human health and the environment;
    - o determine appropriate control measures and their costs; and
    - o evaluate the benefits of planned action to human health and the environment;
- ability to develop CAAPs/CAIPs for local conditions; and
- close cooperation between government agencies and all relevant stakeholders to ensure effective implementation and enforcement of planned actions.

The EU and the US have achieved significant improvements in air quality (Kuklinska et al., 2015) which involved good practices such as:

- 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;
- development of comprehensive CAAPs (EU) and State Implementation Plans (SIPs) (US);
- provision of sufficient funding for the implementation and enforcement of the plans; and
- involvement and active participation of all relevant stakeholders.

To ensure the applicability of 'best' practice and technologies from developed countries to developing countries, the success of the 'best practice' application needs to be discounted to take account of better than average favorable conditions (see Box 2). This could include increased stakeholder enthusiasm; advantageous political/ economic conditions; less bureaucratic resistance; and influence of a 'champion.'

Sharing information on failed actions could also be helpful in formulating policies and action plans with the objective to avoid identified failures.

BOX 2

Factors to be Considered in Using Best Practice

- Manage expectations.
- Identify and adapt the core of the practice which allows flexibility to be applied in different locations.
- Ensure the context from which the practice is derived is comparable to the context in which it will be applied.
- Anticipate risks to implementing the best practice to maximize the likelihood of success.

Best practices activities should result in tangible, concrete results in the short-term, which will allow quick wins that can be built on and/or replicated in the long-term. However, these "quick wins" also need to be anchored on existing/planned programs or policies and complement or contribute to them. This can help maximize benefits and sustain lessons and good practice (Snow, 2015).

This study assessed the strengths and gaps in existing AQM initiatives in Chengdu, Kathmandu, Metro Manila, and Xiangtan – and Nepal, the Philippines, PRC, and Thailand. It identified challenges and proposes solutions to address these issues through the development and implementation of CAAPs or CAIPs based on an integrated AQM framework. Recommendations are given on how cities can better integrate AQM measures into urban development plans and programs.

Based on case studies in the US and Germany[10], the first serious steps towards national air quality management started in the 1950s and 1960s, respectively. The case studies are described here and in succeeding chapters. Good AQM practices from Asian countries (e.g., Singapore, Thailand) and cities (e.g., Hong Kong, China; Bangkok; Kawasaki City; Chengdu and Xiangtan; Kathmandu and cities within Metro Manila) are also described in this chapter because their experiences are helpful in addressing the common challenges identified from the city and country assessments.

4.1 AQM Practice in the US

In the U.S., good AQM practice included a nationwide clean air enforcement program based on the Clean Air Act (CAA) of 1963 and its amendments in 1965, 1970, 1977, and 1990. The Environmental Protection Agency (EPA) was created in 1970 to consolidate and expand existing activities on AQM, including federal research, monitoring and enforcement. Its mission is to protect human health by safeguarding the various environmental media. In the air medium, its major achievements include the establishment and enforcement of national emissions standards for stationary and mobile sources, National Ambient Air Quality Standards (NAAQS) for criteria pollutants (PM (PM10 and PM2.5), SO2, NO2, CO, Pb, and O3). National emissions standards were also set for 187 hazardous air pollutants including benzene, formaldehyde, phenol, and heavy metals compounds such as arsenic, cadmium, chromium, lead, manganese, mercury, and nickel.

Highlights of good AQM practices included the 1) the establishment of motor vehicle emissions standards and their enforcement through motor vehicle laboratory testing and certification; 2) development of low emission vehicles; 3) setting of aircraft emission standards; 4) and the development of State Implementation Plans (SIPs) in geographic areas were the NAAQS are not attained (known as "non-attainment areas"). The participation of all key stakeholders in AQM and setting of emission standards and NAAQS are considered indispensable.

Historically, air quality standards and their implementation plans have played important roles in the practice of AQM in the U.S. In a major amendment of the Clean Air Act in 1970, the EPA was granted authority to create and maintain the NAAQS-driven AQM system. State, local and tribal governments were required to develop and continue to modify and implement their SIPs to improve local air quality. The SIPs are designed to prevent air quality deterioration for areas that are in attainment with the NAAQS and to reduce emissions in non-attainment areas to levels that will achieve compliance with the NAAQS (normally in 3-5 years). If the relevant state authority failed to achieve the proposed improvement, EPA requires a new round of SIP revisions and implementation.

[10] *"Air quality management in North-Rhine Westphalia, Germany, in the last 50 years" and "Air quality management in the United States in the last 60 years" are reports prepared in 2015 under the first phase of the ADB project as inputs to the consultation of the 13th Five Year Plan of PRC*

Failure to submit SIP revisions to EPA for approval can result in sanctions, either as emission offset requirements or through withholding of highway construction funding.

The U.S. implements a two-layer AQM: (i) federal government promulgates the rules, including formulating the NAAQS and the emission standards, proposing and implementing federal programs such as the Acid Rain Plan, and reviewing and assessing the status and progress of state plans, and (ii) the state, local and tribal governments propose the plans, operate the preconstruction and operating permit programs, and are responsible for programs to regulate in-use vehicles. In a few cases, local governments have air quality management authority. EPA's ten regional offices oversee day to day communication and coordination with their respective assigned state governments. Other stakeholders, such as private businesses and industries, consulting firms, NGOs, and other social communities, are involved in AQM as well. The regulated enterprises are required to operate their facilities in compliance with the applicable requirements in their operating permits and are encouraged to improve their environmental performance. Consulting firms or professional trade associations may provide analysis and suggested solutions to the enterprises to tackle the air pollution problems. NGOs, other social communities, and private citizens may be active in monitoring both the government actions and the emission sources.

Co-benefits on AQ improvement and GHGs mitigation are being quantified. In the U.S., GHGs are controlled together with air pollutants, and the government department responsible for air pollution control is also in charge in addressing the GHGs emissions. Many sources of air pollutants also are sources of greenhouse gases. Control strategies exist that can both reduce air pollution and the impacts of climate change. For example, controls for organic compounds will reduce emissions of pollutants that form ground-level ozone and also emissions of methane, a pollutant that has global warming potential. Also, black carbon is a component of fine particulate matter that has climate warming properties. Measures that lessen the demand for energy (e.g., using more energy efficient products) reduce associated air pollution and carbon emissions from power plants.

Emission permitting systems are widely used in western countries to regulate the emission activity of stationary sources. In the U.S., Congress established the operating permit program under Title V of the 1990 Clean Air Act Amendments. The 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. The program is designed to make it easier for sources to understand and comply with control requirements, which in turn leads to improved air quality. Over the past decades, the EPA has worked with state and local governments to establish over 100 operating permit programs. Through these efforts, state and local agencies have issued approximately 14,000 permits nationwide.

The introduction of emissions standards for new vehicles plays an important role in controlling exhaust emissions. The emission levels of

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individual vehicles have been significantly lowered with the implementation of the standards, hence significantly boosting urban AQ improvement efforts.

In addition to new vehicle control, in-use vehicle control is particularly important for heavy duty vehicles (HDVs), a significant emission source. Although new US vehicle emission standards can result in major emission reductions for new vehicles, the slow turnover of HDVs limits the near-term impact of new vehicle emission standards on total vehicle emissions. In contrast, the in-use vehicles control measures help address the existing in-use stock of vehicles in the short term. Measures implemented in the US include: inspection and maintenance (I/M) programs, a systematic approach to complementary standards in vehicles and fuels, and retrofitting of HDVs.

New non-road engines are currently subject to the Tier 4 emission standards that tighten the limits on HC, NOx, and PM, compared with previous standards. End-of-pipe technologies, such as diesel particulate filters and selective catalytic reduction, are required for standards compliance. Non-road engines are required to meet the Non-Road Transient Cycle (NRTC) and pass the 1,000-hour durability test to guarantee their ability to meet the standards in working conditions.

Finally, the U.S. implements a registration system to estimate emissions of each machine through an identification tag which is installed in a prominent location of the fuselage. This allows users access to the actual technical parameters of the engines and emissions estimates. Financial subsidies are also allocated to encourage the installation of after-treatment devices in old machinery to reduce emissions.

4.2 AQM Practice in Germany and the EU

Air quality management in Germany started in State of North-Rhine Westphalia, which promulgated the first smog ordinance and developed the first CAIPs based on the "Federal Exposure Protection Act" (FEPA) for pollution mitigation and the "Technical Instructions for Air Quality Control" (TI Air).

The FEPA regulates, among others, the installation and operation of industrial plants, the assessment of emissions from stationary and mobile sources, emission declarations, composition of plants, materials, products, fuels, and lubricants, the exposure of the population and the composition and operation of vehicles, construction of roads and railways, surveillance and improvement of air quality, and clean air implementation planning to protect public health.

TI Air regulates prescriptions for approval and upgrade of industrial facilities, sets emission and air quality standards, and regulates air quality monitoring, instrumentation, and QA/QC. The FEPA and TI Air were and are to be updated and amended according to EU Directives, in particular, setting Euro standards for vehicle emissions, the Framework Directive[11], four Daughter Directives[12] [13] [14] [15], and the ambient air quality Directive of 2008.[16] Stakeholder participation is essential for national AQM in Germany as well as the other EU Member States. Information and participation is a right of the public established in the Aarhus Convention[17] and regulated in several EC Directives such as Directive 2003/4/EC[18] that ensures public access to environmental information.

In the EU, air quality limits or targets and compliance timeline (e.g., 96/62/EC) form an important pillar of the EU's policy for clean air. The Framework Directive on Ambient Air Quality Assessment (EC, 1996a) and four sub-directives related to limiting values for specific air pollutants (EC, 1999; 2000; 2002; 2004) were milestones for cleaning up the air in the EU. The most important requirements of the Framework Directive for EU member states include (1) the development of action plans with short-term measures achieve limit values and/or alert when thresholds are being exceeded; (2) measures that ensure a plan or program is developed and implemented to attain the limit value within a specific timeframe; and (3) an integrated plan covering all pollutants for which the level of more than one pollutant is higher than the limit values. In 2001, the European Commission recognized the residual problems related to air pollution in Europe in spite of the great successes in mitigating air pollution in the previous four decades. The Clean Air for Europe (CAFÉ) program and the Thematic Strategy on Air Pollution (EC, 2005) were developed thereafter as a coherent, thematic strategy to combat air pollution, and the framework and the first three daughter directives were merged and updated in 2008 (EC, 2008).

[11] Council Directive 96/62/EC of 27 September 1996 on ambient air quality assessment and management.
[12] Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulfur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in the air.
[13] Directive 2000/69/EC of the European Parliament and the Council of 16 November 2000 relating to limit values for benzene, and carbon monoxide in ambient air
[14] Directive 2002/3/EC of the European Parliament and the Council of 12 February 2002 relating to ozone in ambient air.
[15] Directive 2004/107/EC of the European Parliament and the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air.
[16] Directive 2008/50/EC of the European Parliament and the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.
[17] United Nations Economic Commission for Europe Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters.
[18] Directive 2003/4/EC of the European Parliament and the Council of 28 January 2003 on public access to environmental information and repealing Council Directive 90/313/EEC.

Responsibilities for AQM are clearly defined. EU member states are responsible for achieving the legally binding target of Air Quality and National Emission Ceilings. They are also responsible for translating the European Directives into national laws. The local governments in EU countries are responsible for implementing the national laws, including granting permits to industrial sources and supervising them according to the permit, operating an inspection and maintence (I/M) program for vehicles, and so on. The polluters have the responsibility to operate and emit air pollutants according to the permits (for large- and medium-sized point sources) or emission standards (mobile sources). The general public participates in every part of AQM by monitoring their governments and the emitters.

At the early stage of air pollution control in developed countries, restructuring the energy system was one important approach. For example, London gradually moved its coal-fired power stations and boilers after the occurrence of heavy smog in 1952, and eventually became a coal-free city. This action played a key role in London's AQ improvement practice. Recently, energy plans in developed countries have taken into consideration climate change and air pollution. The recent clean energy plans in EU countries will reduce coal and fossil fuel consumption to improve AQ and mitigate GHGs. For example, more fossil fuel power plants in Germany will be replaced by wind power and other renewable power sources.

The European Commission developed the emission control framework that consists of source- and product-related legislation. The Integrated Pollution Prevention and Control (IPPC) Directive, now replaced by the Industrial Emission Directive (IED), regulated stationary source emission control. According to the IPPC Directive, the basic principle for receiving a permit for an industrial facility is the application of best available technology (BAT) in order to prevent significant environmental impact on air, water, soil, and others. For this purpose, BAT reference documents were drafted, reviewed and updated through information exchange among all stakeholders including experts from member states, concerned industries, non-governmental organizations, and the Commission. Permits were updated according to developments in BAT. Early BAT reference documents served as benchmarks for the competent authorities. The IED required the reference documents to be legally binding and all the industrial installations have to follow the BAT requirements.

In the 1970s, the EU promulgated regulations for exhaust emission of light duty vehicles for PM, NO_x and VOCs. For heavy duty vehicles, exhaust emissions of gaseous pollutants from diesel engines was first regulated in 1988. The amendments to relevant directives introduced the exhaust regulations for light-duty vehicles (Euro 1 to Euro 6) and for heavy-duty vehicles (Euro I to Euro VI). In-use vehicles control measures in Germany include: I/M programs and remote sensing, applying on-board diagnostics (OBD) to identify vehicles with high emissions, a systematic approach in terms of complementary standards in vehicles and fuels, mandatory or subsidized program to phase out old vehicles, retrofitting of HDVs with DPF and/or diesel oxidation catalysts (DOCs), or Low Emission Zones (LEZs) to control emissions of light- and heavy-duty vehicles in certain areas of a city.

Low-sulfur diesel fuel is a common requirement for non-road mobile sources. For example, EU requires ships to burn fuels with 0.1% (or less) sulfur within its ports or inland waterways and offshore Emission Control Areas (ECAs). Since 2010, these ECAs include the Baltic Sea, North Sea, and North American East and West coasts.

4.3 AQM Practice in Singapore

Air quality in Singapore meets WHO air quality guidelines except for PM and SO_2. It has set air quality objectives that it aims to achieve by 2020. Among the major sources of PM and SO_2 emissions are vehicles and industrial plants. Vehicle emissions are controlled through the application of Euro VI emission standards.

Singapore promulgated strong legislation in its Environmental Pollution and Management Act and ensures strict enforcement. It applies the 'polluter pays principle' and tightens emission standards for stationary and mobile sources towards European limits. It also adopts internationally recognized test methods and protocols, and industrial emissions standards are regularly reviewed through international benchmarking and studies on industrial processes and technology levels and fuels used, and eventually tightened by reducing emission caps. A review of industrial emission standards was carried out in 2012 to 2015 through consultations with stakeholders including oil refineries, power stations, trade associations, and government agencies. A decision was made to tighten the standards and a phased implementation approach was followed. All new industrial plants were to meet the standards starting July 2015 and onwards. Existing plants, on the other hand, are to

meet specific standards in two phases, starting on 1 July 2018 and 1 July 2023.

The source emissions testing scheme was implemented to determine the emission levels from industries. Third-party testing companies were accredited and trained on the use of equipment and following testing protocols. In the beginning, the industries resisted the new scheme because of the cost of testing. To address this, the government decided to require only the major emitters to conduct the tests. When more testing companies were accredited, the cost of the tests eventually went down. Industries are required to monitor and control emissions and in cases of non-compliance with standards, they are required to implement emissions reducing measures. In some cases, plant owners were prosecuted and penalized. As a result, compliance with the standards improved and noncompliant industries decreased from 10 to 1%. Continuous emissions monitoring systems are enforced and supported the source emission testing scheme (Tuck, 2017).

4.4 AQM Practice in Thailand

Thailand developed several good practices in AQM, including emissions standards set for industries, power plants, and refineries. It likewise has specified ambient air quality standards for CO, NO_2, SO_2, Pb, PM_{10} and TSP.

Thailand has progressively imposed European vehicle emissions standards. Since 2012, Euro 4 emissions standards have been imposed for new and imported light-duty vehicles and fuel specifications have been continually tightened. Lead was successfully phased out in 1996, and sulfur content in diesel fuel was reduced to 50 parts per million (ppm) since 2012. Thailand also developed a policy of encouraging the use of natural gas and ethanol in transport. Both command-and-control (standard) and economic instrument (tax on leaded gasoline) were applied which mobilized key stakeholders (refinery industry, vehicle owners, public) to act. The country also implemented a policy to subsidize liquefied petroleum gas (LPG) for cooking to promote its wider use.

Several EIs were conducted and databases updated for key man-made and natural air pollution sources.

An integrated emissions reduction approach for the Mae Moh coal-fired power plant, a huge source of SO_2 and PM, included the enforcement of emission standards, fuel quality improvement, and use of alternative fuels.

Since the 1980s, the automatic ambient air quality monitoring network has been successfully operated with almost 70 stations at present. Equipment calibration and data QA/QC procedure are well documented and implemented. Data is shared with, and disseminated to, key stakeholders online, on display boards, and on a mobile application. A strong collaboration between government offices and the academe has been implemented.

Providing real-time information on the state of air quality is important for mobilizing citizens and protecting their health. Cloud and mobile applications and utilizing satellite data could be used. For example, the Thailand PCD established the Air4Thai application, which reports hourly data on Thai AQI to disseminate information to the general public (PCD, 2017).

BOX
3

Air Quality Monitoring in Thailand

The Thailand PCD has monitored ambient air quality since 1983. Ambient air pollutants routinely measured include CO, NO_x, SO_2, O_3, Total TSP, PM_{10} and Pb, as well as meteorological parameters. As of October 2017, the air quality monitoring network consists of 63 monitoring stations, five meteorological stations, and nine mobile units spread throughout Thailand. Monitoring stations are focused on Bangkok due to the concentration and magnitude of people affected.

Other government agencies, such as the Bangkok Metropolitan Authority (BMA), Electricity Generating Authority of Thailand (EGAT), and the Industrial Estate Authority of Thailand, also monitor air quality and coordinate with the PCD. The BMA operates and maintains its own stations that endeavor to cover all districts of Bangkok. Its network comprises of continuous automated ambient air quality stations and roadside continuous and short-term temporary air quality stations that monitor TSP, PM_{10}, and $PM_{2.5}$. A temporary roadside monitoring program was conducted in 18 sites in Bangkok in 2017. The EGAT focuses on monitoring specific AQ parameters in areas where it operates. Air quality data generation and assessment are coordinated with and reported to PCD by the government agencies. In addition, some industrial groups also conduct monitoring but are not required to report to PCD.

The PCD received assistance from Japan and Sweden in the early stages of its air quality monitoring (ADB, 2014). The Swedish Government provided assistance in 1992 for the preparation of the design of a nationwide air quality monitoring network and a meteorological monitoring network (Site Visit Information, 2017).

OPERATING MONITORING STATIONS

Monitoring activities are determined by budget allocation, identified AQM issues in a particular jurisdiction, and other related development priorities. For example, due to air pollution episodes, the need to monitor haze was identified in Northeastern Thailand, and similarly actual pollutants monitored may differ every year depending on the area (i.e., if the pollutant exceeds standards or guideline values), budget, and priorities.

Continuous automated analyzers monitor PM_{10}, $PM_{2.5}$, O_3, SO_2(subscript), hydrosulfuric acid (H_2S), NO_x, NO, NO_2, and VOCs all year round. Continuous sampling and measurement are conducted monthly for TSP, PM_{10}, $PM_{2.5}$, Pb, and VOCs. Meteorological parameters, such as temperature, wind direction, wind speed, relative humidity, solar radiation, net radiation, pressure, and rain are also tracked. Eighteen stations currently measure VOCs throughout the country, with seven stations located in the Bangkok Metropolitan area. Monitoring of $PM_{2.5}$ was initiated with one station in the Samut Sakhon province in 2013, and with two stations in Bangkok since 2014. While some of the monitoring stations include H_2S in the parameters observed, Thailand currently does not have standards for the pollutant.

QUALITY ASSURANCE/ QUALITY CONTROL

Thailand's air quality monitoring system is equipped with data loggers and data is transmitted from remote sites to the central processing computer at PCD for storage and analysis. The PCD implements QA/QC procedures for all monitoring stations and ensures data quality checks for hourly SO_2, NO_2, CO, O_3, and PM_{10} on a daily basis. Data analysis is based on Thailand's NAAQS and system performance audits could be undertaken by a third party.

The PCD adopts US EPA QA/QC procedures, which in theory can be adopted by other agencies as well as the private sector to help facilitate data comparison and reiteration of methods for verification. However, there is no standard or common QA/QC protocol across agencies. Different agencies that undertake air quality monitoring activities do not adopt the same protocols that the PCD uses. While data across different stations operated by different agencies are not comparable, these are still useful to generate trends. Further, PCD confirmed that even without a common QA/QC protocol, assessment and comparison of AQ data may be undertaken, depending on the air quality objective set and budget allocated by concerned agencies (Site Visit Information, 2017).

COMMUNICATING DATA TO THE PUBLIC

Monitoring data in AQI format is displayed on screens at certain locations. It can also be accessed through a mobile app and PCD's website (www.air4thai.pcd.go.th).

COSTS OF AIR QUALITY MONITORING

Investment costs of air quality monitoring depend on the parameters to be monitored. Monitoring full parameters and setting up of a meteorological tower can cost THB7-8 million ($220,000 to 250,000). Monitoring less parameters would entail less costs. Annual operating costs include maintenance, which are also dependent on location and parameters covered. Estimated annual operating costs are around THB400,000-900,000 ($12,700-28,700). Regular audit is done annually, but this is also contingent on available funding.

OUTSOURCING OF AIR QUALITY MONITORING

Currently, the PCD outsources the technical and maintenance service of almost half of its air quality monitoring stations (Personal Communication, 2017). Monitoring stations and system performance are audited by a third party (Suwanathada, 2017) and occasionally put under service contracts depending on the budget of PCD. With sufficient funds, it puts all monitoring stations under service contracts and hires companies to operate the stations. If funds are limited, PCD puts some stations under service contracts and operates the rest themselves (ADB, 2014). The service contracts cover sampling/data acquisition system/ single point calibration/log book (every 15 days), multi-point calibration (every 3-4 months), maintenance of mass flow controller (every 6 months), maintenance of meteorological equipment (every 6 months), efficiency test of Molybdenum converter, accuracy test of zero-air scrubbers and ozone generator of the calibrator, air conditioning system test and cleaning, handling of emergency cases, and data reporting (Site Visit Information, 2017). In 2017, 23 stations were outsourced by PCD. PCD owns the monitoring stations and the air quality data collected but the land stations are owned by different government agencies and/ or local governments.

Third-party contractors are selected through competitive bidding. Terms of Reference are prepared by PCD and are posted on its website. Data quality and the procedures that need to be followed are included in the TOR. Monthly inspections are done by PCD staff and the payment for outsourced services is dependent on the quality of data generated. PCD requires at least 85 percent of good quality data. If data quality is deemed to be below this percentage, the contractor pays a fine. During haze episodes, contractors are fined if good quality $PM_{2.5}$ data is not available.

MOBILE MONITORING UNITS

Mobile monitoring units supplement operations of the AQ monitoring stations. These are typically placed at locations where budget is insufficient to have a fixed station. The mobile unit is sent to the identified location thrice a year. In Northern Thailand where the incidence of open burning is high, mobile monitoring units are used to gather information because the fixed stations don't cover this area.

4.5 AQM Practice in Hong Kong, China

Air quality issues in Hong Kong, China include local emissions from land and sea transport, power plants, emissions from regional sources in the Pearl River Delta (PRD), such as power plants, industries, non-metallic mineral product manufacturing, paper and pulp industry, light industrial manufacturing, and oil refineries (Hung, 2017).

In order to abate emissions from road transport, almost all diesel taxis and about two-thirds of diesel light buses were replaced with LPG vehicles. Stakeholder participation involved engaging polluters, fuel suppliers, and academics as partners in government-funded trial schemes such as the diesel-to-LPG trial scheme for taxis and minibuses. Further measures included the installation of particle reduction devices in pre-Euro diesel vehicles. To mandate ultra-low sulfur diesel fuel use by vehicles, an advanced dynamometer smoke test was implemented and the most stringent and international good practice for vehicle emissions and fuel standards were also adopted where practicable.

Hong Kong, China installed also roadside remote sensing equipment to identify excessively emitting in-use petrol and LPG vehicles and requested owners to take repair action. Pre-Euro IV diesel commercial vehicles (DCVs) were phased out and the age of new DCVs was limited to 15 years. Euro II- and III- franchised buses were retrofitted with selective catalytic reduction devices in order to reduce NO_x emissions (Hung, 2017). The investments in these projects were substantial (Table 8), but concentration of PM_{10} and NO_x were reduced by 50% over seven years and $PM_{2.5}$ by 20% over five years. However, NO_2 levels were not reduced (Table 9).

Table 8: Measures for Vehicle Emission Reduction

Measure	Cost [USDm]
LPG taxi program	19
PM reduction devices for pre-Euro diesel vehicles	1500
Retrofit some 1 400 Euro II and III franchised buses	52
Launsch of Pilot Green Transport Fund	39
Test of alternative vehicles (electric buses, hybrid vehicles, solar air conditioning, etc.)	12

Table 9: Historical NO_2 levels in Hong Kong, China

Pollutant [µg/m³]	Time, Year		
	1999	2011	2015
PM_{10}	90		46
$PM_{2.5}$		30	38
NOx	220		450
NO_2	100		100

Emissions abatement action for marine transport included the use of Euro V diesel engines with 10 ppm sulfur in 2008, a speed control in harbor areas, the imposition of a statutory 0.05% sulfur limit on locally supplied marine light diesel in 2014, and the reduction of port dues by 50% for ocean going vehicles if they switch to low sulfur fuel ($S \leq 0.5\%$) while berthing. Regional collaboration with Guangdong and Shenzhen is ongoing to mandate fuel switch at berth in the short term and establish ECAs in the long term (Hung, 2017).

Emissions abatement actions for power plants include the implementation of emission caps and permitting emissions trading, retrofitting existing coal-fired power plants with flue gas desulfurization devices, wider use of natural gas in power plants, and the promotion of renewable energy facilities such as wind power stations, photovoltaic systems, and off-shore wind farms (Hung, 2017).

The Guangdong and Hong Kong, China, local governments endorsed a new air pollutant emissions reduction plan for the PRD with the aim of reducing SO_2 emissions by 35-75%, and NO_x emissions by 20-30%, respirable suspended particulate emissions by 15-40%, and VOC emissions by 15% in Hong Kong, China, and by 20-37%, 20-4%, 15-25% and 15-25%, respectively, in the PRD Economic Zone (Hung, 2017).

4.6 AQM Practice in Bangkok

Key sources in the Bangkok Metropolitan Region[19] (BMR) include light and heavy-duty vehicles, vehicles of the Bangkok Metropolitan Administration[20] (BMA), motorcycles and motorboats, building construction works, open burning, and open air grilled food (BMA, 2017).

In the BMR, four EIs for stationary and mobile sources were developed in the BMR for the base years: 1992, 1997, 2000, and 2010 to address the emissions of PM, CO, NO_x, SO_2, VOCs, Pb, TSP, CO_2, CH_4, PM_{10}, NMVOCs).

Automotive air pollution control includes the improvement of fuel quality, adoption of emission standards for new and in-use vehicles, an I/M program and roadside inspection, emission minimizing traffic management, and a gasoline vapour recovery system at service stations.

Dispersion modelling results from analyzing O_3 formation and the impacts of different control measures in five different scenarios in the BMR were reported in 2004. Ground-level O_3 was also studied using advanced Meso-scale Model 5, Comprehensive Air Quality Model with Extensions (MM5-CAMx).

The PCD has defined monitoring objectives for air quality monitoring and a QA/QC in the BMR to:

- o Determine whether the general levels of pollutants in the atmosphere are likely to be harmful;
- o Evaluate long-term air pollution trends from which to formulate policy on abatement action;
- o Assess effectiveness of the air pollution control program and mitigation measures implemented;
- o Provide more information on a particular AQM concern for which actions are needed;
- o Serve as source data on which to base planning decisions and for use in EIA of a particular installation or project;
- o Isolate individual rogue emissions to justify control action; and
- o Provide information for correlation with medical studies.

PCD also developed the NAAQS and ensures that QA/QC protocols are applied at all stations to achieve and produce valid and reliable air quality monitoring data. The regulation on the NAAQS also specifies the monitoring method for each air quality indicator.

For data communication and dissemination, PCD also developed an Android-based mobile application from which users can get AQI values near real-time. Dissemination of AQI values to the public in the BMR is done through four display boards. Air quality information is also published in the Bangkok Post, and through the public relation department radio.

The BMR has the power to develop, implement, and enforce clean air action plans and Bangkok has developed an Air Quality and Noise Management Action Plan (AQNMP). The AQNMP's objective is to manage and control air quality and noise pollution levels within acceptable standards and to formulate strategies for different sources to be completed by the responsible stakeholders. Apart from emissions inventories and air quality monitoring results, Bangkok AQNMP also provides details on activities and amounts and sources of funding.

The government of BMA integrated global warming mitigation and energy conservation in their 12-year development plan (2009-2020). They formulated the BMA Action Plan on Global Warming Mitigation 2007-2012 with the ultimate goal of reducing 15% of GHGs under the designated five initiatives, viz. mass rapid transport, renewable energy, energy efficiency in buildings, solid waste management and water treatment improvement, and parking area expansion. BMA, with support from the Japan International Cooperation Agency (JICA), formulated a 10-year Master Plan, 2013 - 2023, which covers an adaptation and mitigation plan for climate change.

Additional good practice examples in the BMR include the establishment of the BMR ambient air quality network; phase-out of lead in gasoline; phase- out of two-stroke motorcycles; continuous improvement in vehicle emissions and fuel quality standards; reduction of SO_2 and other emissions from power plants and manufacturers; promotion of non-burning agriculture; enforcement of EIA, VOC emission control from industries, transport and diffuse sources such as underground oil bunkers at service stations; installation of CEMS, enhancing capacity in regulating compliance and enforcement; and a co-benefit approach to air pollutant and GHG emissions.

Kawasaki City, with an area of 144 square kilometers, is the seventh most populated city in Japan with about 1.5 million people and 710,000 households. Its manufacturing industries produce steel, precision machinery, and petrochemicals. Most industries are located along the coast.

[19] BMR encompasses Bangkok metropolis and five surrounding provinces. Area: 7,861 km2. Population: 15.9 million.

[20] BMA administers Bangkok metropolitan area (1,568 km2), which has a night time population of 8.8. million.

4.7 AQM Practice in Kawasaki City

During the period of Japan's rapid economic growth from the 1950s to the 1970s, Kawasaki was the engine of economic growth and caused air and water pollution in the area. Agricultural crops were damaged by air pollution in the 1950s when the industrial area was developed, air pollution from sulfur oxides occurred when industrial complexes were built in the 1960s, and photochemical smog was observed for the first time in the city and the health of several thousands of people were affected by air pollution in the 1970s.

To address the worsening SO_2 pollution, several policies were issued and enforcement measures instituted. The enforcement of the Ordinance of Kawasaki City on Pollution Control in 1972 and the application of the total SO_x emission control in 1974-1980 resulted in the achievement of the SO_2 environmental standards in 1980. Additional policies and measures include the promulgation of the Ordinance of Kawasaki City on Preservation of the Living Environment including Pollution Control in 1999 and the introduction of suspended particulate matter comprehensive reduction measures in 2000.

To reduce NO_2 emissions from industries, the same Ordinance on Pollution Control was enforced in 1972 and in 1978, total NO_x emission control was introduced. In 1992, the Automobile NO_x Law was promulgated, followed by the enforcement of the Automobile NO_x and PM Law in 2002 which was revised in 2007. Because of these NO_x emissions reduction control policies and measures, the environmental standard was achieved in 2013.

On suspended particulate matter emissions reduction, Kawasaki City promulgated and enforced the Ordinance of Kawasaki City on Pollution Control (1972), total emission control standards relating to soot and dust (1974), Ordinance of Kawasaki City on Preservation of the Living Environment including Pollution Control (1999), Automobile NO_x and PM Law (2002), and transportation control in eight prefectures and cities (2003). These efforts resulted in a significant drop in the dust fall in three districts in Kawasaki City, from 178 tons square kilometer per month in the 1960s to 8.2 tons per square kilometer per month in 2014 (Ono, 2017).

Efforts to reduce emissions from industrial sources included regulating SO_2, NO_2, PM, hydrogen chloride and other emissions, on-site inspections of and maintenance actions at the plants, and installation of automatic emissions monitoring systems at the facilities. Control methods included concentration control of emissions from the outlet(s) of each facility, comparison with emission standards, total emissions control from the whole plant, and inspection of the facility pollution control devices and their distribution in the facility structure.

The two main control measures implemented by Kawasaki City are (a) regulations on plants and workplaces and on-site inspection, and (b) automatic monitoring system for emission sources.

Kawasaki City introduced the method of regulating sulfur oxide emissions from plants ahead of other municipalities in Japan. The city introduced the "Kawasaki Method," its own total emission control system, under the Pollution Prevention Ordinance in 1972. Under this ordinance, the city sets its own environmental target values for air pollutants, which are more ambitious than national environmental quality standards. Different emission standards were set for each facility based on the simulation results of ambient concentration using an atmospheric dispersion model (Clean Air Asia, 2016). The city applied standards for SO_x and dust in 1974, for nitrogen oxides in 1978, and for particulates in 2000.

The city receives information on the installation or change in soot- and smoke-emitting facilities like boilers. The notification includes the representative's name, plant location, type of soot and smoke emitting facility, structure and use of the facility, and waste disposal method to be used for soot and smoke (Ono, 2017).

On-site inspection of the plant or workplace measures the emissions, temperature, and flow rate soot and smoke; checks the exhausts of processing facilities; and checks if emissions records are kept, among others. In 2015, about 1,700 on-site environmental inspections were conducted in Kawasaki City and of these, about 1,150 were related to air pollution. Hearings were conducted following the inspections and instructions for improvement were issued to the industries.

The success of the control measures was achieved by agreements on air pollution prevention between the City of Kawasaki and the leading companies in the city. These agreements required the companies to develop an air pollution prevention plan, develop policies to respond to an air pollution emergency, and report essential input parameters such as the amounts of fuel used, sulfur content, and others. Kawasaki City entered into agreements with 37 companies and monitored emissions sources using telemeters. In 1972, the city installed source telemeters in 42 large plants to enhance the monitoring of sulfur oxides. The city also started telemetric monitoring of nitrogen oxides in 1979. Telemetric monitors are currently installed in 11 and 23 plants to monitor SO_2 and NO_2 concentrations, respectively (Ono, 2017).

In order to assess the population exposure to air pollution, Kawasaki employs an automatic air quality monitoring system at nine general stations and nine roadside stations in addition to the telemetric stations installed at plants. Data from the general and roadside networks are communicated to the Kawasaki Environment Research Institute, processed and disseminated to the city office, and to TV stations and the internet for public information. Data from the telemetric plant network is compiled at the city office's intranet (Ono, 2017). Air quality improved significantly over 21 years: NO_x went down by 30%, SO_x by 93%, and SPM by 60% (Table 10). The annual cost of automatic air quality monitoring system in Kawasaki City, excluding personnel costs, is about JPY 47 million ($440,000).

Kawasaki City has 32 staff in the Air Quality Section of the Environmental Protection Bureau responsible for ambient air quality, air quality at source plants, odor, asbestos, noise and vibration, and traffic environmental control.

To address its GHG emissions, Kawasaki developed a Promotion Plan for Global Warming Countermeasures, which aims to reduce 25% or more of GHG emissions by 2020 as compared to 1990 (Kawasaki Environment Research Institute, 2014).

Table 10: Emission Reduction and Air Quality Improvement in Kawasaki City

Pollutant	Year	Emission [t/y]	Annual mean concentration [ppb]	
SOx	1973	46,000	30	
	1993	2,000	6	
	2013	500	2	
			General site	Roadside site
NOx	1973	28,000	30	38
	1993	13,000	31	39
	2013	9,000	19	26
			Annual mean concentration [µg/m³]	
			General site	Roadside site
SPM	1976	2,700	-	-
	1995	600	55	75
	2015	500	18	20

4.8 AQM Practice in Chengdu and Xiangtan

Chengdu and Xiangtan adopted a series of pollution control measures for SO_2, NO_x, VOCs, $PM_{2.5}$ and PM_{10} by optimizing the industrial and energy structure, using improved abatement technology and phasing out obsolete production facilities, strengthening supervision and law enforcement, and promoting departmental cooperation to improve air pollution prevention and control. Apart from industrial sources, mobile, fugitive dust and agricultural sources are controlled using a multi-pronged approach. Departments responsible for environmental protection carry out quarterly on-site inspections and the inspection results are reflected in the environmental performance appraisal of leaders at all levels.

Chengdu also minimized the environmental impact of socio-economic and development projects by implementing the EIA-based approach and enforcing its recommendations.

Xiangtan sets a strong signal for joint law enforcement by environmental protection departments. It investigated and dealt with the country's first case of environmental administrative detention, as well as investigated the province's first criminal case of air pollution. Xiangtan enforced the ban on straw burning and imposed vehicle emissions control by tightening vehicle standards, strengthening supervision on vehicle fuel quality and phasing-out yellow-labelled vehicles (vehicles that fail to meet Chinese fuel and vehicle standards) and old vehicles, in line with the central government's decision to take more than five million aging vehicles off the roads (D. Stanway, 2014).

4.9 AQM Practice in Kathmandu

Kathmandu has strengthened the collaboration between the Nepal Department of Environment and International Centre for Integrated Mountain Development (ICIMOD) towards setting up an air quality monitoring network in the Valley and the country. Kathmandu enforced a ban on old-fashioned brick kilns still used in Kathmandu Valley to support of the government's active promotion of cleaner brick kiln technologies. Workshops were organized to show brick kiln owners how to use new and clean technologies, which allowed them to minimize cost, improve brick quality, and reduce pollutant emissions. The 2015 earthquake, which affected 98 percent of brick kilns in the Valley, provided a unique opportunity to rebuild using energy-efficient and cleaner kilns.

flickr.com/adam_jones

Since 1996, the Kathmandu Metropolitan Authority promoted electric three-wheelers known as SAFA tempos for public transport. Low custom duties on private and public electric vehicles provide incentives to reduce vehicle emissions and improve air quality. As Nepal uses hydropower for electricity generation, additional emissions from power plants due to transport electrification did not occur.

Organizations like ICIMOD and Institute for Advanced Sustainability Studies (IASS) are involved in increasing public awareness. They created a short film about air pollution from open fires. The film uses comedy to increase air pollution awareness and foster behavioral change. The film was premiered at a movie theatre in Kathmandu, telecasted on Nepal television, and is available on YouTube.[21]

[21] *The video is available here https://www.youtube.com/watch?v=82Bmq0eYMmk*

4.10 AQM Practice in Philippine Cities

Cities in the Philippines have taken initiatives to reduce mobile emissions by introducing and promoting electric tricycles and jeepneys (Pasig, Makati, Manila) and dedicating separate road lanes for electric jeepneys (Makati).

The cities of Mandaluyong and Pasig promoted and facilitated the switch from 2-stroke to 4-stroke motorcycles.

The city of Marikina mandated tricycle operators and motorcycle owners to shift to less-emitting engines. It also has prohibited the entry and parking of motorized vehicles in the jogging lanes along Marikina River Park, Meralco Park, and the playground areas.

The city of Pasig promoted non-motorized transport by encouraging citizens to walk (Ortigas Walkways Project) or bike to work and other destinations (Tutubi Bike Sharing System) and providing pedestrian and bicycle pathways.

The forging of partnerships between the city authorities of Metro Manila and different stakeholders including the national government, donors, and NGOs has been critical in mobilizing resources and implementing key activities.

The Department of Environment and Natural Resources (DENR) proposed a "no exposed soil" policy, which applies best practice in minimizing fugitive dust from construction sites and unpaved roads. It included prohibiting the use of bagged cement and on-site mixing of concrete and mortar, and requiring the use of enclosures and covers to minimize dust movement (DENR, 2011).

Bridging the Gap

AQM ASSESSMENT UNDERTAKEN UNDER THE TA HIGHLIGHTED THE STATE OF AIR QUALITY, THE REGULATORY FRAMEWORK, INSTITUTIONAL ARRANGEMENTS, TECHNICAL CAPACITIES, AND COMMON AIR POLLUTION CHALLENGES IN FOUR ASIAN CITIES AND COUNTRIES.

While national and local governments in the selected Asian countries and cities have developed strategies to address the deterioration in urban air quality, their scope and effectiveness vary. Progress has been made in implementing key aspects of an integrated AQM system; however, further action is required to improve air quality and contribute to the implementation of the SDGs. In particular, there is potential to exploit air and climate co-benefits and address SLCP emissions.

Each country and city have specific challenges unique to the national or local context. The assessment identified common challenges to managing air quality and effective approaches to air pollution prevention and control.

Based on the results of the assessment, a number of recommendations can be made to further promote air pollution prevention and control and its integration into urban development planning.

5.1 Develop clean air action plans with clear objectives, roles and accountability

A comprehensive strategy and an integrated evidence-based action plan (i.e., CAAP or CAIP) to address poor air quality needs to be developed, implemented and enforced. This should address the main components of AQM such as EI and source apportionment by receptor modeling, dispersion modeling, monitoring, data management, and health and environmental impact assessments. City level CAAPs/CAIPs are a means of mainstreaming air quality concerns in urban development and they also present the costs of source control and the expected benefits of avoided health and environmental impacts due to the implementation of control measures. The benefits are expressed as much as possible in monetary terms.

A CAAP/CAIP provides an overarching document that sets clear air quality objectives for all sectors and stakeholders. It clarifies the different sectoral agencies and stakeholders; facilitates collaboration; defines accountability, reporting and monitoring and should be supported by a financial/investment and resource commitment plan.

However, in some countries the trans-regional nature of air pollution together with weak coordination among geographically adjacent provinces or regions may hinder improvements in air quality. In such cases, an alternative integrated regional-based approach could be adopted to address air pollution that spreads across a number of domestic regions.

The PRC adopted effective regional AQM approaches for the Beijing Olympics, Shanghai Expo, Guangzhou Asian Games, and regions such as the Jing-Jin-Ji Region, the Yangtze River Delta and the Pearl River Delta. Although a regional approach can deliver improvements in air quality, this approach is not without challenges. Issues of weak coordination, limited financial and monitoring capacity still need to be addressed for the regional AQM approach to be successful (Zhou and Elder, 2013).

Designating an 'airshed' is another approach, wherein an Airshed Governing Board (comprised of LGUs, NGOs, the private sector, and the academe) can create and carry out action plans and formulate policies that fulfill the common needs of 'airshed' members. This approach was adopted by the Philippines where EMB regional offices act as the technical-administrative secretariat of their respective 'airsheds'. The 'airshed' system enables LGUs to exercise administrative and fiscal authority.

The US uses SIPs to maintain compliance with NAAQS in attainment areas and to achieve NAAQS for non-attainment areas. States and local agencies prepare a draft SIP and organize a public hearing on it and the recommendation (called 'rules'). Following the deliberations and suggestions made at the public hearing, the State makes appropriate revisions, adopts the SIP and then submits the draft SIP to the US EPA Regional Office, which reviews the SIP for completeness. If the SIP is incomplete, it is returned to the state for preparation of a new draft SIP. If the SIP is complete, US EPA proposes approval or disapproval in the US Code of Federal Regulations and requests for public comments. Considering the public comments on the SIP, US EPA approves or disapproves the plan.

In the event of SIP disapproval or if a complete SIP is never submitted, the US EPA must promulgate a Federal Implementation Plan (FIP). After approval, the control measures of the FIP are enforceable at both the state and national levels. However, SIPs are considered to have a number of weaknesses such as over emphasizing air quality modelling. If standards are not met, the entire SIP process restarts, instead of simply adjusting the SIP, slowing down the approval procedure. There have been calls for a more integrated and streamlined approach to SIP planning.

In Europe, the EU Air Quality Directive (2008/50/EC) requires member states to draw up CAAPs that should include short-term measures when there is a risk of exceeding air quality limits and/or alert thresholds. Measures need to ensure that a plan or program is prepared or implemented to attain the limit value within the specific timeframe. An integrated plan must be produced which covers all the pollutants where the level of more than one pollutant is higher than the limit values.

Whether or not an 'airshed', city, region or state approach to AQM is taken will be dependent on the sources and types of pollution and level of cooperation among agencies and stakeholders.

Recommendation

Develop CAAPs/CAIPs through an iterative process until emission and air quality standards are met. Stakeholder participation is an indispensable ingredient for CAAPs/CAIPs.

5.2 Tighten ambient air quality standards

The World Health Organization (WHO) developed air quality guidelines (AQGs) to achieve air quality that protects public health in different contexts. AQGs are not the same as air quality standards, but are recommendations that are not enforceable. Air quality standards, on the other hand, are set by each country to protect public health and as such are enforceable and an important component of national risk management and environmental policies. National standards will vary according to the approach adopted for balancing health risks, technological feasibility, economic considerations and various other political, cultural, and social factors, which in turn will depend on, among other things, the level of development and national AQM capabilities.

In 2005, WHO revised its AQGs for key air pollutants and published them as an update to the first globally applicable guidelines (WHO, 2006; WHO 2000a). The major changes as compared to the previous guidelines included the following (WHO, 2000b):

- For PM_{10} and $PM_{2.5}$, a step to a paradigm shift[22] was carried out to set guideline values for particulate matter although the fact that there were no thresholds for the onset of health effects at the lowest concentrations had been considered in 2000 as a reason to perform risk assessments for these compounds using the established exposure-response curves (WHO, 2000a);
- For SO_2, the 24-hour guideline value of 2000 was reduced by a factor of more than 6 to the very low value of 20 µg/m³. No annual mean was also established; and
- For O_3, the guideline value was also reduced to 100 µg/m³.

National governments should make efforts to align national standards with WHO guideline values. However, when formulating policy targets, governments should consider their own local circumstances before adopting WHO guidelines directly as legally based standards.

[22] This paradigm shift becomes even more evident since WHO in 2013 declared air pollution and, in particular, particulate matter as carcinogenic (ACS, 2013; IARC, 2013; WHO, 2013; WHO, 2016a). For carcinogens, WHO usually determines unit risks or concentration response relationships (WHO, 2000a), not guideline values (WHO, 2006).

The government of Nepal should set and enforce annual standards for PM_{10} and $PM_{2.5}$ and the Philippines needs to promulgate and enforce an annual standard for NO_2. It is recommended that PRC set an 8-hour CO standard.

Recommendation

Once compliance with national air quality standards in urban aggregations is achieved, the four countries should consider tightening their air quality standards towards the WHO intermediate and final guidance values and to enforce them. The concentration averaging times of the WHO should also be adopted.

5.3 Increase political and public awareness on air pollution impacts

Increasing political and public awareness is necessary to change attitudes and foster behavioral change to address poor air quality. This is important to garner public support and political will to prioritize air pollution-related health and environmental impacts and mobilize appropriate resources to confront the sources of air pollution at the country and city level. A range of methods and approaches to communicate air pollution issues to stakeholders exist (see Guidance Framework for Better Air Quality in Asian Cities (Clean Air Asia, 2016)).

Stakeholder involvement and participation is important in the development of CAAPs/CAIPs. For example, industrial control measures that mitigate air pollutant emissions need the collaboration of facility managers to find viable and affordable technical solutions. This also applies to the transport sector, where changes in the transportation system are required, stakeholders should also be involved. For example, if a Bus Rapid Transport (BRT) system is to replace informal transport or if car use is to be reduced by promoting public transport or non-motorized transport.

Recommendation

Increase awareness and strengthen stakeholder involvement in air quality management in the four cities and countries.

5.4 Enhance technical capacity in key aspects of integrated AQM

Evidence-based policymaking requires an accurate understanding of the state of air quality, sources and types of pollution, and their health and environmental impacts. Strengthening technical capacity is needed in air quality monitoring, data management and analysis, impact assessment, and source emission control.

Good air quality information is essential to set clear targets and identify priorities for action. This requires an improvement in existing ambient air monitoring to include $PM_{2.5}$ and hazardous air pollutants that may cause cancer or other serious health effects (e.g., benzene, 1,3-butadiene and acetaldehyde). A denser air quality monitoring network using sensors could also be achieved, for example, via citizen/participatory science monitoring initiatives (Guidance Framework for Better Air Quality in Asian Cities, Clean Air Asia, 2016).

Air quality sensors can be used to collect data on the state of air quality (Box 4) and low-cost sensors, provide an opportunity for cities to engage citizens in long-term ubiquitous monitoring (Takingspace, 2017). These sensors could also be integrated into new or existing infrastructure, but could be costly (> $ 5,000) and cities may be unable to install them ubiquitously.

The accuracy and precision of low-cost sensor data is currently still poor because comparisons with reference monitors have not yet been performed. A proper lifetime analysis has also not been done in order to determine these sensors' e-waste burden and carbon footprint.

BOX 4

City Air Quality Monitoring Sensors

Cities have initiated the use of low- to mid-cost air quality sensors to augment air quality monitoring efforts at the national level. Categories of such initiatives include:

a) Initiatives that integrate sensors into existing infrastructure:

- Chicago's Array of Things, a city-wide network of sensors mounted on lampposts and monitoring among air pollutants such as NO_2, O_3, CO, H_2S, and SO_2 (Argonne National Laboratory, 2017);
- Barcelona's Lighting Masterplan launched its Internet of Things (IoT) program, deploying a smart lighting system with embedded air quality sensors that relay information to city authorities and the public (Adler, 2016);
- Solar-powered benches (Soofa, Boston) providing free Wi-Fi, and USB ports to charge cell phones, and house sensors that record air quality and other city variables (http://www.soofa.co/).

b) Initiatives that leverage mobile sensors, and others:

- Belfast and Dublin bikes with air quality sensors measuring CO_2, CO, smoke and particulate matter (Irishcycle, 2017);
- London Pigeon Air Patrol project attaching 25-gram air quality sensors to pigeons' backs to monitor NO_2, O_3, and VOCs during flights (Pigeonair, 2017);
- Air Louisville, Kentucky, initiative uses smart connected inhalers that track when, where and how often asthma patients use their inhalers in combination with assessing weather and air quality data (https://www.airlouisville.com/).

c) Initiatives that analyze cell phone data to understand resident exposure to poor air quality:

- Massachusetts Institute of Technology's (MIT) SENSEable City Lab pairs anonymised cell phone data with air quality sensor data to determine exposure of citizens (MIT, et al, 2015).

It is important to consolidate existing monitoring data from various agencies and projects and ensure timely data sharing for use in AQM. For example, a searchable database from various monitoring agencies in a city or country would be an asset.

Evidence on which measures to take to improve AQM requires greater capacity to undertake exposure assessment of air pollution and its effects on health and the environment. Estimates of health and economic impacts are crucial to generate political will and convince policymakers to invest in implementing CAAPs. If local health impact studies are unavailable, health impact estimates of morbidity and mortality from air pollution using existing global health impact databases such as the Global Burden of Disease (GBD) can be used (Global Burden of Disease 2016 Sustainable Development Goals Collaborators. 2017).

For the sake of cost-efficient monitoring, it is important to carefully define air quality monitoring objectives before deciding on the monitoring devices to be purchased. For a monitoring objective of screening and mapping air quality, passive samplers may be sufficient. These samplers may also be useful for an initial test whether air quality standards are exceeded or not. Moreover, existing monitoring skill and experience have to be assessed. There is little use in installing a sophisticated automatic monitoring network if the skill for running it is absent. The following table presents the advantages, disadvantages and ranges of capital costs of various monitoring device types.

Recommendation

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

Table 11: Air Quality Monitoring Options Comparison

Method	Advantages	Disadvantages	Capital Cost	Recurring Cost
Passive Samplers 	• Very low cost • Very simple • No dependence on electricity • Can be deployed in very large numbers • Useful for screening and mapping	• Unproven for some pollutants • In general, only provide monthly, weekly, and/or daily averages. • Labor-intensive deployment/analysis • Slow data throughput	$10-50 per sample	Analysis: $60-100 per parameter
Active Samplers 	• Low cost • Easy to operate • Reliable operation/ performance • Historical dataset	• Provide daily averages • Labour-intensive sample collection and analysis • Laboratory analysis required	~ $2,000 - $20,000 per unit	~ $4,000 – 30,000 (low to high volume sampling)
Automatic Analysers 	• Proven • High performance • Hourly data • On-line information	• Complex • Expensive • High skill requirement • High recurrent costs	~ $10,000 - $25,000 per analyzer	~ $10,000-100,000 or more (for continuous, automatic sampling and dependent on parameters covered)
Remote sensors 	• Provide path or range-resolved data • Useful near sources • Multi-component measurements	• Very complex and expensive • Difficult to support, operate, calibrate and validate • Not readily comparable with point data • Atmospheric visibility and interferences	~ $100,000 - $300,000 per sensor, or more	No data available

Sources: WHO/UNEP, 1994. GEMS/AIR Methodology Review Handbook Series, Volume 1. Quality assurance in urban air quality monitoring. Earthwatch Global Environment Monitoring System. World Health Organization, Geneva, United Nations Environment Programme, Nairobi. Images: Courtesy of Jon Bower, AEA Technology, Harwell, UK. Various sources compiled by Clean Air Asia.

5.5 Strengthen emission prevention and control and use of economic instruments

Measures to prevent and control emissions from different air pollutant sources contribute to achieving air quality targets and implementing CAAPs. These include optimizing the composition and growth of industrial plants and using stringent emissions standards and caps, especially for thermal power plants. Progressive Euro standards for fuel and new vehicles, and stronger vehicle inspection and maintenance systems for in-use vehicles can reduce emissions from transportation. Taxing polluting vehicles and restricting or banning the importation of second-hand motor vehicles can also assist in reducing transport emissions. Banning open burning and implementing interventions to prevent the burning of crop residue, including improving solid waste management, can reduce open source emissions. Shifting from biomass fuels to cleaner fuels for use in cooking and heating can reduce indoor air pollution. These and other measures are applied in Singapore (Box 5) and Kawasaki, Japan (Box 6).

Economic instruments such as taxes, levying penalties, differential pricing of fuels and energy source, and incentivization for greener options or investments are rarely used in Asian cities to manage air pollution. Subsidies to electric vehicles, penalties for emission violations and steeper parking fees are examples. There is a need to build a tool-box of economic instruments, gather application experience, contextualize the tools and pilot their application in some of the highly polluted cities in Asia.

Recommendation

Prioritize cost-effective pollution prevention and control actions and use of economic instruments to reduce emissions.

BOX 5

Air Quality Measures in Singapore

Singapore adopted controls on vehicle emissions through Euro 6/VI emission standards. It controls industrial emissions with industrial emission standards tighter than those of Europe and through reduction of SO_2 emission caps. Industries have to monitor and control emissions by continuous emission monitoring system (CEMS), and if failing to comply with standards, required to take emission reducing measures.

Singapore, through its Environmental Pollution and Management Act, promulgated strong and consistent legislation and strict enforcement of policies and measures to address air pollution. It applies the 'polluter pays principle' and reviews and regularly tightens industrial air pollutant emissions standards through international benchmarking, studies of fuels used, industrial processes, and levels of technology. Singapore adopted a phased implementation approach for emissions standards enforcement and also adopted internationally recognized test methods and protocols. Singapore uses WHO air quality guideline values as standards, except for PM and SO_2, where Singapore has set its own air quality standards to be met by 2020.

BOX 6

Air Quality Measures in Kawasaki

The Ordinance of Kawasaki City on Pollution Control, initially promulgated in 1972 and regularly updated and amended, sets environmental targets, total permissible emission levels for districts, and emission standards for plants within districts. It uses dispersion modeling to set emission limits.

Emissions are controlled by regulations on plants and workplaces, and on-site inspection of the facilities. An automatic monitoring system is used to measure the status of soot and smoke (emissions, temperature, flow rate, air pollutants). The municipal government checks the exhaust, processing and other facilities if an emissions monitoring record is kept.

The government concludes agreements with key industrial facilities on pollution prevention, which require the companies to develop an air pollution prevention plan, policies on response to an air pollution emergency, and report the amounts of fuels used and sulfur content, among others.

Since 1974, the total SO_x emission control for industries was applied and companies have complied with the SO_2 environmental standards by 1980. In 1978, the total NO_x emission control was introduced in the city's ordinance and in 1999 the Ordinance of Kawasaki City on Preservation of Living Environment Including Pollution Control was promulgated to promote, among other issues, a preventive approach for SO_2 and NO_x emissions.

In 2002, Kawasaki City enforced the emission standards of the Automobile NO_x Law, which was promulgated in 1998 and revised in 2007, and started to implement and enforce suspended particulate matter (SPM) comprehensive reduction measures, including enforcing emission standards for specified vehicle categories. Environmental standards for SO_2, NO_x, and PM have not been exceeded since 2013.

Kawasaki City runs an automatic air monitoring system with general monitoring stations, roadside stations, and source-related stations.

Institutional responsibility in Kawasaki City is mandated to one agency, the Environmental Policy Department in the Environmental Protection Bureau.

5.6 Integrate air pollution prevention and control into sectoral policies

Policies, plans, and programs of different agencies and sectors such as transport, power and energy, and industry can influence urban air quality (UNEP, 2017; Landrigan, 2017). Sectoral policies are general statements of intent that provide a framework for government decision making, outlining responsibilities and establishing procedures. In contrast, sectoral plans provide details on how to achieve policy goals/objectives, while sectoral programs outline coordinated and interrelated activities that are implemented to meet specific objectives.

The sector policy cycle can involve seven distinct stages: agenda setting, consultations, formulation, legitimation, implementation, assessment and formulation, and termination (Koojo Amooti, 2006). Each stage offers an opportunity for integrating air pollution prevention and control issues.

Emissions from three key sectors affect air quality: transport, power and energy production, and industry (including agriculture). These include emissions from individual sites such as large-scale industrial activities, transport routes, and diffused sources such as agriculture.

Strategic environmental assessment (SEA) of policies, plans, and programs can integrate AQM into urban development. SEA provides a systematic, rigorous, and consistent framework with which to assess environmental impacts of air pollution. The level of detail appropriate for the SEA objectives depends on the characteristics of the PPPs being assessed and the potential significance of its environmental effects (Scottish Government, Strategic Environmental Assessment Guidance).

Hong Kong, China was one of the first Asian countries to apply SEA to major development plans including territorial development, transport, waste, and energy. For example, the application of SEA to a railway development strategy assessed the environmental effects (including air and noise pollution) of providing rail instead of roads. Environmental opportunities and constraints were identified for input into the formulation of corridors. The SEA outlined more than 60 potential links and alternatives for evaluation (Hong Kong EPD, 2017).

The application of SEA in Hong Kong, China has provided decision-makers with key information on potential environmental impacts of air pollution arising from proposed developments. The SEA process has influenced the formulation and selection of strategies and regional development resulting in greater accountability and transparency in the decision-making process and environmental protection (Ng and Obbard, 2005).

Indonesia, South Korea, and Viet Nam also have SEA legislation, while countries such as Japan and Pakistan have voluntarily implemented elements of SEA, such as public participation without legislative provisions. However, challenges have impeded SEA implementation (e.g., level of public participation). The SEA process can provide a strategic and rational approach to integrating air pollution prevention and control into urban development, in practice. The SEA process requires political will, a legislative framework and a transparent stakeholder engagement process within the cultural context of each Asian country (Victor and Agamuthu, 2014).

Recommendation

Strategic Environmental Assessments can be used to integrate air pollution prevention and control into policies, plans, and programs.

BOX 7

Advantages of Strategic Environmental Assessment

Better environmental protection: SEA can identify environmental impacts and help the planners avoid potential air pollution problems by proposing alternative solutions.

Improved plans: SEA can help planning more systematic and evidence-based plans by providing meaningful environmental information.

Providing insights: SEA can offer a different perspective to planners by looking at air pollution from an environmental perspective.

Exploration of 'reasonable alternatives': SEA can be a source of creativity for planners by considering reasonable alternatives to tackling air pollution and secure benefits beyond the environment.

Enhanced communication and transparency: SEA can help enhance public understanding on the effects of air quality and improve transparency in decision-making through systematic reporting.

Reduced long-term costs: An effective SEA can minimize remedial actions by helping to avoid unforeseen air pollution effects.

Source: Scottish Government (2013)

5.6.1 Transport

Sustainable Urban Mobility Plans (SUMPs) have been used to integrate air pollution issues into the transport sector. These plans have been applied in the EU to improve accessibility in urban areas while providing high quality and sustainable urban mobility and transport to meet the needs of a 'functioning city' rather than a municipal administrative region (EC, 2017).

Plans such as SUMPs have been credited with being able to address several objectives (e.g., reduced air pollution, improved safety and quality of life, and economic growth) as well as engaging citizens and changing the planning process. For example, large transport infrastructure schemes often provide lower value for money while smaller local schemes (e.g., traffic calming, local roads and cycle ways) can generate more jobs (Rye, 2015).

In cooperation with citizens and other stakeholders, SUMPs are developed across different policy areas and sectors, and across different levels of government and administrations. They include measures such as integrated planning, urban logistics, collective transport, clean fuel and vehicles, intelligent transport systems, safety and security and mobility demand management. All these contribute to an integrated transport system, which improves quality of life and wellbeing.

Several tools are available to assist in developing urban mobility measures (e.g., clean fuels and vehicles, urban freight, demand management strategies, mobility management, collective passenger transport and transport telematics) (EC, 2009). For example, the Transport Emissions Evaluation Models for Projects (TEEMP) could be used to measure the emissions benefits of different transport projects. The TEEMP is a suite of excel-based, free-of-charge, spreadsheet models and methods that can be used to evaluate the GHG, air pollution, and other impacts of many types of transportation projects (Clean Air Asia, ITDP, et al., 2015).

Another tool that could be used to identify urban mobility measures is the Rapid Assessment of City Emissions (RACE) from transport and energy. This is a tool that estimates PM, NO_x, and CO_2 emissions from urban transport and energy use. The tool uses the Activity-Structure-Intensity-Fuel methodology that calculates transport emissions for different scenarios and identifies priorities for intervention in cities (Clean Air Asia, 2015).

BOX 8

Transportation Control in Singapore

Since 1975, the Government of Singapore has introduced a series of traditional and experimental measures to slow down the growth of motor vehicle population and to control its usage. These include an area licensing system and general price restraints, a quota system on new cars, a weekend car scheme, and an electronic road pricing (ERP) system (Phang and Toh, 2004). The various policies adopted by the Singapore government to reduce traffic congestion and pollutant emissions have been largely successful because they are based on integrated city planning.

Other countries can profit from the Singapore experience (Institute for Global Environmental Strategies, 2007) through:

- Periodical adjustment of policies using feedback from the public and other stakeholders, made possible by transparency in policy formulation. Singapore has learned by doing. For example, ERP charges are subject to review every three months, and charge structures and times change depending on traffic and economic conditions.
- Investments in infrastructure. Demand-side management supplemented construction of additional road infrastructure, proper road maintenance, coordination of traffic-light systems, and building of expressways and mass rapid transit. The taxes and fees imposed on vehicles generated huge financial resources, which were not only invested in demand- and supply-side management but also applied to reducing less-desirable taxes.
- Technology factors play an important role. The ERP system, for example, depends on sophisticated technology that allows time-of-day pricing that reflects traffic conditions. A computerized traffic control system was already in place by 1986 in central business districts. It was replaced with a more advanced automated traffic signaling system called 'Green Link Determining System', a traffic-adaptive signal control system monitored centrally to adjust to changing traffic conditions.

Source:
Phang and Toh. 2004. Road Congestion Pricing in Singapore: 1975-2003.
IGES. 2007. De-coupling of urban mobility need from environmental degradation in Singapore.

Other tools include the OpenEI Transport Assessment Toolkit[23] that assists national, regional, and local governments plan the development of economically and environmentally sustainable transport system (OpenEI, 2017). The toolkit prescribes five steps: gathering transport-related data and information, setting goals and objectives, evaluating and selecting options, creating an implementation plan, and enforcing the plan.

Finally, the California Air Resources Board's Local Government Toolkit provides a one-stop-shop of guidance and resources to assist local governments to reduce GHG emissions relating to actions on energy efficiency and conservation, renewable energy, green transportation, and other environment-related actions (California Air Resources Board, 2017).

Recommendation

Use the sustainable urban mobility plans and frameworks and existing transport tools to develop effective measures that reduce emissions from the transport sector.

5.6.2 Power and Energy

Energy plans are developed at a national level and provide an economic response to meeting the projected electricity demand by outlining a mix of energy sources (e.g., thermal, hydropower, renewables) and energy efficiency measures. Power plants usually have a 20-year vision with 10- and 5-year planning horizons. National policies such as the promotion of renewable energy, energy efficiency and conservation, power import and export, and environmental concerns may be reflected in the process, but only to a limited extent. Environmental and social impacts and their costs need to be factored into planning, choice of technology, and locations of power plants.

Sustainable Energy Action Plans (SEAPs) have been used by the Covenant of Mayors initiative to achieve emission reductions. These plans use the results of the baseline EI to identify areas for action and opportunities for reaching the local authority's CO_2 reduction target. It defines concrete reduction measures, together with timeframes and assigned responsibilities, which translate the long-term strategy into action (EC JRC, 2014). Measures cover residential, industrial, and transport sectors such as promoting energy and vehicle efficiency measures and low carbon and renewable energy and fuels. This has potential co-benefits by improving local air quality and reducing GHG emissions.

The SEAP and the SUMP provide examples of frameworks that allow city authorities to take an integrated approach to emissions reduction outlining measures that can have significant impacts on reducing air pollutant emissions. SEAPs have the potential to achieve a 25% reduction in CO_2 emissions (Croci et al., 2017).

Recommendation

Use the sustainable energy plan framework to identify opportunities to reduce power and energy sector emissions and address poor air quality and SLCPs.

5.6.3 Industry

More extensive and intensive industrial use of materials and energy has created cumulative pressures on air quality at the local and regional levels. While the application of pollution control measures by some countries have been successful in controlling local air pollution, they have been less successful at the regional or global level (e.g., acid rain, tropospheric O_3 growth and climate change).

Pollution prevention is emerging as a preferred strategy in developed countries, central to implementing the shift to sustainable development. The pollution prevention approach focuses directly on the application of best available control technologies with respect to processes, practices, materials, and energy. These can deliver emissions and cost savings. For example, improved pipeline insulation in one US energy company resulted in a reduction in natural gas use and air emissions saving equivalent to 95 metric tons of CO_2 equivalent (US EPA, 2014).

As environmental pollution control technologies become more sophisticated and expensive, there has been a growing pressure to incorporate prevention in the actual design of industrial processes. However, corporate commitment plays a critical role in the decision to pursue pollution prevention.

Recommendation

Promote air pollution prevention integration into sectoral policies by highlighting the economic and environmental benefits.

5.6.4 Land Use

Air pollution is connected to land-use and transport, including issues such as community planning, road

[23] OpenEI is developed and maintained by National Renewable Energy Laboratory with funding and support from the US Department of Energy and a network of international partners and sponsors.

design, traffic control, and mass public transport. Demography, topography, and economic and social concerns can all influence decisions that might affect air quality (Schwela and Goelzer, 1995).

Land-use planning for air pollution control includes zoning codes and performance standards, land-use controls, housing and land development, and land-use planning policies. Land-use zoning was the initial attempt to accomplish protection of the people, their property and their economic opportunity. However, the ubiquitous nature of air pollutants requires more than physical separation of industries and residential areas to protect the individual.

Long-term land-use planning requires identifying the assimilative capacity of the environment. Then, land-use controls can be developed to prorate the capacity equitably among desired local activities. Land-use controls include permit systems for review of new stationary sources, zoning regulation between industrial and residential areas, restriction by easement or purchase of land, receptor location control, emissions-density zoning and emissions allocation regulations.

New housing developments should be integrated simultaneously with the development of efficient transportation systems to ensure the travel needs of new communities are met. This requires coordinated and integrated land use approach.

Land-use planning must be examined at national, provincial or state, regional and local levels to adequately ensure long-term protection of the environment. Governmental programs usually start with power plant siting, mineral extraction sites, coastal zoning and desert, mountain or other recreational development. As the multiplicity of local governments in a region cannot adequately deal with regional environmental problems, regional governments or agencies should coordinate land development and density patterns by supervising the spatial arrangement and location of new construction and use, and transportation facilities. Land-use and transportation planning must be interrelated with enforcement of regulations to maintain desired air quality. Ideally, air pollution control should be planned by the same regional agency that does land-use planning because of the overlapping externalities associated with both issues.

Recommendation

Move towards greater integration of air pollution issues into land use planning.

5.7 Enforce Air Quality Laws and Regulations

Enforcement of emissions control regulations is needed to ensure industries, power plants, motor vehicles, and other sources (e.g., open burning, construction sites) meet the emissions limits set in standards. The traditional methods for government to monitor compliance by industry with emissions standards include stack monitoring, requiring industry to report emissions, and mandating the set-up of continuous emissions monitoring systems. In Europe (Box 9) and the US (Box 10) a specific procedure has been adopted when cities or states fail to meet air quality limits. In addition, there is a range of methods available to monitor compliance from different sectors (Appendix III).

The four cities and countries examined here have specific enforcement challenges.

In Chengdu, the linkage between specific control measures to reduce emissions and the effects of these measures on human health and the environment is not understood. This is due to the lack of studies on the impacts of air pollution on human health and the environment. In order to ensure that enforcement of control measures leads to avoidance of human health and environmental impact, the capacity to study such impacts needs to be raised.

Another challenge in Chengdu is the failure to undertake an EIA before launching construction projects. Without EIA there are no recommendations for the environmental sustainability of a project.

In Xiangtan, different agencies are responsible for the enforcement of Environmental Laws.

For example, the Municipal Bureau of Urban Management and Law Enforcement is responsible for controlling road dust, cooking fume pollution, open fires, and waste incineration, the Municipal Bureau of Environmental Protection is responsible for controlling emissions from coal-fired enterprises, and other municipal bureaus are responsible for dust control at construction sites. These environmental issues overlap and it is unclear if an overarching bureau is responsible for controlling particulate matter in its totality.

An integrated plan for the enforcement of air quality standards should be developed in the PRC. The MEP and the provincial governments are authorized to enforce emissions standards, but cities enforce the Special Limitation for air pollutants. The enforcement of energy saving and environmental protection in market entrance requirements in the ten National Measures of the Action Plan should be integrated.

The Action Plan also requires streamlining the responsibilities among different MEP departments to facilitate AQM. It is necessary to enhance the responsibility of other government agencies regarding AQM and to delegate the responsibility to provincial and local governments to "better engage and involve emitters and the general public". For these reasons, the tenth measure of the Action Plan encompasses the definition of responsibilities and engagement with government, private sector, and the public for environmental protection and delineation of a clear hierarchy of responsibilities at the national, provincial, and local levels.

The 10 National Measures of PRC's Action Plan:

- Reduced emission of multi-pollutants;
- Promotion of industry upgrades and restructuring;
- Acceleration of companies' technology upgrading;
- Acceleration of energy restructuring;
- Enforcement of energy-saving and environmental protection in market entrance requirements;
- Application of market-oriented instruments and environmental economic policies;
- Improvement of the legal framework, implementation and enforcement;
- Establishment of regional collaboration mechanisms;
- Establishment of monitoring, alerting and emergency response systems for air pollution episodes; and
- Definition of responsibilities and engage with government, private sector and the public for environmental protection.

In Nepal, enforcement is addressed with respect to national emission standards but it remains unclear which agency is responsible for their enforcement.

There is a need in Metro Manila to enforce more stringent emission standards for two- and three-wheelers. The city report also emphasizes the need to improve coordination between national government agencies and LGUs in program implementation/enforcement. The EMB is primarily responsible for the enforcement of policies and regulation relating to stationary sources, but the LGUs also implement systems that aim to manage emissions from stationary sources. It is unclear which of the two agencies has the overall responsibility. In addition, the DENR "is expected to undertake activities that provide policy, program, and technical support to LGUs, specifically to enforce pollution control and environmental protection laws, rules, and regulations." Therefore, the roles of the DENR, EMB, and LGUs do not appear to be defined with respect to their responsibility for enforcement.

The EMB and its Air Quality Management Section and Environmental Compliance Assistance Center are the primary government agencies responsible for the enforcement of the Clean Air Act. More than 10 other government agencies are also mandated to support the Clean Air Act, and the Inter-Agency Committee on Environmental Health (IACEH) was created to harmonize policies and programs that intend to safeguard environmental health. It is not clear if a transparent hierarchy exists among the various agencies. The creation of 'airshed' governing boards and defining their functions need to be enforced.

In Thailand, law enforcement is important to facilitate policy implementation and needs strengthening. In particular, stakeholder involvement is required to enforce the ban on open burning of crop residues and municipal solid waste. Moreover, added measures to control fugitive VOC emissions from existing industries also need to be enforced. The coordination among government offices dealing with traffic/automobile industry and air quality should be strengthened to avoid tradeoff of air quality and the sale of motor vehicles.

Recommendation

Strengthen capacities to enforce existing and air pollution laws and regulations using innovative methods and proven procedures.

BOX 9

Air Quality Enforcement Procedure in the European Union

In the EU, Directive 2008/50/EC sets strict limit values on air pollutant concentrations for SO_2, NO_2, PM_{10}, $PM_{2.5}$, CO, C_6H_6, and Pb. A 'limit value' is defined as "a level fixed on the basis of scientific knowledge, with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole, to be attained within a given period and not to be exceeded once attained". For O_3 the Directive sets a target value that has a more lenient definition.

EC Directive 2004/107/EC sets target values for arsenic, cadmium, mercury, nickel, and BaP. A 'target value' means "a concentration in the ambient air fixed with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole, to be attained where possible over a given period."

Law enforcement relies on a monitoring and reporting system to inform the European Commission (EC) and the public. Due to air quality monitoring uncertainties, some air pollutant concentrations, notably $PM_{2.5}$, NO_x, O_3, and BaP temporarily do not comply with their respective limit or target values in the majority of Member States. However, only a few Member States exceed air quality limits (i.e., the lower 95% confidence levels are above the limit or target values in only a few countries) (EEA, 2017; Gemmer and Xiao, 2013). If an EU Member State exceeds a limit or target values, the EC can set a fine in order to enforce non-exceedance.

Sources:
EEA. 2017. Exceedance of air quality standards in urban areas. 20 October 2017.
Gemmer and Xiao. 2013. Air quality legislation and standards in the European Union: Background, Status and Public Participation.

BOX 10

Air Quality Enforcement Procedure in the USA

In the US, sanctions and consequences of failure to attain NAAQSs in a SIP are regulated in 42 U.S. Code § 7509 (Cornell Law School Legal Information Institute, 2017). If the US EPA:

- finds that a State has failed, for a non-attainment area to submit a SIP or to submit one or more of the elements applicable to such an area, or has failed to make a submission for such an area that satisfies the minimum criteria established in relation to any such element, or
- disapproves a SIP for an area designated nonattainment, based on the submission's failure to meet one or more of the elements applicable to such an area, or
- finds that any requirement of an approved SIP is not being implemented and enforced within a fixed time period.

One of the following two sanctions are applied:

- Highway sanctions: The US EPA may impose a prohibition, applicable to a non-attainment area, of any projects or the awarding of any grants, except for projects related to the safety of or reduction of accidents on highways, capital programs for public transit, and other transportation-related programs specified in the code.
- Offset sanctions: In applying the emissions offset requirements to new or modified sources or emissions units for which a permit is required, the ratio of emission reductions to increased emissions shall be at least two to one.

Within a year after the US EPA publishes the notice of failure to attain, each State containing a non-attainment area shall submit a revision to the SIP meeting the requirements prescribed by the law and as the US EPA may reasonably prescribe.

Notes:
NAAQS: National Ambient Air Quality Standard; SIP: State Implementation Plan/s; US EPA: United States Environmental Protection Agency.

5.8 Secure adequate financial resources

Having adequate financial resources to implement the different components of an integrated AQM system is essential. This requires national governments to recognize that air pollution is a priority and allocating the appropriate level of funding, implementing the polluter-pays principle, and allocating emissions fees to air pollution prevention and control are required.

The PRC provides approximately $1.4 billion per year to provinces and cities for AQM. The local government of Chengdu has allocated around $70 million per year for AQM. The human resource for AQM is not enough for most cities, but not mainly because of budget but quota limitation of government staff.

The Nepalese government has allocated around $74 million for programs related to environmental conservation including installation of air quality monitoring stations.

The Clean Air Act of the Philippines has stipulated that an AQM Fund (AQMF) should be established to support AQM activities at the national and 'airshed' levels. The Philippine government also established the Special Vehicle Pollution Control Fund (SVPCF) to support transport emissions reduction initiatives covering vehicle standards and regulations, vehicle pollution control research, education, training and public information, vehicle pollution management, and alternative vehicle pollution control and technology (Transport and Climate Change, 2015). However, most funds from the SVPCF currently remain undisbursed due to lack of clear guidelines for accessing the fund.

In Kawasaki City, financing is provided by the national, provincial and municipal governments.

In Beijing, funding is available from the national government, but non-financial barriers, such as regulatory and other barriers related to the private sector, inhibit the flow of funds.

Public-private partnerships[24] have the potential to develop projects that address aspects of AQM, including air quality monitoring or vehicle testing. Public-private partnerships can provide the "basic physical and organizational structures" needed to make government AQM possible. AQM functions transferred to the private party – such as design, construction, financing, operations, and maintenance – make the private sector accountable for project performance and bears significant risk and management responsibility. Risk transfer is instrumental for full transfer of management responsibility and for the alignment of private interests with public interest (World Bank, 2017). An example of a public-private partnership relevant to air pollutant emission reduction is the Energy Services Company (ESCo) financing model[25] for energy savings at municipal, university, school, hospital, industrial and commercial buildings (USDoE, 2017). It could be advantageous for Asian countries to explore such a public-private partnership model to access funds and human resources to improve AQM. The PCD of Thailand's experience in subcontracting air quality monitoring operations is a good example (Box 3 in Chapter 4).

International donors have been important sources of funding for air pollution reduction in Asia and have funded air quality monitoring, capacity building and research projects. For example, ADB funded the Sustainable Urban Transport Project in Kathmandu, and the Institute for Advanced Sustainability Studies (IASS) is financially supporting the Sustainable Atmosphere for Kathmandu (SusKat) research project. However, each donor has different funding priorities and interests. Greater coordination among funders is necessary to ensure adequate funding is available for all aspects of AQM and to ensure long-term sustainability of the initiative when funding has ceased. National government agencies should be involved in the development of funding initiatives. Information on funding opportunities should be made available to national governments and city authorities.

The WHO and CCAC Urban Health Initiative are working to improve air quality in cities and countries to reduce the health burden and health costs from air pollution-related diseases and support sustainable growth. Actions to reduce air pollution can also bring added climate benefits, as many of the air pollution sources are also heavy emitters of short-lived climate pollutants (SLCPs), such as black carbon and methane, as

[24] There is no single, universal definition of public-private partnership. The public-private partnership reference guide defines it as (World Bank Group, 2017): A long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility and remuneration is linked to performance.

[25] In the ESCo financing model an ESCo concludes an energy savings contract with a property owner, in which the ESCo achieves energy savings at a property or portfolio of properties as a service. An ESCo charges the property owner a fee to deliver energy savings on the owner's utility payments. This model guarantees savings for a set period of time in exchange for payment from the energy costs savings (USDoE, 2017).

well as carbon dioxide. Over the next five years, the Urban Health Initiative aims to increase public demand for action to reduce SLCPs and other air pollutants. At the same time the initiative is supporting national, city and subregional efforts to improve air quality, strengthening capacity of the health sector, and creating health and cost evidence for rapid mitigation action.

BreatheLife is a Climate and Clean Air Coalition initiative led by the WHO and UN Environment to raise awareness about the health and climate benefits from improving air quality, and promote solutions to mitigate short-lived climate pollutants and other air pollutants. BreatheLife shares stories of success, and examples of actions, from a growing number of 42 cities, regions and countries representing more than 94 million citizens in the BreatheLife Network. Key messages are shared through videos and infographics. For more information: http://breathelife2030.org/

ADB support for AQM is founded on three pillars: support for developing a policy and regulatory framework, promotion of the implementation of advanced technology, and mobilizing funds for 'green projects'. Green projects include biomass power generation, waste heat capture and delivery for district heating, energy saving and domestic emission reduction, smart transport and electric vehicles, application of ESCo models for SMEs, and installation of rooftop photovoltaic facilities.

The support works via a 'Green Financing Platform' that helps activate innovative financing tools, leverage domestic financing, and enhance local financial institutions' capacity and willingness to provide funds for green projects. The green financing platform helped in the promotion of high technology for major polluting sources in the Beijing-Tianjin-Hebei region including projects such as advanced biomass generation; fuel cell transport infrastructure; intelligent low-emission industrial park development; cleaner transport fuels; deep-well geothermal heating; and reduction of fossil fuel emission throughout the supply chain.

Apart from loans, funds also came from large ESCo–type public-private partnership approaches and were facilitated by PRC's Guarantee Fund Program. This approach shows that private investments and commercial financing are possible in an inclusive financing framework and a targeted comprehensive solution (Lu, 2017).

Recommendation

Countries should prepare comprehensive investment programs for AQM, including public-private partnership models in order to ensure appropriate funding for AQM.

5.9 Way Forward

Economic development considerations have guided urban development in Asian cities. Concerns about environmental deterioration and air pollution have often had to take second place. This has resulted in a management approach with a heavy emphasis on technological solutions and limited attention for preventive approaches.

As illustrated in the four countries and four cities examined in this study, many Asian countries face common challenges in tackling deteriorating air quality in cities. However, Asian countries can gain from sharing experiences and learning about success stories in Asia as well as from outside the region.

An integrated approach to AQM is required to manage better air quality in Asia. This has to be comprehensive and provide direction on setting air quality priorities and providing institutional development and capacity enhancement. The Guidance Framework for Better Air Quality in Asian Cities (Clean Air Asia, 2016) outlines such an approach.

By adopting an integrated approach to AQM some of the common challenges highlighted here can be addressed. This requires achieving a balance among planning, prevention, control, and enforcement[26] as described in the recommended actions:

a. Develop clean air action plans with clear objectives, roles and accountability,
b. Tighten ambient air quality standards,
c. Increase political and public awareness of air pollution impacts,
d. Enhance technical capacity in key aspects of integrated AQM,
e. Strengthen enforcement of air pollution laws and regulations and use of economic

[26] ***Planning:*** *Use clean air action plans, sustainable urban mobility plans, sustainable energy action plans and strategic environmental assessment to provide the framework to integrate air quality into urban development.* ***Prevention:*** *Raise stakeholder awareness of the social, economic and environment benefits from air pollution prevention to gain support for AQM measures.* ***Control:*** *Enhance technical capacity to understand and monitor air emissions from different sources.* ***Enforcement:*** *strengthen capacity to enforce air pollution regulations.*

instruments,

f. Integrate air pollution prevention and control into sectoral policies, plans and programs, and
g. Secure adequate financial resources.

For Asian cities to be able to meet air quality goals, they should further integrate air pollution issues into sectoral planning. This is needed to revitalise Asian cities and provide a liveable urban environment where every citizen can breathe clean air.

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Appendix I: Health Impacts of Air Pollutants

Air Pollutant	Potential Health Impact
Particulate matter (PM_{10})	Exposure to particles of aerodynamic diameter less than 10 µm can pose a variety of problems, including[29]: • Decreased lung function • Increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing • Irregular heartbeat • Nonfatal heart attacks • Aggravated asthma • Emergency department visits • Hospital admissions for cardiovascular or respiratory diseases • Premature death in people with heart or lung disease. People with heart or lung diseases, children, and older adults are the most likely to be affected by particle pollution exposure.
Sulfur dioxide (SO_2)	Short-term exposures to SO_2 can affect the human respiratory system and make breathing difficult. Children, the elderly, and asthmatics are particularly sensitive to effects of SO_2[30].
Ozone (O_3)	Short-term inhalation exposure to O_3 can cause the following impacts[31]: • Difficulty to breathe deeply and vigorously. • Shortness of breath, and pain when taking a deep breath. • Coughing and sore or scratchy throat. • Inflame and damage the airways. • Aggravate lung diseases such as asthma, emphysema, and chronic bronchitis. • Increase the frequency of asthma attacks. • Make the lungs more susceptible to infection. • Continue to damage the lungs even when the symptoms have disappeared. • Chronic obstructive pulmonary disease (COPD). • Increased school absences • Increased medication use, visits to doctors and emergency rooms, and hospital admissions • Increased mortality. Long-term exposure to O_3 can aggravate asthma, and is likely to be one of many causes of asthma development. Long-term exposures to higher concentrations of O_3 may also be linked to permanent lung damage, such as abnormal lung development in children, and may increase the risk of death from respiratory causes.
Nitrogen dioxide (NO_2)	Short-term inhalation exposure due to a high concentration of NO_2 can irritate human airways and aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency departments. Long-term exposures to elevated concentrations of NO_2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. Asthmatics, as well as children and the elderly are generally at greater risk for the health effects of NO_2[32].
Carbon monoxide (CO)	Inhalation exposure to high concentration of CO reduces the amount of oxygen that can be transported in the blood stream to critical organs like the heart and brain. It can also cause dizziness, confusion, chest pain, unconsciousness, and death. Such levels can be of particular concern for people with some types of heart disease, reduced ability for getting oxygenated blood to their hearts in situations when exercising or under increased stress[33].
	exercising or under increased stress[33].

[29] US EPA. 2017. *Health and Environmental Effects of Particulate Matter.*
[30] US EPA. 2017. *Sulfur Dioxide Pollution*
[31] US EPA. 2017. *Health Effects of Ozone Pollution*
[32] US EPA. 2017. *Effects of NO2.*
[33] US EPA, 2017. *Carbon Monoxide Pollution in Outdoor Air*

Air Pollutant	Potential Health Impact
Benzene (C_6H_6)	Short-term inhalation exposure of humans to C_6H_6 may cause drowsiness, dizziness, headaches, as well as eye, skin, and respiratory tract irritation. At high levels, C_6H_6 can cause unconsciousness. Long-term inhalation exposure can cause various disorders in the blood such as reduced numbers of red blood cells, and leukemia (cancer of the tissue that form white blood cells) in humans occupationally exposed to C_6H_6[34].
Arsenic (As)	Short-term inhalation exposure to high levels of As dust or fumes can cause gastrointestinal effects such as nausea, diarrhea and abdominal pain. Inorganic As compounds can cause peripheral nervous system disorders in occupationally exposed humans. Long-term inhalation exposure to inorganic arsenic compounds can lead to irritation of the skin and mucous membranes, effects in the brain and gastrointestinal system, anemia, peripheral neuropathy, skin lesions, hyperpigmentation, liver or kidney damage, and lung cancer. Ingestion of inorganic As compounds can cause skin, bladder, liver, and lung cancer[34].
Cadmium (Cd)	Short-term inhalation exposure to Cd compounds may cause pulmonary irritation. Long-term inhalation or oral exposure can cause kidney disease[34].
Chromium (Cr)	Short-term inhalation exposure to Cr^{VI} compounds can cause shortness of breath, coughing, and wheezing. Long-term inhalation exposure to Cr^{VI} compounds can cause perforations and ulcerations of the septum, bronchitis, decreased pulmonary function, pneumonia, and lung cancer[34].
Lead (Pb)	Inhalation and ingestion exposure of Pb compounds can cause effects on the blood, as well as the nervous, immune, renal and cardiovascular systems. Early childhood and prenatal exposures are associated with slow cognitive development and learning deficits. Ingestion exposure to high amounts of lead can cause gastrointestinal symptoms, severely damage the brain and kidneys, and may cause reproductive effects[34].
Mercury (Hg)	Short-term exposure to high levels of elemental Hg can result in central nervous system (CNS) effects such as tremor, mood changes, and slowed sensory and motor nerve function. Long-term exposure to elemental Hg can affect the CNS, with effects such as increased irritability, excessive shyness, and tremors. Short-term ingestion exposure to inorganic Hg compounds may result in effects such as nausea, vomiting, and severe abdominal pain. Long-term exposure to inorganic Hg compounds can cause kidney damage[34]. Short-term exposure to methyl mercury can cause CNS effects such as blindness, deafness, and impaired level of consciousness. Long-term exposure to methyl mercury can affect the CNS with symptoms such as a sensation of pricking on the skin, blurred vision, malaise, speech difficulties, and constriction of the visual field. Ingestion exposure of methyl mercury of pregnant women to high levels of methyl mercury can cause mental retardation, ataxia, constriction of the visual field, blindness, and cerebral palsy in newborn children[34].
Nickel (Ni)	Short-term inhalation exposure to Ni can cause respiratory effects. Long-term inhalation exposure to Ni compounds (Ni refinery dust and Ni subsulfide) may result in an increased risk of lung and nasal cancers[34].

[34] *US EPA, 2017. Health Effects Notebook for Hazardous Air Pollutants.*

People's Republic of China (PRC)

Capital: Beijing

GENERAL INFORMATION

Total Population: 1,378,665,000 (2016)[1]

Urban Population: 782,778,414 (2016)[2]

Percent Urbanization by 2050: 79%[3]

Energy use: 2,237 kg of oil equivalent/capita (2014)[4]

Fossil fuel energy consumption: 87.5% (2014)[5]

Dominant energy sources:
coal (72%), hydro (19.3%)[6]

Total Vehicle Population: 303,835,500 (2015)[7]

Vehicle Population Percent Increase: 54% (2012-2015) [8]

No. of cars: 268,331,100 (2015)[9]

No. of trucks: 33,962,700 (2015)[10]

No. of 2-3 wheelers: 1,541,700 (2015)[11]

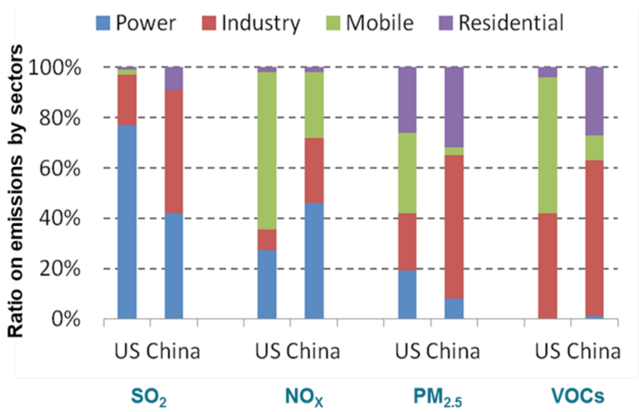
Motorization Index: 222 vehicles per 1000 persons (2015)[12]

Road sector diesel fuel consumption:
115,099 kt of oil equivalent (2012)[13]

AIR QUALITY STATUS and POLLUTION SOURCES

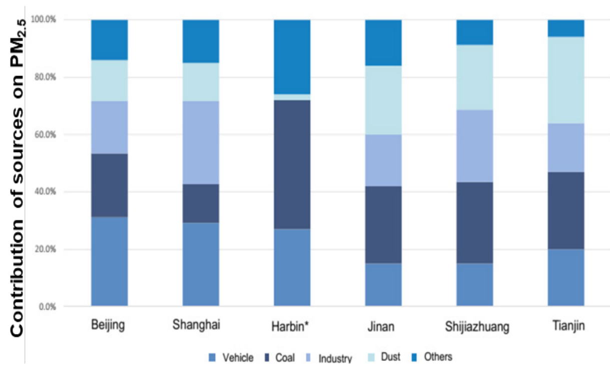
- PRC remains to be the largest emitter of major air pollutants (SO_2, NO_x, primary PM, VOCs and NH_3), with total SO_2 and NO_x emissions at 17.5 and 17.8 million tons, respectively in 2016. Emission inventories for $PM_{2.5}$ and VOCs were estimated at approximately 12 and 30 million tons, in separate studies conducted by Tsinghua University and Peking University in 2015.
- Although PRC has significant air pollutant emissions, efforts to mitigate major pollutants, such as SO_2 and NO_x, have been effective. During the 12th FYP, both SO_2 and NO_x emissions were reduced by 18%, which was significantly higher than the five-year targets of 8% and 10%, respectively.
- Industrial sources, such as iron and steel, cement, chemical, and nonmetal mineral product industries contributed the highest levels of SO_2, primary PM, NO_x, and VOC emissions in 2015 for the PRC.

SHARES OF EMISSIONS FROM DIFFERENT SECTORS IN THE PRC (2015)



Source: Tsinghua University in: MEIC, 2015[14]

EMISSION PROFILE FOR PM2.5 IN VARIOUS CITIES IN THE PRC (2015)



Source: City EPBs, Compiled by Clean Air Asia in 2015[15]

AIR QUALITY MANAGEMENT

National Environmental Agency: Ministry of Environmental Protection

- The Chinese government revised its Ambient Air Quality Standards (AAQS), specifically GB3095-2012 in 2012 to include a standard for $PM_{2.5}$ and set a more stringent standard for PM_{10} and NO_2.
- Earlier in 2013, China's State Council released an Action Plan on Fighting Air Pollution which aims to cut the density of inhalable particulate matter in major cities by 10% by 2017. In 2012, its National Development and Reform Commission issued a notice on coal fired plant rehabilitation.[16]
- In 2014, Chinese legislators passed an amendment to the country's Environmental Protection Law, the first in 25 years, which includes heightened consequences for violating PRC's environmental laws, expanded scope of projects subject to environmental impact assessment requirements and allowing non-governmental organizations to take legal action against polluters on behalf of public interest.
- The Law on the Prevention and Control of Air Pollution was also amended in 2015, which included an increased accountability of provincial and local governments on air quality compliance, an emission permit system for managing the emissions of stationary sources; and authorizing and requesting the government to regulate the transportation system and fuel quality to boost emission control from mobile sources.
- Recently, the country has carried out the Action Plan for Prevention and Control of Air Pollution and the Reinforced Action Plan for Prevention and Control of Air Pollution in Beijing-Tianjin-Hebei Region (2016-2017). [17]
- The PRC has also developed the Action Plan "10 National Measures", implemented since 2013, which comprises the country's 10 National Measures for climate change mitigation. The central government has also provided 10 million RMB for the implementation of the program, whereas the local governments have also provided additional funding to encourage the emitters to retrofit or replace their devices, subsidize the additional cost for better-quality coal or cleaner energy and support scientific studies. An additional amount of RMB 10.6 billion in 2015 was given as a special fund for air pollution prevention and control. Another RMB 11.2 billion was allocated in 2016 to support the implementation of the action plan in key regions.[18]
- The Ministry of Environmental Protection published the Programme of Comprehensive Control of Volatile Organic Compounds in Petrochemical Industry in order to encourage the reduction of VOC emissions.
- In 2016, the 13th Five-Year Ecological Environmental Protection Plan included VOCs in its total emission indicators.

AIR QUALITY STANDARDS

Pollutant (μg/m^3)	China Grade I	China Grade II
Annual SO_2	20	60
24-hr SO_2	50	150
Annual NO_2	40	40
24-hr NO_2	80	80
Annual PM_{10}	40	70
24-hr PM_{10}	50	150
Annual $PM_{2.5}$	15	35
24-hr $PM_{2.5}$	35	75
24-hr CO	4,000	4,000
8-hr O_3	100	160

Source: Guobiao Standards (GBS) 3095-2012[19]
*National Implementation in 2016

AIR QUALITY MONITORING

Number of Cities with Air Quality Data
338

Source: Ministry of Environmental Protection

AIR QUALITY INDEX (AQI)

AQI	Numerical Value
Good	0 to 50
Moderate	51 to 100
Lightly Polluted	101 to 150
Medially Polluted	151 to 200
Heavily Polluted	201 to 300
Severely Polluted	301 to 500

Source: GBS 3095-2012[20]

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19. Guobiao Standards 3095-2012
20. (footnote 19)

Nepal

Capital: Kathmandu

GENERAL INFORMATION

Total Population: 28,982,771 (2016)[1]

Urban Population: 5,505,277 (2016)[2]

Percent Urbanization by 2050: 36%[3]

Energy use: 413 kg of oil equivalent/capita (2014)[4]

Energy Consumption Status: 8257 TOE (2016/17) [5]

Dominant energy sources: Traditional (74.5%), Commercial (22%) Renewable (3.5%)[5]

Petroleum Products energy consumption: 1,139 TOE (2016/17)[5]

Coal Consumption: 332 TOE (2016/17)[5]

Total Vehicle Population: 2, 602,986 (2016/17)[5]

No. of cars/Jeep/Van: 209,199 (2016/17)[5]

No. of trucks/Crane/Dozer/Excavator: 75,296 (2016/17)[5]

No. of 2 wheelers: 2,034,936 (2016/17)[5]

No. of 3 wheelers: 15,348 (2016/17)[5]

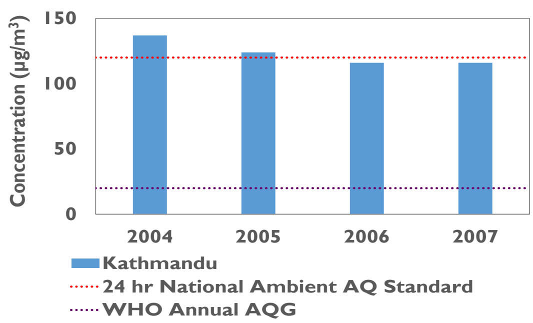
Vehicle Population Percent Increase: 52% (2010-2013)[6]

Motorization Index: 12 vehicles per 1000 persons (2015)[7]

AIR QUALITY STATUS and POLLUTION SOURCES

- Major sources of ambient air pollution in the country include cement plants (36% of TSP, ~17% of PM_{10}) and brick kilns (31% of the TSP, 28% of PM_{10}).
- Traffic-related emissions and soil/dust/construction materials were noted as the main sources of $PM_{2.5}$ in the Kathmandu Valley.
- Indoor air pollution from the burning of solid fuels for cooking and heating purposes is also a major concern.
- Ambient air quality monitoring in 2002–2007 discovered high PM_{10} levels that exceeded the World Health Organization (WHO) guidelines and Nepal's daily PM_{10} standard (120 μg/m³).
- The daily PM_{10} measurements from October 2013–March 2014 at Putalisdak in the Kathmandu Valley showed that the levels exceeded the NAAQS at all times and were even higher than the WHO guidelines in several instances.[8]

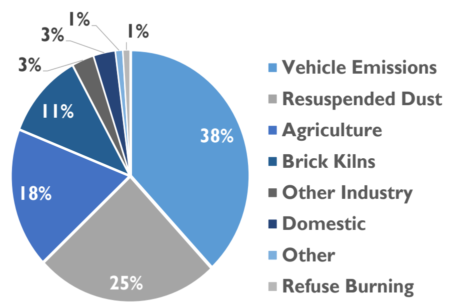
ANNUAL AVERAGE PM_{10} LEVELS IN KATHMANDU (2004-2007)



*No annual PM_{10} national standard

Source: Environment Statistics of Nepal 2011[9]

EMISSION PROFILE PM_{10} IN KATHMANDU (2006)



Source: Gautam, 2006[10]

AIR QUALITY MANAGEMENT

National Environmental Agency: Ministry of Population and Environment (MoPE) as the policy level agency and the Department of Environment (DOE) as the implementation and enforcement agency.

Summary: Environmental law has strengthened in Nepal which allowed the establishment of different emission standards for vehicles, ambient air, industrial boilers, cement and crusher industries, indoor air quality, and brick kilns.[10] Important steps that Nepal can take in order to improve air quality include improving public transportation systems, regular monitoring of air quality, and establishing a funding mechanism for air quality projects.[11]

- Table below shows the national policies issued by the Nepali Government for Air Quality Management.
- In 2003, the National Ambient Air Quality Standard (NAAQS) was introduced and revised in 2012.
- In 2012, emission standards were then introduced for diesel generators, industrial boilers, cement industries, and crusher industries.
- In 2015, the DoE collaborated with the International Center for Integrated Mountain Development (ICIMOD) to prepare a decade-long plan for a nationwide air pollution monitoring network of fifty-six sites. The ICIMOD supports the operation and maintenance of the pollution monitoring network in Nepal. Twelve sites were set up in Nepal under the collaboration between DoE and ICIMOD.
- An air quality management system was established by the MoPE in 2017.
- In June 2017, the MoPE completed the Air Quality Management Action Plan for Kathmandu Valley.
- The MoPE is working on the "National Pollution Control Strategy and Action Plan for Nepal" to develop a long-term plan for the growing problem of air pollution in the country.
- Tax revenues collected by the government, loan and grant from ADB, international donors, international NGOs and Environment Protection Fund under EPA by MoPE provide the sources of funds for tackling environmental issues, such as air pollution, in Nepal.

National Policies Issued by the Nepali Government for Air Quality Management

Year	National Policies
1987	National Conservation Strategy
1992	Industrial Policy
1993	Nepal Environmental Policy and Action Plan
1993	Vehicle and Transport Management Act
2001	National Transport Policy
2002	10th Five-Year Plan
2003	Sustainable Development Agenda for Nepal
2007	Interim Constitution
2009	National Indoor Air Quality Standards
2012	National Ambient Air Quality Standards (Updated from 2003)
2012	Nepal Vehicle Mass Emission Standards (NVMES)

National Ambient Air Quality Standards

Parameters	Units	Averaging Time	Concentration
TSP	mg/m^3	24 hours	230
PM_{10}	mg/m^3	24 hours	120
$PM_{2.5}$	mg/m^3	24 hours	40
Sulfur dioxide	mg/m^3	Annual	50
	mg/m^3	24 hours	70
Nitrogen dioxide	mg/m^3	Annual	40
	mg/m^3	24 hours	80
Carbon monoxide	mg/m^3	8 hours	10,000
Ozone	mg/m^3	8 hours	157

Source: National Ambient Air Quality Standards 2012[12]

Ambient Air Quality Monitoring Network in Nepal

Location	Frequency of Measurement	Parameters Monitored	Operational Agency
Ratnapark, Kathmandu	1 minute	PM_{10} $PM_{2.5}$ PM_1 TSP	DoE, ICIMOD
Pulchowk, Lalitpur	1 minute	PM_{10} $PM_{2.5}$ PM_1 TSP	DoE, ICIMOD
Shankhapark, Kathmandu	1 minute	PM_{10} $PM_{2.5}$ PM_1 TSP	DoE, ICIMOD
BIrendra School, Kathmandu	1 minute	PM_{10} $PM_{2.5}$ PM_1 TSP	DoE, ICIMOD
Bhaisipati, Kathmandu	1 minute	PM_{10} $PM_{2.5}$ PM_1 TSP	DoE, ICIMOD
Tribhuvan University, Kathmandu	1 minute	PM_{10} $PM_{2.5}$ PM_1 TSP	DoE, ICIMOD
Dhulikhel, Kavre	1 minute	PM_{10} $PM_{2.5}$ PM_1 TSP	DoE, ICIMOD
Sauraha, Chitwan	1 minute	PM_{10} $PM_{2.5}$ PM_1 TSP	DoE, ICIMOD
Lumbini, Rupendehi	1 minute	PM_{10} $PM_{2.5}$ PM_1 TSP	DoE, ICIMOD
Pokhara University, Pokhara	1 minute	PM_{10} $PM_{2.5}$ PM_1 TSP	DoE, ICIMOD
Gandaki Boarding School, Pokhara	1 minute	PM_{10} $PM_{2.5}$ PM_1 TSP	DoE, ICIMOD
Department of Hydrology and Meterology, Pokhara	1 minute	PM_{10} $PM_{2.5}$ PM_1 TSP	DoE, ICIMOD
Maharajgunj, Kathmandu	1 minute	PM_{10}, $PM_{2.5,}$ O_3	US Embassy
Phoradurbar, Kathmandu	1 minute	PM_{10}, $PM_{2.5,}$ O_3	US Embassy

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Air Quality Management Fact Sheet

Thailand

Capital: Bangkok

GENERAL INFORMATION

Total Population: 68,863,514 (2016)[1]

Urban Population: 35,492,255 (2016)[2]

Percent Urbanization by 2050: 72%[3]

Energy use: 1,970 kg of oil equivalent/capita (2014)[4]

Fossil fuel energy consumption: 79.8% (2014)[5]

Dominant energy sources: oil (39%), natural gas (28.2%), coal (12.9%)[6]

Total Vehicle Population: 36,731,023 (2015)[7]

Vehicle Population Percent Increase: 4.5% (2007- 2015)[8]

No. of cars: 6,737,000 (2013)[9]

No. of 2-3 wheelers: 19,853,000 (2013)[10]

No. of trucks: 963,173 (2013)[11]

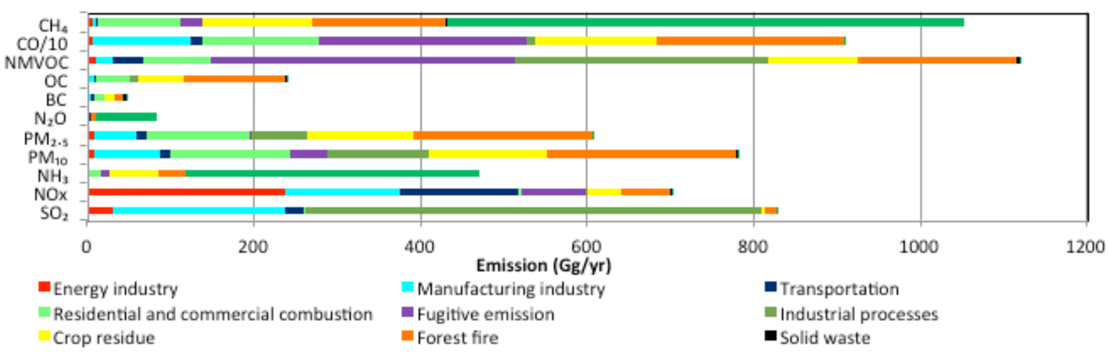
Motorization Index: 497 vehicles per 1000 persons (2013)

Road sector diesel fuel consumption:
18,796 kt of oil equivalent (2012)[12]

AIR QUALITY STATUS and POLLUTION SOURCES

- Major contributing emission sources in the country include biomass open burning (area source), transportation (mobile source), industry and thermal power generation (point sources).[13]
- In 2010, the public sector and academic institutions developed a refined emission database for Bangkok Metropolitan Region (BMR) and Central Thailand to produce the emission input data for three-dimensional (3D) air quality modeling.[14] Emission Inventory (EI) databases are available for other cities like Chiang Mai and Nakhon Ratchasima conducted under the "Clean Air for Smaller Cities in the Association of Southeast Asian Nation (ASEAN) region" project funded by GIZ.
- Several efforts of air quality modeling have been reported which analyzed the emissions of current and future projected scenarios and impacts on air quality in Thailand.[15,16,17,18]
- The ambient air quality monitoring network consists of seventy (70) continuous ambient air quality monitoring stations spread over the whole country.[19]
- The Pollution Control Department (PCD) of Thailand outsources the maintenance and technical service of almost half of the air quality monitoring stations to private sector companies.[20] Quality Control (QC) procedures and an audit system assessment have been implemented to ensure all stations meet all necessary requirements.
- As of 2016, $PM_{2.5}$ monitoring equipment has been installed in 33 stations throughout the country and would be expanded to 20 more stations in 2017. As of 2017, Bangkok city has a total of 12 continuous automatic monitoring stations operated by PCD.
- Annual average PM_{10} levels in Bangkok are within national ambient air quality standard (NAAQS) and World Health Organization Guideline values.

Major anthropogenic emission sources in Thailand



Source: Permadi et al, 2017[21]

AIR QUALITY MANAGEMENT

National Environmental Agency: Ministry of Natural Resources and Environment

Summary: Air quality monitoring network, standards, and index are available. The country has also ratified or acceded important environmental agreements. For the next two years, the country aims to continue its efforts on promoting sustainable vehicles, expanding mass transit systems, improving stakeholder cooperation, and collaborating with various ASEAN countries regarding ASEAN haze agreement.[22]

- In 1992, the Enhancement and Conservation of the National Environmental Quality Act provided the general framework for environmental management in the country. The Public Health Act B. E. 2535 was passed empowering local government to protect public health. The Factory Act B.E. 2535 was established to limit industrial air emissions of various contaminants.[23,24]
- In 1995, the National Environmental Board established the National Ambient Air Quality Standards.
- In 2006, the National Emissions Standards were implemented for other air pollutants: CO, Hydrogen Sulfide, Hydrogen Chloride, Sulfuric Acid, Xylene, Cresol, Antimony, Arsenic, Copper, Lead, Chlorine and Mercury.
- In 2007, the Energy Conservation Promotion Act was updated to improve energy management in the country.[25]
- In 2008, the Land Transport Act B.E. 2522 controlled registration of new vehicles by checking their emissions.[26]
- Bangkok has an Air Quality and Noise Management Action Plan (AQNMP) from 2012-2016 while the development of the City Action Plan (CAP) of the cities of Chiang Mai and Korat were facilitated by the "Clean Air for Smaller Cities" project supported by GIZ.
- In 2013, the Air4Thai mobile application was created to better disseminate air quality information in various parts of the country.[27]
- In 2017, the PCD launched the 20 Year Pollution Management Strategy and Pollution Management Plan 2017-2021 for Thailand.

NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant (µg/m^3)	Average Time	NAAQS (µg/m^3)
TSP	Annual	100
PM_{10}	Annual	50
Pb	Monthly	1.5
SO_2	Annual	100
NO_2	Annual	57
O_3	8-Hour	140
CO	8-Hour	10,260

Source: Pollution Control Department

AIR POLLUTANT INDEX (API)

API	Numerical Value
Good	0 to 50
Moderate	51 to 100
Unhealthy	101 to 200
Very Unhealthy	201 to 300
Dangerous	>300

Source: Pollution Control Department
API is accessible through http://air4thai.pcd.go.th/web/

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Philippines

Capital: Manila

GENERAL INFORMATION

Total Population: 103,320,222 (2016)[1]

Urban Population: 45,759,493 (2016)[2]

Energy use: 476 kg of oil equivalent/capita (2014)[3]

Fossil fuel energy consumption: 62.0% (2014)[4]

Dominant energy sources: coal (48%), natural gas (22%), geothermal (12%)[5]

Total Vehicle Population: 9,251,565 (2016)[6]

Motorization Index: 90 vehicles per 1000 persons (2016)[7]

No. of cars and utility vehicles: 3,434,329 (2016)[8]

No. of trucks: 407, 357 (2016)[9]

No. of 2-3 wheelers: 5,329,770 (2016)[10]

AIR QUALITY STATUS andPOLLUTION SOURCES

- Annual PM_{10}, SO_2, and NO_2 levels in Metro Manila and Cebu are generally within the National Ambient Air Quality Guideline Values (NAAQGV). In 2015, the 24-hour average $PM_{2.5}$ level in Metro Manila was 25 µg/m^3. This is within the NAAQGV for $PM_{2.5}$ (35 µg/m^3, also equivalent to WHO's first interim target (IT)[11].

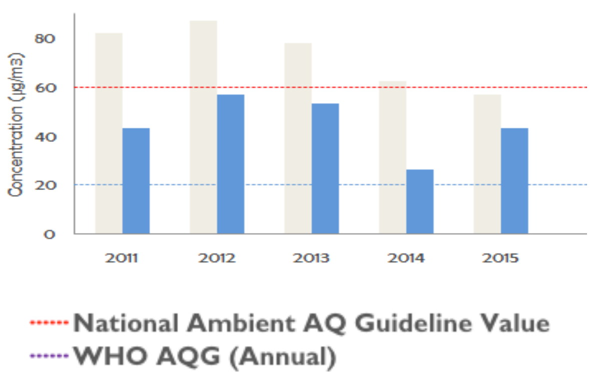
- A National Emissions Inventory is compiled by the Department of Natural Resources and Environment-Environmental Management Bureau (DENR-EMB) through their regional offices. 2015 data shows that majority of regions identify the transport sector as the major source of air pollution, for much of the NO_x, CO, VOC emissions, and is second to industries (stationary sources) for SO_x emissions and to area sources for PM emissions.

- The transport sector has been identified as the most significant source of pollution in the Philippines, accounting for 50% to 90% of the country's emissions. Diesel engine jeepneys have been identified as the primary emission source among road vehicles, contributing significant amounts of CO, PM, NO_x, SO_x, and climate-relevant emissions such as CO_2.

- Typical area source emissions reported are the resuspended dust from roads or construction activities, open burning of solid wastes, agricultural wastes, and by-products, and slash-and-burn farming (kaingin).

- The Philippines is not particularly vulnerable to long-range transport of air pollution due to its geographic and meteorological conditions. In some of the most extreme cases due to forest fires in Indonesia that occurred in 1997 and 2015, the southern part of the Philippines experienced haze episodes for several days.

ANNUAL AVERAGE PM_{10} levels (2010-2015)



Source: Environmental Management Bureau[12]

AIR QUALITY MANAGEMENT

National Environmental Agency: Department of Environment and Natural Resources (DENR) through its Environmental Management Bureau (EMB)

- Air quality management in the country is guided by the Clean Air Act of 1999 or Republic Act (RA) 8749. This law recognizes the right to breathe clean air and the right to be informed about air quality in the country.[13]
- Ambient air quality monitoring system and standards are in place. The official air quality monitoring system is solely being carried out and managed by the EMB. As of 2017, a total of 102 monitoring stations or sampling sites are in place across the country.
- The EMB conducts an emissions inventory published every three years. Major challenges experienced by the country include limited data for non-point or areas sources for the development of the National Emissions Inventory.
- National Air Quality Status Reports are intermittently published which cover sources of emissions, health impacts estimates, air quality management programs, civil society and international development projects, and public awareness initiatives. The most recent available National Air Quality Status Report covers the period of 2012-2013.
- The EMB adopted the Air Quality Index (AQI) method of the US EPA, to better demonstrate the implications of air quality levels on the public's health.
- Policies and programs targeting primary sources of pollution are starting to take effect.
- Being one of the most vulnerable countries to climate change, the Philippines, in addition to existing laws and programs, has developed new policies and actions to prevent and combat the possible effects of such phenomenon. Continuous development and implementation of the National Strategic Framework on Climate Change (NSFCC), as well as the National Climate Change Action Plan (NCCAP), have been the country's way forward to climate change mitigation.
- Under the Clean Air Act of 1999, financing of projects related to air quality management is made possible through the Air Quality Management Fund. In addition to this general fund, the government has also established the Special Vehicle Pollution Control Fund (SVPCF) to support transport emission reduction initiatives, including vehicle standards and regulations, and vehicle pollution control research. Based on Administrative Order (No. 2015-04), all new vehicle types except motorcycles/tricycles effective January 1, 2016 shall comply with the Euro 4/IV emission standards in order acquire a certificate of conformity from the DENR-EMB[14].

AIR QUALITY STANDARDS

Pollutant	Averaging time	Value µg/Nm^3
TSP	Annual	90
PM_{10}	Annual	60
	24-hour	150
$PM_{2.5}$	Annual	35
	24-hour	75
SO_2	Annual	80
NO_2	24-hour	150
CO	8-hour	10,000
O_3	8-hour	60

Source: : Environmental Management Bureau[15]

AIR QUALITY MONITORING

Parameters	Type	No. of stations
$PM_{2.5}$	Manual/Reference Method	2
PM_{10}	Manual/Reference Method	29
TSP	Manual/Reference Method	19
PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, CO, BTEX	Continuous Monitoring using Differential Optical Absorption Spectroscopy (DOAS)	21
PM_{10}, $PM_{2.5}$	Continuous monitoring	27
SO_2, NO_2, O_3, CO, and CH_4(1 unit); (2 units) PM_{10}	Continuous Monitoring Van	4
	Total	102

Source: Environmental Management Bureau[16]

AIR QUALITY INDEX (AQI)

Pollutant, Unit, Averaging time		Good	Fair	Unhealthy for sensitive groups	Very unhealthy	Acutely unhealthy	Emergency
TSP	µg/m³ 24-hr	0-80	81-320	231-349	350-599	600 – 899	900 and greater
PM_{10}	µg/m³ 24-hr	0-54	55-154	155-254	255-354	355 – 424	425 – 504
SO_2	µg/m³ 24-hr	0.000-0.034	0.035-0.144	0.145-0.224	0.225-0.304	0.305 – 0.604	0.605 – 0.804
O_3	ppm 8-hour	0.000-0.064	0.065-0.084	0.085-0.104	0.105-0.124	0.125 – 0.374	[a]
	ppm, 1-hr	-	-	0.125-0.164	0.165-0.204	0.205 – 0.404	0.405 – 0.504
CO	ppm 8-hour	0.0-4.4	4.5-9.4	9.5-12.4	12.5-15.4	15.5 – 30.4	30.5 – 40.4
NO_2	ppm, 1-hr	[b]	[b]	[b]	[b]	0.65 – 1.24	1.25 – 1.64

[a] *When 8-hour O_3 concentrations exceed 0.374 ppm, AQI values of 301 or higher must be calculated with 1-hour O_3 concentrations.*
[b] *NO_2 has no 1-hour term NAAQG*
Source: Environmental Management Bureau[17]

AQI is accessible through http://denr-dashboard.herokuapp.com/

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Chengdu

GENERAL INFORMATION

Geography and climate: The city is located in the hinterland of the Chengdu Plain in the western Sichuan Basin, and is characterized by widely varied terrain—high in the northwest and low in the southeast region. The western part of the city is mainly covered by hills and mountains (1,000–3,000 m above sea level) while the eastern part is characterized by Quaternary alluvial plains, terraces, and low hills. Chengdu has a monsoon-induced subtropical humid climate with basin-characteristic meteorological conditions.

Total Population: 15.92 million (2016)

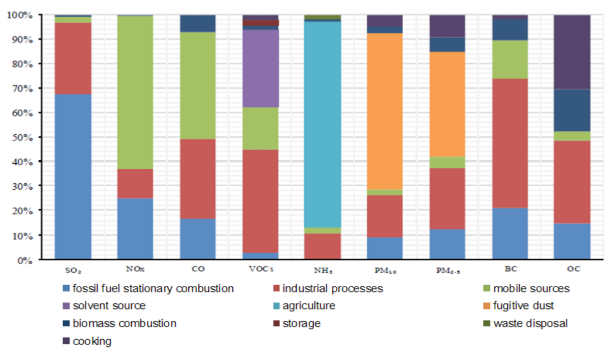
No. of districts/municipalities: 12 districts; 4 county-level cities

Total Vehicle Population: 4.67 million (2016)

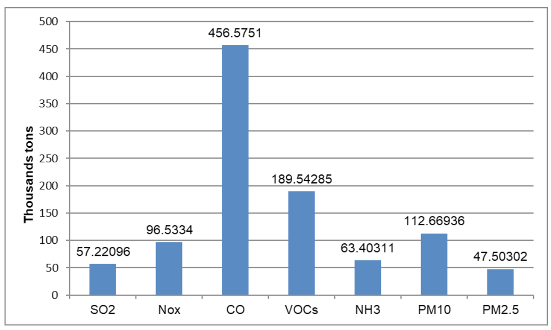
AIR QUALITY STATUS and POLLUTION SOURCES

- The monitoring program for the six criteria pollutants, including $PM_{2.5}$, O_3, and CO in Chengdu started in 2013. The marked increase in O_3 concentration levels in 2015 indicated that ozone pollution was worsening.
- The annual concentrations of SO_2, NO_2, PM_{10}, and $PM_{2.5}$ in 2015 were 14, 53, 108, and 64 µg/m^3, respectively.
- The annual concentrations of NO_2, PM_{10}, and $PM_{2.5}$ in Chengdu failed to meet the NAAQS, exceeding the limits by 32.5%, 54.3%, and 82.9%, respectively.
- A 2014 emissions inventory for Chengdu identified ten source categories: fossil fuel combustion, bio-fuel combustion, industrial processes, mobiles, solvent use, agriculture, fugitive dust, storage, waste treatment, and cooking.
- The major emission source of SO_2 was stationary fossil fuel combustion; for NO_x and CO were mobile sources; for VOCs was industrial process; for NH_3 was agricultural sources; and for PM_{10} and $PM_{2.5}$ was fugitive dust.

CONTRIBUTION OF DIFFERENT EMISSION SOURCES IN CHENGDU (2014)



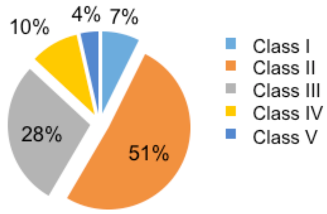
AIR POLLUTANT EMISSIONS IN CHENGDU



AIR POLLUTANT LEVELS IN CHENGDU (2016)

Pollutant	SO_2 (µg/m³)	NO_2 (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	CO (mg/m³)	O_3 (µg/m³)
Annual value	14	54	105	63	1.8	168
NAAQS	60	40	70	35	4 (24 h avg)	160 (24 h avg)
WHO guidelines	20	40	20	10	--	100 (24 h avg)

DISTRIBUTION OF AIR QUALITY INDEX LEVELS IN CHENGDU (2016)



AIR QUALITY MANAGEMENT

- The newly amended Environmental Protection Law identified local governments as the leading authority for local environment quality. Aside from the Department of Environmental Protection, more departments (development and reform, construction, agriculture, etc.) are starting to participate in air pollution control.
- The environmental protection department provides an overall supervision of urban air quality, and the other departments accomplish supervision and management within the scope of their respective responsibilities, such as development and reform, agriculture, public security, housing, and urban management.
- Since 2013, a series of environmental laws and regulations have been introduced, including the Action Plan for Air Pollution Prevention and Control, the Environmental Protection Law, and the Law on Air Pollution Prevention and Control.
- Chengdu released its local Air Pollution Prevention and Control Action Plan to achieve the air quality improvement targets dictated by the 2013 national Action Plan.
- The city has achieved significant results in air pollution prevention and control by implementing a series of measures, such as clean energy transformation, industrial structure optimization, industrial waste gas treatment, vehicle exhaust gas treatment, and dust and agricultural source control. In 2015, the annual average concentrations of PM_{10} and $PM_{2.5}$ were decreased by 28% and 34%, respectively, from the 2013 levels, exceeding the targets and tasks assigned by the provincial government for 2017.
- In addition to the financial support provided by the central and provincial governments, the Chengdu municipal government has provided 0.5 billion RMB per year for air pollution control and capability building.
- Several initiatives on air pollution prevention have been implemented, including: the EIA-based approval system for industrial development; adjustment and optimization of composition, development, and growth of industries; coal-to-gas project implementation; control measures for VOCs and the VOC Treatment Program for Petrochemical Industry; advocating of green construction and implementation of on-line monitoring of large-scale construction sites; fireworks ban.
- In 2014, Chengdu signed the Cooperation Agreement on Joint Prevention and Control of Air Pollution in Chengdu and the Surrounding Areas and developed the Working Rules of the Working Group for Joint Prevention and Control of Air Pollution in Chengdu and the Surrounding Areas with Deyang, Mianyang, Suining, Leshan, Meishan, and Ziyang cities.
- Chengdu's experience in air pollution control is mainly reflected in the following aspects: strengthened source control, implement integrated management of key sources, and improving the regulatory mechanisms, technical support, capital investment, and information disclosure.

STATE AIR QUALITY MONITORING STATIONS IN CHENGDU

Category	Parameters	No. of stations
Continuous, urban area	$PM_{2.5}$, PM_{10}, NO_2, SO_2, O_3, and CO	7
Continuous, rural and other areas	$PM_{2.5}$, PM_{10}, NO_2, SO_2, O_3, and CO	1

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Xiangtan

GENERAL INFORMATION

Geography and climate: The city is located in the central part of Hunan Province and on the middle and lower reaches of Xiangjiang River, surrounded by high terrains in the west and the north, and by low terrains in the east, the south, and the center. It is characterized by a subtropical humid monsoon climate.

Total Population: 283.8 million (2016)

Total Vehicle Population: 610,974 (2015)

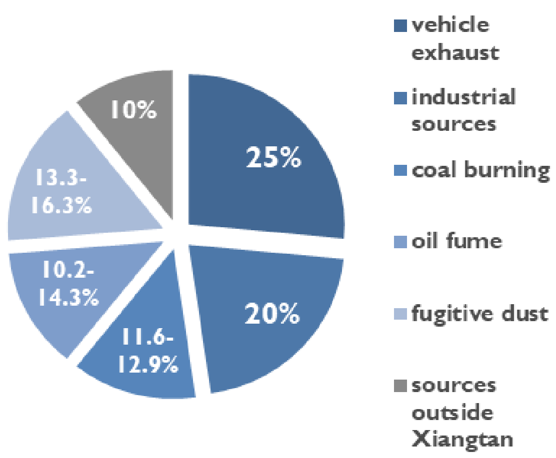
AIR QUALITY STATUS and POLLUTION SOURCES

- In 2015, the annual average concentrations of SO_2, NO_2, PM_{10}, and $PM_{2.5}$ in Xiangtan were 24, 41, 88, and 56 μg/m^3, respectively. The 90thpercentile of the 8-h average O_3 concentration was 145 μg/m^3, and the 95thpercentile of 24-h average CO concentration was 1.4 μg/m^3.
- In the same year, the number of days that exhibited the different levels of air quality was as follows: 76 (excellent, Class I); 192 (good, Class II); 67 (slightly polluted, Class III); 22 (moderately polluted, Class IV); 4 (heavily polluted, Class V); and 0 (extremely heavily polluted, Class VI).
- $PM_{2.5}$ was the most significant air pollutant for 162 days, followed by PM_{10} for 62 days, accounting for 44.4% and 17.0% of the year, respectively. The 8-h O_3 was the leading air pollutant for 60 days. Then, $PM_{2.5}$ remained as the major pollutant throughout the year.

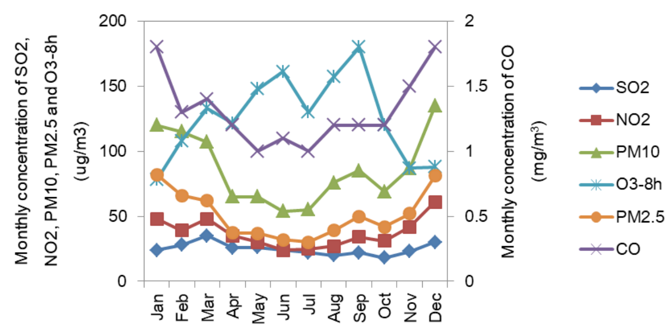
AIR QUALITY MONITORING

Category	Parameters	No. of stations
Continuous, urban area	$PM_{2.5}$, PM_{10}, NO_2, SO_2, O_3, and CO	5
Continuous, rural and other areas	$PM_{2.5}$, PM_{10}, NO_2, SO_2, O_3, and CO	1

PRELIMINARY RESULTS OF PM2.5 SOURCE APPORTIONMENT IN CHANGSHA, ZHUZHOU, AND XIANGTAN (2013)



SEASONAL TREND OF SIX CRITERIA POLLUTANTS IN XIANGTAN (2016)



AIR QUALITY MANAGEMENT

- The newly amended Environmental Protection Law identified local governments as the leading authority for local environment quality. Aside from the Department of Environmental Protection, more departments (development and reform, construction, agriculture, etc.) are starting to participate in air pollution control.
- The environmental protection department provides an overall supervision of urban air quality, and the other departments accomplish supervision and management within the scope of their respective responsibilities, such as development and reform, agriculture, public security, housing, and urban management.
- The Hunan Province issued the Implementation Rules for the Action Plan for Air Pollution Prevention and Control in October 2013, which stated the targets for annual average PM_{10} concentrations in the cities under its jurisdiction. In Xiangtan, the annual average PM_{10} concentration should be cut by about 10% in 2015 and by more than 20% in 2017 compared with that in 2012.
- In June 2016, Hunan Province released the Special Plan of Action for Air Pollution Prevention and Control (2016–2017), requiring the Xiangtan to further reduce its annual average PM_{10} levels and identified targets for $PM_{2.5}$ concentration and good ambient air quality (measured as the number of days without exceedances).
- Since 2013, a series of environmental laws and regulations have been introduced, including the Action Plan for Air Pollution Prevention and Control, the Environmental Protection Law, and the Law on Air Pollution Prevention and Control.
- In 2013, only 0.33% of the revenue collected by the city government was used for environmental protection, and this value further declined in 2014.
- Xiangtan has established a mayor-convening joint meeting system for environmental protection that includes air pollution prevention and control in its priorities.
- The task of air pollution prevention and control is also included in the performance appraisal and delegated to districts, counties, industrial parks, and departments directly under Xiantan's jurisdiction.
- Air pollution control actions in the city include: 1) upgrading of abatement technology and phasing out old production facilities that emit high pollutant levels; 2) controlling vehicle emission by tightening vehicle standards, strengthening the supervision on vehicle fuel quality, and phasing out yellow-labeled vehicles (gasoline vehicles failing to meet phase I standards and diesel vehicles failing to meet phase III standards) and old vehicles (vehicles failing to meet phase IV standards); 3) controlling fugitive dust; and 4) prohibiting straw burning.

AIR QUALITY IMPROVEMENTS AND TARGETS FOR XIANGTAN

Indicator	Annual average PM_{10} concentration (μg/m^3)			Annual average $PM_{2.5}$ concentration (μg /m^3)	Good quality rate
Target year	2015	2016	2017	2016	2017
Target level	71.1(1)	72.7(2)	63.2(1)/71.1(2)	54.3(2)	80%(2)
Actual level	89	85	NA	51	NA

(1) Targets set in the Implementation Rules for the Action Plan for Air Pollution Prevention and Control.
(2) Targets set in the Special Plan of Action for Air Pollution Prevention and Control (2016-2017).

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Kathmandu

GENERAL INFORMATION

Geography and climate: The city is situated in the Kathmandu Valley and is surrounded by hills with heights ranging from 500 m to 1400 m; it is characterized by a sub-tropical, temperate climate with four distinct seasons in a year with ambient temperatures from 35°C in summer and -1°C in winter.

Total Population: 1.003 million (2011)

No. of districts/municipalities: 2 Metropolitan cities and 16 municipalities

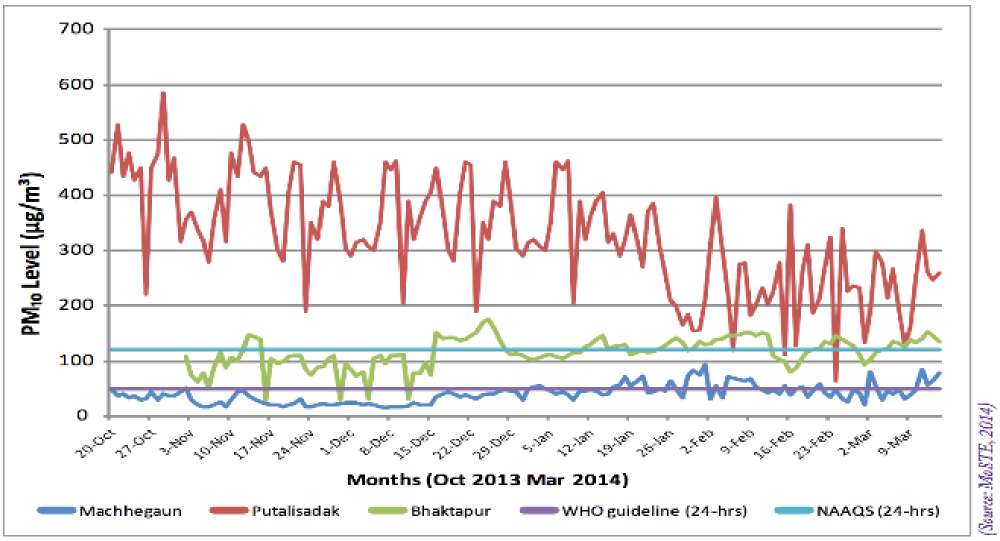
Gross Domestic Product per Capita: USD 691.7 (2014)

Total Vehicle Population: 1,178,000 (2013)

AIR QUALITY STATUS and POLLUTION SOURCES

- Daily PM_{10} measurements from October 2013 to March 2014 at Putalisdak in the Kathmandu Valley showed that the levels exceeded the National Ambient Air Quality Standards (NAAQS) at all times and were even higher than the WHO guidelines in several instances.
- The four primary sources of particulate carbon in Kathmandu Valley during winter are: brick kilns, motor vehicles, fugitive soil dust, and biomass/garbage burning.
- A 1993 emissions inventory showed that cement factories (~36% of total suspended particles (TSP); ~17% of PM_{10}) and brick kilns (~31% of TSP; ~28% of PM_{10}) were the major PM ambient air pollution. By 2005, the vehicular emission was responsible for 38% of the total PM_{10} emitted in the Kathmandu Valley, which was considerably greater than the emission from the agricultural sector (18%) and brick kilns (11%).
- Cooking and indoor heating during winter also contribute to the poor air quality in the Valley. About 25% of households in Bhaktapur still use firewood for cooking.

DAILY PM_{10} LEVELS IN KATHMANDU



(Oct 2013 – Mar 2014)

AIR QUALITY MANAGEMENT

- The Department of Environment (DoE), which is under the Ministry of Population and Environment (MoPE), is the main government agency responsible for issues related to air pollution in Nepal.
- Vehicle exhaust emissions monitoring was initiated in Kathmandu Valley in 1993. By 1999, the Green Sticker system was established, which certified vehicles that met Euro III emission standards; the banning of two-stroke engines and diesel-fueled three-wheelers was also implemented.
- In 1998, the Environment Department and the Urban Environment Section were established in the Kathmandu Metropolitan City Office to elevate air pollution as an important issue. The Urban Environment Section actively collaborated with various NGOs to form the Citizens Monitoring Group.
- The Local Self Governance Act of 1999 allows municipalities to be primarily responsible for urban environmental management and environmental protection.
- The Ministry of Physical Infrastructure and Transport (MoPIT) is mandated to create and implement vehicle standards, including emission standards.
- In June 2003, MoPE established the National Ambient Air Quality Standards for seven major pollutants; this was subsequently updated in 2012.
- The registration of brick kilns that used the outdated bulls trench kiln technology was stopped in 2002. In 2004, the operation of this old technology was banned from the Valley, as the government actively promoted cleaner brick kiln technologies.
- The Nepal Vehicle Mass Emission Standard was introduced in 2000 and revised in 2012, such that all imported vehicles must comply with the Euro III emission standards. Emission standards for diesel generators, industrial boilers, cement industries, and crusher industries were introduced in 2012.
- The collection of pollution tax of NRs 0.5 per liter of petrol and diesel sold in the Kathmandu Valley was initiated in 2007. This tax shall be used for pollution control, environmental protection, and road development.
- In 2015, the DoE collaborated with the International Center for Integrated Mountain Development (ICIMOD) to establish a nationwide air pollution monitoring network. Under this collaboration, 12 sites were set up in Nepal, of which eight are located in the Kathmandu Valley. Data is published on a website at http://pollution.gov.np. The US Embassy in Nepal also conducts an independent air quality monitoring in Kathmandu Metropolitan City.
- The MoPE is working on the “National Pollution Control Strategy and Action Plan for Nepal” to develop long-term plan for the growing problem of air pollution in the country.
- In March 2017, the government started banning 20-year old public vehicles to reduce air pollution and ease traffic congestion.
- ICIMOD, in collaboration with the Climate and Clean Air Coalition, the Federation of Nepal Brick Industries, MinErgy, and the Government of Nepal, solicited a team of engineers to work closely with brick entrepreneurs to design modifications to existing kilns that can reduce energy consumption and pollutant emissions by 30%.
- The Kathmandu Sustainable Urban Transport Project was set up through a loan and grant from the Asian Development Bank, which aims to improve the quality of urban life in the capital city by developing sustainable urban transport system, improving traffic management, increasing walkability, and mitigating air pollution.

AIR QUALITY MONITORING

Category	Parameters	No. of stations	Operating agency
Continuous	PM_{10}, $PM_{2.5}$, PM_1, TSP	8	DoE, ICIMOD
Continuous	PM_{10}, $PM_{2.5}$, O_3	2	US Embassy

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Manila

GENERAL INFORMATION

Geography and climate: The city is bounded by the plains of Central Luzon in the North, the Sierra Madre Mountains in the East, and Laguna de Bay in the South; Manila Bay spreads on the West. Its climate in Metro Manila is categorized by dry months from November to April and rains throughout the year

Total Population: 12.9 million (2015)

No. of cities/municipalities: 16 cities and 1 municipality

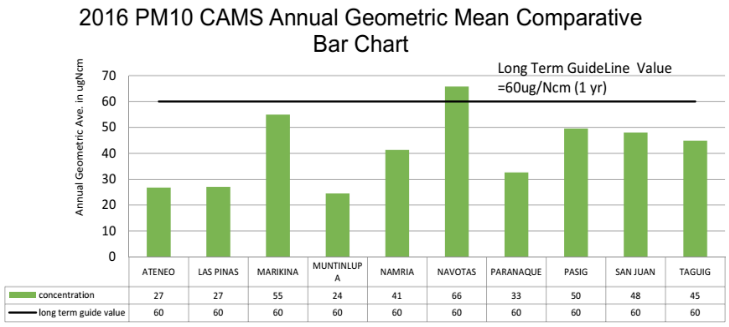
Gross Regional Domestic Product: PhP5,521,580,999 (2016)

Total Vehicle Population: 2.3 million (2015)

AIR QUALITY STATUS and POLLUTION SOURCES

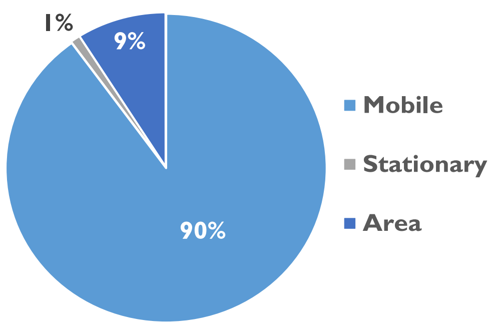
- In 2016, the air quality monitoring results suggest considerable contribution of mobile sources, particularly road transport, to TSP and PM_{10} concentration levels.
- Manual and automatic sampling of PM_{10} at roadside areas have recorded the highest average concentration levels, at 69 and 66µg/Ncm, respectively. These exceed the long-term guideline value of 60µg/Ncm.
- Area sources, particularly building constructions, are also apparent PM_{10} emission sources. Based on a Metro Manila emissions inventory (2015), construction activities account for 17% of the total PM_{10} emissions.

ANNUAL AVERAGE PM_{10} CONCENTRATION FROM CONTINUOUS AMBIENT STATIONS (2016)



Source: EMB NCR

METRO MANILA EMISSION PROFILE FOR PM10 (2012)



Source: Environmental Management Bureau

AIR QUALITY MANAGEMENT

- The policy framework for air quality management specifies the Department of Environment and Natural Resources as the overall lead agency in implementing the Clean Air Act of 1999 (Republic Act 8749). The same framework, along with the Local Government Code (RA 7160), identifies the responsibility of local government units in the implementation of policies, such as upholding of air quality standards, developing and carrying out the action plan for air quality improvement, as well as establishing a city or municipal Environment and Natural Resource Office (ENRO).
- The Philippine Clean Air Act of 1999 and Local Government Code allows local government units to exercise their authority in the management and maintenance of air quality within their jurisdiction.
- The Clean Air Act of 1999 also stipulates that an Air Quality Management Fund (AQMF) should be established to: (a) finance containment, removal, and clean-up operations of the Government in air pollution cases, (b) guarantee restoration of ecosystems and rehabilitate areas affected by the acts of violators; (c) support research, enforcement and monitoring activities and capabilities of relevant agencies.

- In 2011, the National Capital Region (NCR) Airshed Governing Board was established with the signing of the Administrative Order 2011-11. An airshed is primarily tasked to formulate and implement the Common Action Plan, which reflects air quality concerns of the LGUs that comprise it as well as its projects and initiatives.
- The air quality monitoring network in Metro Manila was set up and is currently being maintained by the Environmental Management Bureau (EMB). To date, there are 34 ambient air quality monitoring sites that are part of the EMB's air quality monitoring network. Air Quality Index for all local governments within the NCR airshed is publicly available through the mobile application AirQMet.
- In the latest NCR Airshed Governing Board Action Plan (2016), city- and municipal-level emissions inventory will be developed to help cities identify the major polluting sources.
- The measures to address industrial emissions are mainly on compliance monitoring and include regulations such as the submission of quarterly self-monitoring reports by industries and establishments.
- Initiatives undertaken at the city level are often aimed at reducing emissions from mobile sources, with the objective inherently two-fold: ease traffic congestion and reduce emissions. These include: introduction and promotion of electric vehicles; promotion of non-motorized transport; designation of no-car zones/areas within a city.
- The internal revenue allotment (IRA) from the national government is the main source of funds for LGUs' activities and is usually augmented by tax revenues and fees collected at the local level. Budget allocation for environmental management activities varies from city to city and may include specific items such as air quality monitoring and communication.
- The Metro Manila local government units have forged partnerships with different stakeholder groups – national government, donors, and NGOs. This has been a critical factor in mobilizing resources and implementing key activities and programs.

AIR QUALITY MONITORING

Category	Parameters	No. of stations
Continuous, Roadside Ambient	PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, CO, BTEX, Met	16
Continuous, General Ambient	PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, CO, BTEX, Met	5
Ambient, mobile van	SO_2, NO_2, O_3, CO, THC and CH_4	1
Manual	PM_{10}	5
Manual	TSP	7

Source: Environmental Management Bureau

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Appendix III: Methods Used in Compliance Monitoring

Innovative methods of compliance monitoring include the use of infrared cameras and drones carrying them. Infrared imaging cameras are suitable to detect remote fugitive emissions (VOCs, volatile hazardous pollutants) in gas, oil, petrochemical facilities and chemical manufactures utilizing optical gas imaging (OGI). Where volatile gas is present, OGI cameras are proving to be the safest, most reliable, and most cost-effective solution for volatile gas leak detection. OGI allows live visual image of the gas leak and locates its source on an LCD screen (OPGAL, 2016; Wilson, 2016; Abdel-Moati, 2015). Combined with an accessory device called QL 100 that can quantify and report the mass leak rate, OGI technology allows improved Leak Detection and Repair (LDAR) surveys by efficiently identifying fugitive sources and quantifying emission rates (Camcode, 2018; Drago, 2016; US EPA, 2007-2016).

The Moderate Resolution Imaging Spectro-radiometer (MODIS) sensor onboard NASA's Terra and Aqua satellites has been used to scan the Earth's surface for agricultural and land clearing fires on a daily basis since the 1990s. Since 2012, the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the Suomi National Polar-orbiting Partnership (NPP) satellite has detected fires with higher resolution images of the Earth's surface. This higher resolution enables VIIRS to detect fires that MODIS overlooks (UN-Spider, 2015). VIIRS enables scientists and firefighters to model and predict shifts in a fire's behavior more accurately. Other applications of VIIRS include the estimation of GHG volume released into the atmosphere as a result of a fire. VIIRS is also used as a tool for estimating the public health consequences of smoke exposure. 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 started burning (NASA, 2016- 2017).

For type approval of new vehicle types to be sold in the market, countries conduct type approval testing or in the absence of laboratory equipment needed for type approval testing, countries require the submission of a Certificate of Conformity issued by the vehicles' country of origin which certify that the vehicles have been tested and meet the receiving country's vehicle emission standards; the latter is the system followed in the Philippines (Environmental Management Bureau, 2018). For in-use motor vehicles, vehicle emission testing as part of the vehicle registration process, roadside testing and inspection are ways to monitor compliance with vehicle emission standards.

The development and widespread application of pollution-control technologies (such as the removal of fuel sulfur in petrol and diesel and the development of three-way catalytic converters capable of reducing NOx and HC emissions, optimization of air-to-fuel mixtures, and leak-free exhaust systems) have reduced automobile pollutant emissions even while vehicle kilometers traveled have continually increased. These technologies are being expanded for use on heavy-duty vehicles and non-road equipment. The introduction of new automotive technologies, such as electric-gasoline hybrid vehicles with lower fuel consumption, will further decrease emission levels (National Academic Press, 2004).

In order to measure an in-use vehicle's real driving exhaust emissions, two completely different approaches are used: On-board emission measurement by portable emission measurement systems (PEMS) and remote sensing device (RSD) systems.

PEMS measures 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 Euro 5 emission standard) (International Council for Clean Transportation, 2014). Only the emissions of a few cars per day can be studied by PEMS with one instrument (IVL, 2017). On the other hand, RSD systems provide a snapshot (< 1 second) of a vehicle's emissions and can be employed to measure the momentary emissions of thousands of cars per day.

RSD test sites measure typically at locations where vehicles can be found accelerating or driving under engine load at a moderate speed.

As a vehicle passes by, the RSD equipment measures and analyzes the vehicle's exhaust. The equipment has four stages (Opus Inspection, 2005-2018):

1. The vehicle first passes through detectors which measure speed and acceleration, while a video camera helps identify the license plate;
2. The vehicle then passes through low intensity infrared and ultraviolet laser light beams of the emissions detector;
3. As the light beams intersect with the vehicle's exhaust plume, the detector measures the levels of CO_2, CO, HCs, NOx and PM in the exhaust by light absorption spectroscopy.
4. The emissions readings are matched to the license plate and an official test record is created and compiled.

The use of remote sensing has a number of advantages over a test-center-based inspection system (National Academic Press, 2004). First, it measures in-use vehicle exhaust emissions, representing the real-world data better than the test cycles at inspection facilities, which are limited to test low and high idle emissions. Secondly, it provides a method for identifying certain types of high tailpipe emitters that periodic inspection at a test facility using a test cycle might not capture; Thirdly, it also can identify high-emitting vehicles that are not showing up for testing.

At the same time, challenges remain for remote sensing. RSDs do not do reliably well during adverse weather conditions such as rain, snowfall, and high wind speeds. Further controlled testing of the technology for QA/QC is needed, in particular for PM. In addition, because remote sensing does not monitor a vehicle over its full range of operating conditions and is not yet able to monitor evaporative emissions, it is best used at this time as an adjunct to annual or biennial inspections and PEMS diagnostics. In addition, site selection of the sensing equipment can also influence the results.