GUIDANCE FRAMEWORK
FOR BETTER AIR QUALITY IN ASIAN CITIES

Guidance Area 1: Ambient Air Quality Standards and Monitoring

Integrated Programme for Better Air Quality in Asia

CLEAN AIR ASIA

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ABOUT CLEAN AIR ASIA
www.cleanairasia.org

Clean Air Asia is an international NGO established in 2001 as the premier air quality network for Asia by the Asian Development Bank, World Bank and USAID. Its mission is to promote better air quality and livable cities by translating knowledge to policies and actions that reduce air pollution and greenhouse gas emissions from transport, energy and other sectors.

Clean Air Asia became a UN-recognized partnership in 2007, its network spanning 250 organizations in 31 countries in Asia and worldwide, with 8 country networks: China, India, Indonesia, Nepal, Pakistan, Philippines, Sri Lanka and Vietnam. It is headquartered in Manila and has offices in Beijing and Delhi. Clean Air Asia leads efforts to enable Asia's more than 1000 cities to reduce both air pollution and CO_2 emissions, and thereby contribute to more livable and healthy cities with blue skies and low carbon footprint. Clean Air Asia helps to reduce emissions through policies, plans, programs, and concrete measures that cover air quality, transport and industrial emissions and energy use.

The Better Air Quality (BAQ) Conference is a flagship event of Clean Air Asia covering the key sectors of transport, energy and industry, with a particular emphasis on government policies and measures. Policy makers, practitioners and industry leaders meet at BAQ to network, innovate, learn and share experiences. The biennial event was first held in 2002 and attracts close to a thousand participants from Asia and the rest of the world.

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PREFACE

Air pollution is now considered the world's largest environmental health risk. There have been a number of global efforts calling for air pollution actions in recent years. These global calls for action on air pollution strengthen regional and national initiatives and highlight the need to prioritize addressing this issue through a collaborative and integrated approach.

In 2006, the First Governmental Meeting on Urban Air Quality in Asia[1] recognized the need for guidance in implementing a Long Term Vision for Urban Air Quality in Asia, which describes the desired state of urban air quality management in Asian cities. During the Third Governmental Meeting, environment ministries from the region identified key challenges they are facing to improve urban air quality.

To set the way forward in achieving the vision for cleaner air, Clean Air Asia led the development of the Guidance Framework for Better Air Quality in Asian Cities (Guidance Framework) to address the needs and challenges in the region. It aims to provide a recognized guidance on improving urban air quality and is organized around priority areas of concern in the region, which were translated into key guidance areas with roadmaps on how to progress in a step by step manner.

This voluntary, non-binding document consists of seven individually published chapters covering each of the Guidance Areas. Policy and decision makers in Asia, as well as other relevant stakeholders, can use one or a combination of the Guidance Framework chapters to develop local roadmaps or action plans depending on their priority areas of concern.

The Guidance Framework consists of seven main books with these titles:

- Introduction
- Guidance Area 1 - Ambient air quality standards and monitoring
- Guidance Area 2 - Emissions inventories and modeling
- Guidance Area 3 - Health and other impacts
- Guidance Area 4 - Air quality communication
- Guidance Area 5 - Clean air action plans
- Guidance Area 6 - Governance

These guidance areas come with an Information Sourcebook, which is a compilation of resources to support the implementation of Guidance Framework roadmaps. There is also an accompanying training course on Guidance Framework implementation, which is available online in the Clean Air Asia website and Integrated Programme for Better Air Quality (IBAQ Programme) website: www.cleanairasia.org/ibaq

The Guidance Framework was developed together with a team of international and regional experts and practitioners and has undergone an extensive review process through the Governmental Meetings and the involvement of external reviewers. The draft document was also shared in a number of international events, including the Asia Pacific Clean Air Partnership (APCAP) Joint Forum organized by UNEP ROAP in November 2015. The Guidance Framework was welcomed by participants from 24 countries in Asia and the Pacific, involving environment ministries, intergovernmental organizations, non-governmental organizations, and experts.

1 Governmental Meetings on Urban Air Quality in Asia are biennial meetings organized by the United Nations Environment Programme Regional Office of Asia and the Pacific (UNEP ROAP) and Clean Air Asia that convene environment ministries with the aim to harmonize approaches across the region in tackling air pollution and related fields.

ABBREVIATIONS

AAQC	Ambient Air Quality Criteria
AAQD	Ambient Air Quality Directive
AAQG	Ambient Air Quality Guidelines
AAQGV	Ambient Air Quality Guideline Values
AAQS	Ambient Air Quality Standards
ADB	Asian Development Bank
APMA	Air Pollution and Megacities in Asia
ARB	Air Resources Board – State of California
AQ	Air Quality
AQG	Air Quality Guidelines
AQM	Air Quality Management
AQO	Air Quality Objectives
AQS	Air Quality Standards
CAA	Clean Air Act
CASAC	Clean Air Scientific Advisory Committee
CO	Carbon monoxide
CO_2	Carbon dioxide
DEFRA (UK)	Department for Environment, Food, and Rural Affairs
EC	European Commission
EU	European Union
GAPF	Global Atmospheric Pollution Forum
GHG	Greenhouse Gas
HKSAR	Hong Kong Special Administrative Region
ISA	Integrated Science Assessment
NAAQS	National Ambient Air Quality Standards
NOx	Nitrogen oxides
NO_2	Nitrogen dioxide
NZIER	New Zealand Institute of Economic Research
OMB	United States Office of Management and Budget
O_3	Ozone
PA	Policy Assurance
Pb	Lead
PM	Particulate Matter
PM_{10}	Particulate Matter (≤ 10 micrometers in diameter)
$PM_{2.5}$	Particulate Matter (≤ 2.5 micrometers in diameter)
QA	Quality Assurance
QC	Quality Control
REA	Risk/Exposure Assessment
SEI	Stockholm Environment Institute
SIP	State Implementation Plan
SO_2	Sulfur dioxide
SOP	Standard Operating Procedure
TSP	Total Suspended Particulates
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WHO	World Health Organization

CHAPTER 2

GUIDANCE AREA 1: AMBIENT AIR QUALITY STANDARDS AND MONITORING

2.1 Introduction

The establishment of standards is an important environmental management tool that will help protect public health and the natural environment. In the case of air pollution, air quality standards (AQS) prescribe the acceptable level of air quality (AQ) adopted by a regulatory authority as enforceable (Schwela et al., 2006). Air quality standards are differentiated according to: exposure – i.e. ambient (outdoor) or household (indoor); and what they intend to protect – primary standards for human health protection, and secondary standards for protection of animals, crops, vegetation and buildings.

Air quality standards are established by taking into account various factors: prevailing exposure levels, technical feasibility, source control measures, abatement strategies, and social, economic and cultural conditions. These factors depend on a country's level of development and capability for air quality management (AQM) (World Health Organization [WHO], 2000 and WHO, 2005). Air quality standards necessitate the setting up of a reliable AQ monitoring system that evaluates trends of air pollution and compliance with these standards. Sophistication and sustainability of AQ monitoring networks and systems are often also linked with the country's economic conditions and commitment to environmental protection.

This guidance area will focus on management approaches surrounding ambient air quality standards (AAQS) and its AQ monitoring network.

To **establish and/or strengthen** air quality standards that would protect **public health and the environment**, and sustainable national and local **air quality monitoring** programs that would **enrich understanding** of air quality status.

2.1.1 Objective

To establish and/or strengthen air quality standards that would protect public health and the environment, and sustainable national and local air quality monitoring programs that would enrich understanding of air quality status.

2.1.2 Air quality standards

Various definitions surround the term AQS and related terms such as objectives, guideline values, criteria, and directives (Table 2.1). A review of the definitions of AQS shows that the term may have one or all of the following key components:

- Purpose – usually for protection of general public health or of sensitive groups, protection of environment;
- Pollutant type levels, average, time and form – maximum allowable concentration, maximum number of exceedances from standards;
- Timescale – averaging period for concentration, target date for compliance/attainment;
- Regulatory/Voluntary – defines whether or not the standards are regulatory limits or recommendations/ guides for resource management strategies; and
- Geopolitical boundary – city/province/country, special zones, and/or protected areas

Table 2.1 Summary of definitions of ambient air quality standards and related terms from different regulatory organizations

Terms related to air quality standards and their definitions		Organization/ Country	Key components
National Ambient Air Quality Standards (NAAQS)	Ambient air quality standard means a numerical expression of a specified concentration level for a particular air contaminant and the time averaging interval over which that concentration level is measured. It is a goal to be achieved in a stated time through the application of appropriate preventive and/or control measures. Primary standards set limits to protect public health, including the health of at-risk populations. Secondary standards set limits to protect public welfare, including protection against visibility impairment, damage to animals, crops, vegetation, and buildings.	United States Environmental Protection Agency (USEPA)	Indicator (e.g. PM_{10} [1], $PM_{2.5}$ [2], O_3 [3], etc.) Levels (e.g. 0.075 ppm for O_3, 12 µg/m³ for $PM_{2.5}$, etc.) Averaging time (e.g. 1 hour, 24 hours, annual) Form (e.g. one exceedance per year)
Ambient Air Quality Standards (AAQS)	Ambient air quality standards define clean air, and are established to protect even the most sensitive individuals of the community. An air quality standard defines the maximum amount of a pollutant that can be present in outdoor air without harm to the public's health.	California Air Resources Board (ARB)	Same as U.S. NAAQS with lower concentration levels and more stringent requirements
Air Quality Objectives (AQO)	These are policy targets generally expressed as a maximum ambient concentration to be achieved, either without exception or with a permitted number of exceedances, within a specified timescale.	Department for Environment, Food and Rural Affairs (DEFRA), UK	Timescale, maximum concentration and permitted exceedance
Air Quality Objectives (AQO)	These are limits on the acceptable presence of contaminants in the atmosphere, established by government agencies to protect human health and the environment. Generally expressed in terms of a concentration measured over a specific period of time. These are non-statutory limits used to assess air quality and to guide air management decisions – e.g., issuance of authorizations and advisories, and development of airshed management plans.	Ministry of Environment, British Columbia	Acceptable presence of contaminants Specific period of time
Ambient Air Quality Guideline Values (AAQGV)	These are the minimum requirements that outdoor air quality should meet in order to protect human health and the environment. Where air pollution levels breach guideline values, emissions reduction strategies should be implemented to improve air quality. Where levels do not breach the values, efforts should be made to maintain air quality and, if possible, reduce emissions. Guideline values should not be used as limits. If pollution approaches the guideline value, then air quality is comparatively poor and has been degraded from its background state.	Ministry for the Environment, New Zealand	Minimum air quality levels, averaging period, and guide resource management strategies
Ambient Air Quality Guidelines (AAQG)	These provide a basis for protecting public health from adverse effects of air pollutants to eliminate or reduce exposure to hazardous air pollutants and to guide national and local authorities in their risk management decisions.	WHO	Threshold levels Health risks Averaging period

1 Particulate matter with a diameter less than 10µm
2 Particulate matter with a diameter less than 2.5µm
3 Ground-level ozone

Terms related to air quality standards and their definitions		Organization/ Country	Key components
Ambient Air Quality Criteria (AAQC)	It is a desirable concentration of a contaminant in air, based on protection against adverse effects on health or the environment. The term "ambient" is used to reflect general air quality independent of location or source of a contaminant. These are set with different averaging times appropriate for the effect that they are intended to protect against. Effects considered may be health, odor, vegetation, soiling, visibility, corrosion or other effects. Ambient air quality criteria may be changed from time to time based on new science.	Ontario Ministry of Environment, Canada	Desirable concentration guide Health and other effects
Ambient Air Quality Directives (AAQD)	The European Union (EU) ambient air quality directives set limits and targets for concentrations of various pollutants in outdoor air for the protection of health and ecosystems. It includes controls over fine particulate matter (PM).	EU	Health and ecosystems

Source: ARB, 2014; DEFRA, 2014; WHO, 2000a; Ministry for Environment New Zealand, 2002; Ontario Ministry of Environment, 2012; European Commission, 2008; Province of British Columbia, 2011; USEPA Region 4, 2014.

For the benefit of this framework document, various terms (standards, criteria, objectives and guidelines) will not be classified separately. This framework will also not make any distinction between a legally binding standard and a voluntary standard, but collectively call them AAQS. Lastly, this framework adopts WHO's definition: "A standard is the level of an air pollutant, such as a concentration or a deposition level, that is adopted by a regulatory authority as enforceable". Ambient air quality standards differ from country to country and may be above or below the respective WHO guideline value (WHO, 2000a).

2.1.3 Role of air quality standards in air quality management

Regardless of the manner of definition and establishment, the concept of AAQS is clearly an essential part of AQM or air pollution control.

In fact, the establishment of the NAAQS for the US, following the revisions of the Clean Air Act (CAA) Amendment in 1970, has been a main driver of the AQM system (Figure 2.1) (Bachmann, 2007; Chow et al., 2012).

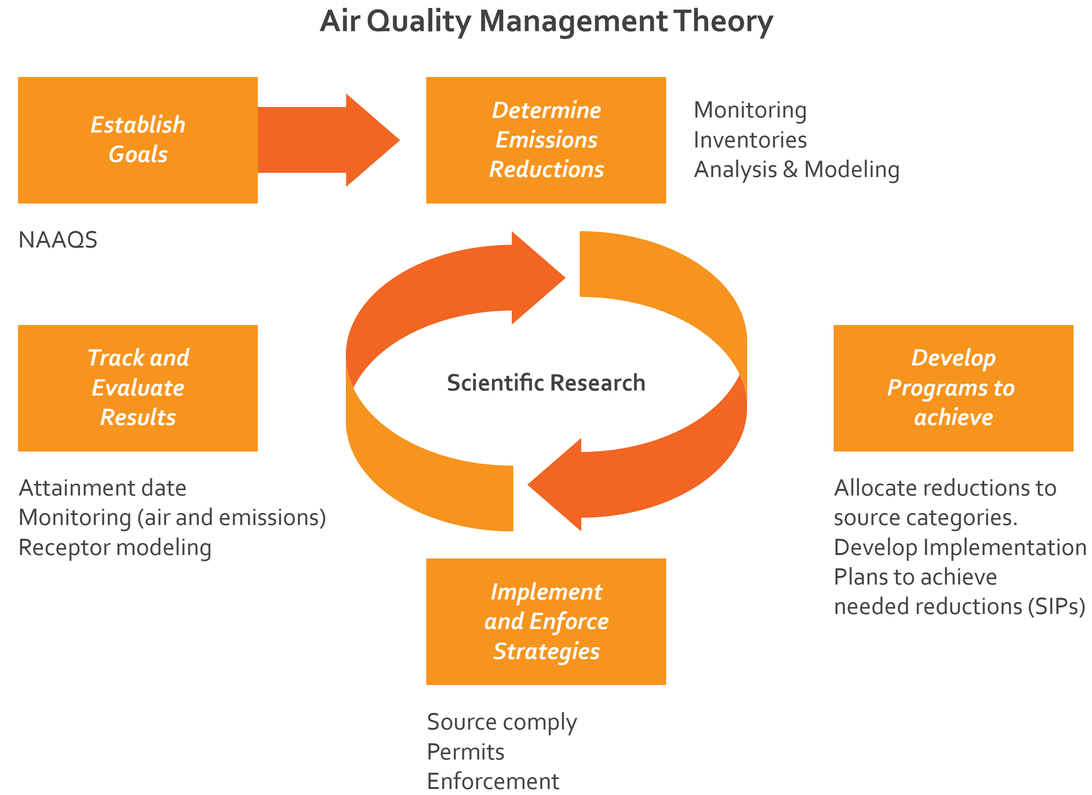


Figure 2.1 Conceptual Air Quality Management Framework
Source: Bachmann, 2007

Policies, including standards, should be set to maximize social benefits. Also, the cost of setting and enforcing AAQS should ideally be considered in order to assess their economic efficiency (Anderson and Ostro, 1982). Implementing AAQS translates into reduction in social cost of poor AQ – mortality and lost years of healthy life – as well as reduction in economic cost – hospital admissions and emergency department visits, outpatient visits, and workdays lost. Losses may include loss of output from mortality and from incapacitation due to health conditions, and may be temporary or permanent (New Zealand Institute of Economic Research, 2009).

There are uncertainties involved in measuring the economic benefits from AAQS; nevertheless, various assessments have shown that the benefits from enforcing AAQS far outweigh the costs of implementing control measures. A sample estimate of cost-benefit analysis of USEPA's 2006 NAAQS for PM alone has estimated benefits at a range of $4 billion-$40 billion per year and with estimated costs of $3 billion per year. Benefits are quantified despite some uncertainties in reducing premature deaths associated with lower PM and in monetary value of reducing mortality risk (United States Office of Management and Budget, 2013). The full attainment of the 2012 PM NAAQS by 2020 can gain as high as $2.9 billion (USEPA, 2012). The Thematic Strategy on Air Pollution that the European Commission (EC) adopted in 2005 – to achieve ambition levels for reducing the impacts of O_3 and $PM_{2.5}$ on health, and acidification and eutrophication on ecosystems – is projected to achieve a total of annual health and non-health benefits in the range of €42-€136 billion for the year 2020 (depending on what values are used for reduced mortality due to particulate matter). The health benefits (estimated at average annual costs of €94-€301) exceed costs (average annual costs of €15) for every EU citizen, by between six and 19 times (Holland, et al., 2005).

2.1.4 Establishing ambient air quality standards

Japan and Germany were two early adopters of AAQS. Japan promulgated a PM standard as early as 1932 and sulfur dioxide (SO_2) standards in 1969 (Wilkening, 2004). West Germany established AAQS for SO_2, PM, dust, nitrogen dioxide (NO_2), and carbon monoxide (CO) in 1964 (Bruckmann et al., 2014). Meanwhile, an early study also cited that the Union of Soviet Socialist Republics, Poland, Canada and Romania (for SO_2 only), as well as the western US state of California, were early adopters of AAQS in the 1960s (Stern, 1964). California's first statewide AAQS dating back to 1959 were set by the California Air Resources Board (ARB) for total suspended particulates (TSP), photochemical oxidants, SO_2, NO_2 and CO (ARB, 2014).

The WHO proposed its first air quality guidelines (AQGs) in 1972 followed by releases and updates in 1987, 2000 and 2005 (WHO, 1972; 1987; 2000a; 2000b; 2005; 2006). The AQG of 1972, 2000b, 2005 and 2006 are globally applicable, while those of 1987 and 2000a were for Europe only. These AQGs intended to provide the basis for protecting public health and the environment from the adverse effects of environmental pollutants and to guide national or local authorities in their risk assessment and risk management decisions (WHO, 2000a). These guidelines were developed and revised based on the growing body of knowledge on air pollution epidemiology and toxicology, as well as developments in risk assessment methods.

In earlier versions of the WHO guidelines, only one guideline was set for each pollutant at specific averaging periods. In the most recent update, however, the concept of interim targets was introduced to encourage countries with high pollution levels to shift to lower pollution levels and achieve significant reductions in health risks (Table 2.2).

Table 2.2 Summary of WHO ambient air quality guidelines (μg/m³)

Guideline/IT	PM_{10}		$PM_{2.5}$		O_3	NO_2		SO_2	
	Annual	24hr	Annual	24hr	Daily max 8hr mean	Annual	24hr	24hr	10min
WHO IT-1	70	150	35	75	160			125	
WHO IT-2	50	100	25	50				50	
WHO IT-3	30	75	15	37.5					
WHO AQG	20	50	10	25	100	40	200	20	500

Notes: AQG –air quality guideline; IT –interim target

Source: WHO, 2005

While the WHO AQGs are intended for worldwide use to achieve a safe AQ for public health, WHO recognizes that governments should consider their own local circumstances before directly adopting these guidelines as their own AQS. WHO further recognizes that countries differ in their level of development and AQM capability, their approach to balancing health risks, and their socioeconomic and political conditions.

When establishing AAQS, governments generally need to consider a number of scientific, social, technical and economic factors (Haq & Schwela, 2008) (Box 2.1).

Additional factors such as AQ monitoring data, existing AAQS in other countries, environmental epidemiology studies, and the WHO AQGs are considered most often in establishing or revising AAQS (Vahlsing & Smith, 2012). Air quality standards in Asia have mostly referred to the US NAAQS or WHO AQGs during their establishment; hence, this guidance area refers to the WHO process in developing and USEPA process in reviewing AAQS.

The US established its first set of NAAQS in 1971, shortly following the 1970 CAA Amendment and almost at the same time WHO released its first guidelines in 1972. As interpreted by the courts, the United States' CAA prohibits considering compliance costs in setting and reviewing AAQS, forcing USEPA to exclusively focus on protecting public health as the main driving factor (Anderson & Ostro, 1982). The US NAAQS, however, are of two types: primary standards that provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly; and secondary standards that provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings (USEPA, 2014) (Table 2.3). The NAAQS are required to be reviewed every five years and, if necessary, revised.

While the **WHO air quality guideline values** are intended for worldwide use **to achieve a safe air quality** for public health, WHO recognizes that **governments** should consider their own **local circumstances** before directly adopting these **guidelines** as their own **air quality standards**.

Box 2.1
Factors considered in setting air quality standards

- **Sensitive receptors** – members of the human population more vulnerable to air pollution than the general population such as children, elderly, and disabled persons; components of the environment or a specific stage in biological organisms' development more sensitive than that of others
- **Pollutant behavior in the atmosphere** – the reactions the pollutant undergoes and its residence time in the atmosphere
- **Pollutant behavior in the environment** – the ability of a substance to bioaccumulate or biodegrade after entering the environment
- **Natural levels and fluctuations** – concentration levels and fluctuations of pollutants that occur naturally or enter the atmosphere from uncontrollable sources (e.g., volcanoes, deserts, forest fires)
- **Technological feasibility** – the cost and availability of technology to control or avoid emissions

Source: Haq & Schwela, 2008

Table 2.3 Summary of US national ambient air quality standards

Pollutant	Primary/ Secondary	Averaging Time	Level	Form
CO	primary	8 hr	9 ppm	not to be exceeded more than once per year
		1 hr	35 ppm	
Pb	primary and secondary	rolling 3 month average	0.15 μg/m^3	not to be exceeded
NO_2	primary	1 hr	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3years
	primary and secondary	Annual	53 ppb	annual mean
O_3	primary and secondary	8 hr	0.075 ppm	annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
$PM_{2.5}$	primary	Annual	12 μg/m^3	annual mean, averaged over 3 years
	secondary	Annual	15 μg/m^3	
	primary and secondary	24 hr	35 μg/m^3	98th percentile, averaged over 3 years
PM_{10}	primary and secondary	24 hr	150 μg/m^3	not to be exceeded more than once per year on average over 3 years
SO_2	primary	1 hr	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	secondary	3 hr	0.5 ppm	not to be exceeded more than once per year

Source: USEPA, 2014

2.1.5 Reviewing the national ambient air quality standards

Considering the process of review of NAAQS in the US is worthwhile, given its long history. As required by the CAA, the standards are reviewed every five years and, if needed, revised. The review process follows five major phases and involves rigorous scientific reviews where all documents and drafts are reviewed by a Clean Air Scientific Advisory Committee (CASAC). Public hearings are held on the proposed decisions as part of the review process (Table 2.4).

An AAQS review process such as the one described can be expensive, and hence cannot be readily performed in less and least developed countries of Asia. In these cases, it is recommended that standard setting and review in those countries be based on the outcomes of the processes in WHO, USEPA and/or other developed countries. Since the WHO AQGs and their interim values were established using a rigorous evidence-based decision-making process, these can be readily chosen as a starting point for setting standards.

Table 2.4 Summary of national ambient air quality standards review process in the US

Phase	Description/Activities
Planning	A science policy workshop is organized to gather inputs from the scientific community and the public regarding policy-relevant issues and questions that will frame the review. The USEPA then prepares an Integrated Review Plan that presents the schedule for the entire review, the process for conducting the review, and the key policy-relevant science issues that will guide the review.
Integrated Science Assessment (ISA)	This assessment is a comprehensive review, synthesis, and evaluation of the most policy-relevant science, including key science judgments that are important to inform the development of the risk and exposure assessments.
Risk/Exposure Assessment (REA)	Following inputs from the ISA, REA develops quantitative characterizations of exposures and associated risks to human health or the environment associated with recent air quality conditions and with air quality estimated to just meet the current or alternative standard(s) under consideration. Risk exposure assessment includes characterization of the uncertainties associated with such estimates.
Policy Assessment (PA)	Policy Assessment provides a transparent staff analysis of the scientific basis for alternative policy options for consideration by senior USEPA management to help "bridge the gap" between the Agency's scientific assessments, presented in the ISA and REA(s), and the judgments required of the USEPA Administrator. In doing so, the PA is also intended to facilitate the CASAC's advice to the Agency and recommendations to the Administrator, as provided for in the CAA, on the adequacy of the existing standards or revisions that may be appropriate to consider. The PA focuses on evaluating the basic elements of the NAAQS: indicator, averaging time, form, and level.
Rulemaking	Taking into consideration the ISA, REA(s), and PA as well as the advice of CASAC, USEPA develops and publishes a notice of proposed rulemaking that communicates the Administrator's proposed decisions regarding the review of the NAAQS. A public comment period, during which public hearings are generally held, is taken into account before USEPA issues a final rule.

Source: USEPA, 2014

Regulatory authorities need to undertake **specific obligations** to ensure that the **standards** are implemented and met, taking into account the **cost of control strategies**.

2.1.6 Implementing national ambient air quality standards

The process does not end with issuing new or revised AAQS. Regulatory authorities need to undertake specific obligations to ensure that the standards are implemented and met, taking into account the cost of control strategies. The process takes years or even decades, especially for pollutants where the level of standards are not easily attainable. In the case of the US, within two years after the NAAQS promulgation, the USEPA must identify and designate attainment areas (meeting standards) and nonattainment areas (not-meeting standards) based on the most recent set of air monitoring data. Two types of State Implementation Plans (SIP) are then developed — an attainment-maintenance SIP if the area is designated as attainment, and an attainment-demonstration SIP if designated as nonattainment. A similar system is implemented in the EU where zones with a likelihood of an exceedance must be monitored more closely. Air quality management plans or programs are also developed to describe how those zones will come into attainment in the future.

Another important area in AQM is multi-pollutant control. Understanding the complex interactions of pollutants with each other as well as their impacts is also critical in achieving better air quality and avoiding adverse impacts (Scheffe et al., 2009; Chow et al., 2012; Cao et al., 2013). Many pollutants can be co-controlled. For example, reducing SO_2, nitrogen oxides (NOx), and CO emissions may result in the reduction of CO_2, O_3 and PM. This approach would be more cost-effective than the implementation of single pollutant AQS.

Figure 2.2 shows simplified relationships and the interactions among various emissions sources, their primary pollutants, the transforming product (Intermediates) in the atmosphere, and the effects by most dominant pollutants. It should be noted that the residence time of each pollutant varies – e.g., from minutes to hours for ultrafine PM to over 100 years for carbon dioxide (CO_2) and some greenhouse gases (GHGs). In addition, the exposed concentration level, lag times and duration dictate the extent of adverse effects. Challenges for $PM_{2.5}$ -focused AQM will involve its interaction with these different pollutants and effects.

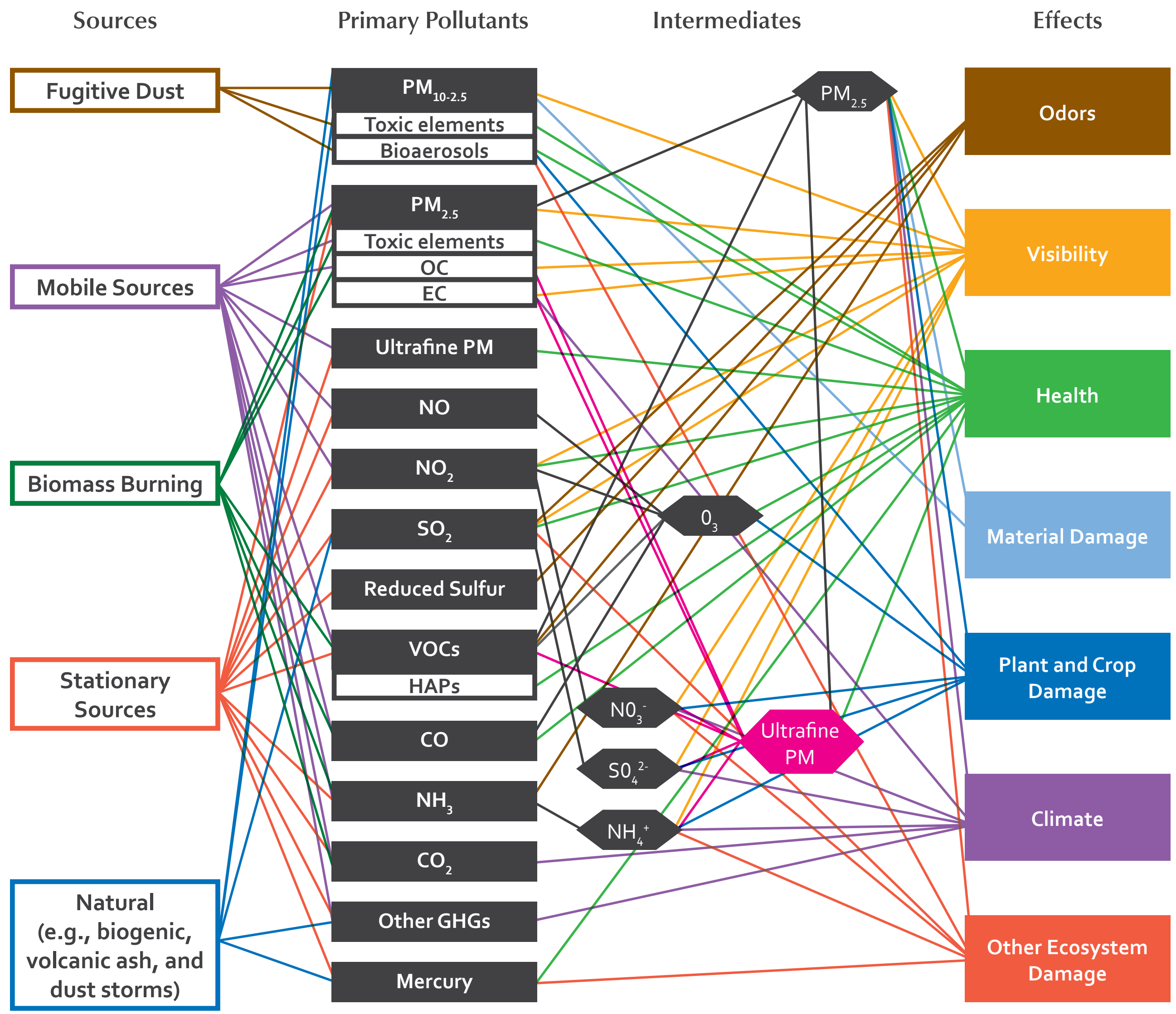


Figure 2.2 Multiple pollutants and their multiple adverse effects

Source: Cao et al., 2013

2.1.7 Air quality monitoring

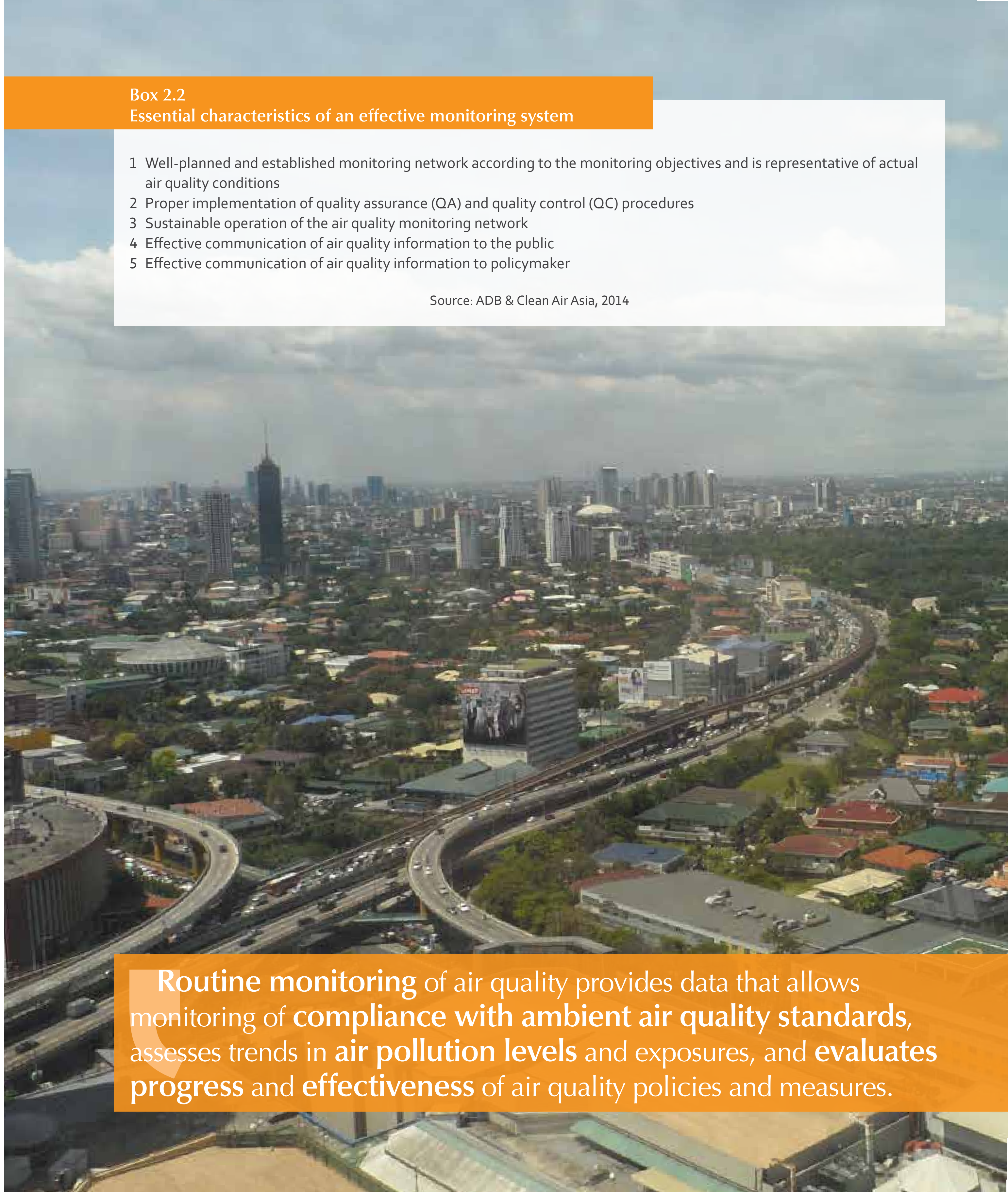
Another key component of effective AQM is a sustainable and efficient AQ monitoring system. Routine monitoring of AQ provides data that allows monitoring of compliance with AAQS, assesses trends in air pollution levels and exposures, and evaluates progress and effectiveness of AQ policies and measures. Robust and credible AQ data contribute to effective decision-making in AQM and this can be achieved only through an effective monitoring system (Box 2.2). Monitoring systems/programs also need to be cost-effective; have stable financial, operational and personnel resources; and adjusted to local needs and conditions (WHO, 1999).

The design of an AQ monitoring program is primarily defined by its purpose or objectives. The design will then determine: size and sophistication of the monitoring network (including equipment); location and number of sampling stations; duration and frequency of sampling; and, most importantly, the financial and manpower resources needed to operate and sustain the network. Air quality monitoring activities can be grouped according to three broad types of objectives: timely public reporting, compliance, and research (Table 2.5).

Table 2.5 Common objectives for conducting air quality monitoring

Basic Objectives	Specific Objectives
Timely public reporting	Assess short-term pollution levels
	Develop an air quality index (or other tools for data communication)
	Forecasting
Compliance	Determine compliance levels with standards
	Observe pollution trends
	Formulate pollution control strategies
	Examine the extent and causes of elevated concentrations
	Enhance understanding of chemical and physical properties of atmospheric pollution and pollution sources
	Evaluate the effectiveness of pollution control strategies
	Support national and international agreements and initiatives
Research	Identify pollutant generation and behavioral characteristics
	Assess impacts to different groups of populations
	Assess impacts to visibility impairment, climate change and ecosystems
	Validate models
	Discover new contaminants

Source: USEPA, 2013 cited in Asian Development Bank (ADB) and Clean Air Asia, 2014



Box 2.2
Essential characteristics of an effective monitoring system

1. Well-planned and established monitoring network according to the monitoring objectives and is representative of actual air quality conditions
2. Proper implementation of quality assurance (QA) and quality control (QC) procedures
3. Sustainable operation of the air quality monitoring network
4. Effective communication of air quality information to the public
5. Effective communication of air quality information to policymaker

Source: ADB & Clean Air Asia, 2014

Routine monitoring of air quality provides data that allows monitoring of **compliance with ambient air quality standards**, assesses trends in **air pollution levels** and exposures, and **evaluates progress** and **effectiveness** of air quality policies and measures.

Air pollution – and its drivers – is **complex in nature**; it requires an **air quality monitoring** program that is **dynamic** — one that needs to be **periodically reviewed** and **improved** to ensure that it is **responsive** to these factors.

There are various technical guidelines for designing and operating an AQ monitoring program/network, including those from WHO, USEPA, and the EU (Table 2.6). Air pollution – and its drivers – is complex in nature; it requires an AQ monitoring program that is dynamic — one that needs to be periodically reviewed and improved to ensure that it is responsive to these factors (ADB & Clean Air Asia, 2014). These guidelines present differences in prescribed specifications for the number of sampling points/stations and the probe height, among others.

Table 2.6 List of internationally accepted technical guidelines for air quality monitoring networks/programs

Organization	Title/Link to Guidelines
WHO	Monitoring Ambient Air Quality for Health Impacts Assessment http://www.euro.who.int/__data/assets/pdf_file/0010/119674/E67902.pdf
USEPA	Air Planning and Standards http://www.epa.gov/airquality/montring.html Guidance for Network Design and Optimum Site Exposure for $PM_{2.5}$ And PM_{10} http://www.epa.gov/ttn/amtic/files/ambient/pm25/network/r-99-022.pdf Guidance for Using Continuous Monitors in $PM_{2.5}$ Monitoring Networks http://www.epa.gov/ttn/amtic/files/ambient/pm25/r-98-012.pdf
EU	Directives for Monitoring Atmospheric Pollution (Directive 2008/50/EC) http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=EN
Stockholm Environment Institute (SEI)	Global Atmospheric Pollution Forum (GAPF) Air Pollution Monitoring Manual http://www.sei-international.org/rapidc/gapforum/html/projects.php
Environment Canada	National Air Pollution Surveillance Program http://www.ec.gc.ca/rnspa-naps/

Source: Updated from ADB & Clean Air Asia, 2014

Established QA/QC protocols and procedures covering various elements is another essential characteristic of an effective AQ monitoring system (Table 2.7 and 2.8). Quality assurance is defined as the external system that verifies the precision, accuracy and validity of AQ measurements. Quality control is defined as the internal system for estimating and maintaining the precision, accuracy and validity of AQ measurements (Chow et al., 2012).

Table 2.7 Key elements in quality assurance and quality control

Quality Assurance	Quality Control
• System audits to assure that procedures are being followed or modified to reflect current practice • Performance audits to evaluate outputs for external standards • Inter-laboratory comparisons and co-located sampling • Interference evaluation with reference materials	• Standard Operating Procedures (SOPs), revised periodically • Periodic instrument calibrations with transfer standards • Periodic zeros and spans with performance standards • Replicate analyses • Cross-instrument comparisons • Internal consistency tests

Source: Chow et al., 2012

Table 2.8 Essential components of a quality assurance/quality control process

Activities in a quality assurance/ quality control process	Elements covered
Develop specifications for operating a monitoring network	Data quality objectives
	Measurement methodology (reference methods)
	Equipment selection and operation
	Site selection (site classification, distribution and location)
	Sampling system (shelter requirements and probe siting)
Assess compliance to the developed guidelines (standard operating procedures and calibration)	Station and analyzer operation (station visits, ensuring that operation procedures are followed, and preventive maintenance)
	Calibration (primary and secondary calibration standards, calibration frequency, calibration procedures, and zero and span verifications)
Implementing corrective actions to ensure compliance	System audits and station performance (includes independent verifications)
	Data validation
	Documentation (log books and operation manuals)
	Personnel training and technical support

Source: USEPA, 2013 and Watson et al., 2013

2.2 Stages of ambient air quality standards and air quality monitoring

In line with enabling cities to establish and strengthen AAQS to protect public health and the environment with sustainable national AQ monitoring programs that enrich understanding of air quality status, Tables 2.9 and 2.10 present indicators to aid cities or countries in identifying their current state of development in terms of AQS and monitoring.

The following are the key indicators for consideration:

- Development of AAQS and alignment with other targets
- Setting up an adequate AQ monitoring system
- Monitoring compliance
- AAQS review process
- Sustainability of AQ monitoring system

Table 2.9 Stages for ambient air quality standards to protect public health and environment

Stages	Indicators
Underdeveloped	Absence of AAQS.
Developing	Ambient air quality standards for selected criteria pollutants are available. Ad hoc AQ monitoring systems monitor compliance to AAQS. There is no review process for AAQS in place.
Emerging	Ambient air quality standards for all criteria pollutants are available. A phased approach to achieve more stringent AAQS is used. Compliance to AAQS is routinely monitored, and attainment and non-attainment assessed. Links to other sector/development plans are envisaged. There is an ad hoc review process for AAQS.
Maturing	Ambient air quality standards for criteria pollutants are in line with WHO ambient AQGs and interim targets; compliance to AAQS monitored and reported regularly to the public. Attainment and non-attainment areas are regularly assessed. Ambient air quality standards are reviewed regularly and linked with other sector/development plans. Standards for pollutants other than criteria pollutants are being considered.
Fully developed	Ambient air quality standards for criteria pollutants and other toxic pollutants are mandatory, and in line with WHO AQGs and/or interim target values; compliance to AAQS is monitored and reported regularly to the public. Ambient air quality standards are reviewed regularly (at least every five years) to improve and protect vulnerable population groups and areas. Review takes into account multiple pollutant control approaches. Attainment and non-attainment areas are designated and regularly assessed. Non-attainment areas are closely monitored and pollution strategies are evaluated in line with achieving the AAQS. Compliance and non-compliance to AAQS are linked with development/sector plans and policies (e.g., airport expansion, vehicle emissions standards, and others).

Table 2.10 Stages for strengthening air quality monitoring

Stages	Indicators
Underdeveloped	Absence of ambient AQ monitoring system.
Developing	Monitoring activities are only project-based or on an ad hoc basis and provides data to a limited range of stakeholders. Existing monitoring data is used to check compliance to AAQS but not sufficient to designate attainment and non-attainment areas. Human resources, technical capacity and financial resources are available for project-based or ad hoc monitoring only.
Emerging	Air quality monitoring system covers selected pollutants of concern and hotspots. There are QA/QC procedures as part of the AQ monitoring that have potential to be strictly implemented. Human resources, technical capacity, and financial resources are sufficient to support AQ monitoring for selected pollutants and hotspots.
Maturing	Air quality monitoring system covers all criteria pollutants and includes continuous monitoring stations, with a mix of different station types: background, roadside, industrial and residential. Quality assurance/quality control procedures are strictly followed. Air quality monitoring data are appropriately shared with different stakeholders. Human resources, technical expertise, and financial resources are sufficient to sustain AQ monitoring systems for all criteria pollutants, which has a mix of different types of monitoring stations. There are initiatives to secure funding support from other sources (aside from government) to support AQ monitoring systems.
Fully developed	Air quality monitoring system covers all criteria pollutants and other pollutants – volatile organic compounds (VOCs), toxics, among others. Adequate size and scope of AQ monitoring system are based on population, size and characteristics of the area. Different station types are present and may cover sensitive receptor sites, as necessary. Sufficient resources, including human and financial resources, are available for sustaining operation of AQ monitoring systems. Quality assurance and quality control procedures are strictly followed. A process for review of AQ monitoring system exists. Proper mechanism for communication of AQ information to target stakeholders – public, government, media, academe, private sector, civil society, development banks and foundations – are in place. Strategies are in place to assess a wide mix of financing sources to sustain AQ monitoring systems.

2.3 Issues and challenges

Despite the availability of technical guidance and assistance from international donors and organizations, issues and challenges surrounding AAQS and AQ monitoring in Asia remain. The issues and challenges on AAQS and AQ monitoring listed below are primarily based on inputs from previous Governmental Meetings on Urban Air Quality in Asia, previous and recent Clean Air Asia project findings, consultations with AQM stakeholders, and online research (SEI et al., 2004 and ADB & Clean Air Asia, 2014).

Air Quality Standards

Of the 22 Asian countries and territories surveyed by Clean Air Asia, only two have not adopted AAQS. Although some of these standards have been in place for years and even decades, challenges in ensuring that these translate into safe AQ levels that protect the health of the public and that of susceptible populations persist. Table 2.11 summarizes the standards available for some selected pollutants. However, various countries may also have standards for many other pollutants.

Table 2.11 Overview of ambient air quality standards (selected pollutants) in selected Asian countries [μg/m³, unless otherwise stated]

Countries	$PM_{2.5}$		PM_{10}		TSP		SO_2			NO_2			O_3		CO ('000)	
	24 hr	Annual	24 hr	Annual	24 hr	Annual	1 hr	24 hr	Annual	1 hr	24 hr	Annual	1 hr	8 hr	1 hr	8 hr
Afghanistan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bangladesh	65	15	150	50	-	-	-	365	80	-	-	100	235	157	40	10
Bhutan (Mixed)	-	-	100	60	200	140	-	80	60	-	80	60	-	-	4	2
Brunei Darussalam	-	15	150	40	-	-	-	-	-	-	-	-	-	-	-	-
Cambodia	-	-	-	-	330	100	500	300	100	300	100	-	200	-	40	22.9
PR China: Grade I[1]	35	15	50	40	120	80	150	50	20	200	80	40	160	100	10	-
PR China: Grade II[1]	75	35	150	70	300	200	500	150	60	200	80	40	200	160	10	-
Fiji			50				350		200				150	150		10
Hong Kong SAR	75	35	100	50	-	-	-	125	-	200	-	40	-	160	30	10
India[2]	60	40	100	60	-	-	-	80	50	-	80	40	180	100	4	2
India[3]	60	40	100	60	-	-	-	80	20	-	80	30	180	100	4	2
Indonesia	65	15	150	-	230	90	900	365	60	400	150	100	235	-	30	-
Iran	25	10	50	20				96.94	18.34			39.48		100	40.075	10.575
Japan	35	15	100*	-	-	-	261.6	104.64	-	-	75-113	-	117.72	-	-	23
Lao PDR	-	-	120	50	330	100	780	300	100	320	-	-	200	-	30	10.26
Malaysia[4]	-	35	150	50	260	90	350	105	-	320	75	-	200	120	35	10
Mongolia	50	25	150	50	150	100	-	20	10	85	40	30	-	100	30	10
Myanmar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nepal	40	-	120	-	230	-	-	70	50	-	80	40	-	157	-	10
Pakistan	35	15	150	120	500	360	-	120	80	-	80	40	130	-	10	5
Philippines	75	35	150	35	230	90	-	180	80	-	150	-	140	60	35	10
Philippines[5]	50	25	150	60	230	90	-	180	80	-	150	-	140	60	35	10
Republic of Korea	50	25	100	50	-	-	392	131	52	188	113	56	196	118	29	10
Singapore[6]	37.5	12	50	20	-	-	-	50	15	200	-	40	-	100	30	10
Singapore[7]	25	10	50	20	-	-	-	20	-	200	-	40	-	100	30	10
Sri Lanka	50	25	100	50	-	-	200	80	-	250	100	-	200	-	30	10
Thailand	50	25	120	50	330	100	780 (0.3 ppm	300 (0.12 ppm)	100 (0.04 ppm)	320 (0.17 ppm)	-	57 (0.03 ppm)	200 (0.10 ppm)	140 (0.07 ppm)	34.2 (30 ppm)	10.26 (9 ppm)
Viet Nam	50	25	150	50	200	140	350	125	50	200	-	40	20	120	30	10

Note: Units are in μg/m³, unless otherwise stated

SAR = Special Administrative Region; PDR = People's Democratic Republic; Pb = lead; PM_{10} = Particles with aerodynamic particle diameters of 10 μm or less; $PM_{2.5}$ = Particles with aerodynamic particle diameters of 2.5 μm or less; China: Grade I = Special protection areas, nature reserves and scenic areas; Grade II = applies to residential areas, mixed commercial/residential areas, cultural, industrial, and rural areas; [1]= GB3095-2012 | National implementation in 2016; [2] = NAAQS for Industrial, Residential, Rural, and Other Areas; [3] = NAAQS for Ecologically Sensitive Areas (notified by Central Government); [4] = Interim target for 2015; [5] = DAO 2013-13 | $PM_{2.5}$ strengthened in 2016; [6] = Singapore targets by 2020; [7] = long term targets.

*Defined as airborne particles that pass through a size-selective inlet with a 100 percent efficiency cut-off at 10 μm aerodynamic diameter.

Ozone (O_3) Conversion factor for ppb to μg/m³: 1.962
Carbon monoxide (CO) Conversion factor for ppb to μg/m³: 1.145

Sulfur dioxide (SO_2) Conversion factor for ppb to μg/m³: 2.616
Nitrogen dioxide (NO_2) Conversion factor for ppb to μg/m³: 1.880

Source: Clean Air Asia, 2014 [collected from various sources].

Institutional

There is no global target/roadmap/framework on air pollution (similar to the Kyoto Protocol or United Nations Framework Convention on Climate Change [UNFCCC]) for climate change or Montreal Protocol for ozone depleting substances), thus there is a lack in alignment of AQS with global guidelines or standards (i.e. WHO guidelines and interim targets)

Alignment between AQS and other sectoral standards (e.g. vehicle and fuel quality standards) at the country or city level is also missing. There are a few local governments (cities or provinces) in Asia with far more advanced fuel and vehicle quality or emissions criteria than those for the rest of the country. This is usually because of the national government's policy to implement stricter standards in key cities prior to implementation at the country level. One of these cities is Jakarta, where SO_2 (24 hr), NO_2 (24 hr and annual), and O_3 (annual) standards are more stringent than those for the rest of Indonesia (Clean Air Asia, 2010).

Management and technical

Air pollution competes with other environment and development issues. Other competing urban environment issues include municipal solid waste, storm water/flood management, access to clean water, etc.

Environmental enforcement and implementation of standards is also generally weak. As a consequence, there are technical capacity deficiencies in assessing compliance with the standards and a wide participation of stakeholders in the implementation of AAQS and policies are lacking.

Alignment of AQM policies with other sector policies and plans are limited. Economic goals to promote certain industries (e.g. automobile) or industrial expansion can counter any air pollution reduction goals.

Some Asian countries have not updated/revised their standards for more than five years. In some cases, countries have kept their AAQS much higher than WHO guidelines even when the actual concentration levels have been met for a long time. This can unintentionally create an allowance to pollute instead of aiming towards AQ improvement.

Financial

The financial constraints for AQS is not so much on the establishment of the standards but more on the implementation of the standards, especially in the lack of funds for AQ monitoring systems to check compliance with the standards. There is also limited funding for local research and studies on exposure risks, policy reviews and relevant pollutant control strategies which are necessary inputs to the establishment or review of **AQS**.

Air Quality Monitoring

While there are now more AQ data available in the region as compared with a decade ago, several issues on AQ monitoring remain.

Institutional

Awareness of AQ monitoring data and results in all levels of government, stakeholder and general public is lacking. This is linked with air pollution not always being a priority agenda for governments and in turn translates to lacking wide stakeholder participation and investment for AQ monitoring.

Collaboration with other relevant stakeholders is weak. There is weak or no coordination among different monitoring agencies, no SOPs, and harmonization of monitoring networks and devices. There is lack of participation in regional monitoring network activities and lacking active participation and investment from private sector and academe.

Management and technical

There is often a lack of staff dedicated to AQ monitoring in Asian cities. Staff often have to simultaneously cover other environmental monitoring and reporting work. Air quality monitoring involves the use of sophisticated equipment and good technical understanding of air quality science. When personnel are trained specifically for AQ monitoring jobs, they often move on to other roles faster than they are replaced and knowledge and skills are often lost in the organization.

There is limited training for new staff and skills upgrade for existing staff which then translate to a wide array of technical issues in AQ monitoring – i.e. calibration, QA/QC, data management, etc.

Technical capability relevant for AQ monitoring is lacking or missing – including meteorological monitoring, data management skills, AQ monitoring equipment repair and troubleshooting.

Financial

Funding for AQ monitoring is often inadequate and not sustainable. Almost all countries in Asia benefited from foreign grants or technical assistance to fund the establishment of their AQ monitoring system. Several of these networks ended as soon as project funds were depleted. Countries and cities also started to make significant investments from local funds but the monitoring activities were also not maintained due to lack of sustainability plans.

2.4 Roadmap for ambient air quality standards and air quality monitoring

To move up the development stages for AAQS and AQ monitoring, there are measures that cities or countries can implement to overcome issues and challenges (Table 2.12 for AAQS and Table 2.13 for AQ monitoring).

Table 2.12 Recommended steps to implement roadmap for better ambient air quality standards to protect public health and environment

Developmental stages	Steps to follow

Underdeveloped	**Management Process**
	• Create advocacy and awareness campaigns to bring air pollution into the public agenda and push for a political decision to establish and adopt AAQS [See *Guidance Area 4 Air quality communication*]
	• Conduct stakeholder meetings and public input workshops so that the process of establishing AAQS recognizes and involves major stakeholders – AQ experts, epidemiologists, toxicologists, medical professionals, ecologists, environmental economists, industries, government line ministries, and non-governmental organizations representing the public. The consultative approach and collective wisdom may provide wider acceptability of the standards and its rationale, and ensure effective implementation through stakeholders' participation
	• Identify thought leaders, decision-makers and influencers to ensure linkages of AAQS with other sector policies
	• Establish Technical Team from different government and non-government stakeholder groups who will be responsible for the oversight of the process to develop AAQS for criteria pollutants. The team would be a small working group of select government staff, with the possible addition of consultants or university experts
	
	Technical Process
	• Determine selection of pollutants and averaging periods, basis for which may include:
	  o Whether or not substances or mixtures pose widespread problem in terms of sources and potential for exposure is large
	  o Availability of significant information on health effects (e.g., WHO guidelines, USEPA criteria documents, other air pollution epidemiological studies)
	  o Past trends in ambient air levels (e.g., rising $PM_{2.5}$ levels due to urbanization and motorization)
	  o Guidance from international standards and established standards from neighboring Asian countries with similar socioeconomic and environment conditions

Developing	**Management Process** • Continue awareness campaigns to sustain public interest on air pollution and demand for more stringent AAQS for all criteria pollutants • Strengthen implementation of AAQS through development of clean air action plans and reporting of progress [See *Guidance Area 5 on Clean air action plans*] • Strengthen co-ordination and integration of AQM policies with other sector policies and plans (e.g., transport, energy, industry, among others) **Technical Process** • Develop at the national level standard/uniform methodologies for AQ monitoring to guide cities • Build capacity for AQ monitoring system to cover selected pollutants of concern and hotspots, monitor compliance to AAQS, and ensure that major cities have at least one monitoring station to designate and assess attainment and non-attainment areas • Build capacity for ad hoc review of AAQS
Emerging	**Management Process** • Strengthen implementation of AAQS • Consider AAQS in the development of other sector plans **Technical Process** • Establish attainment and non-attainment for cities or regions • Cluster cities or zones according to AQ levels, compliance, and attainment; assess for possibility of more stringent standards in "cleaner" cities • Conduct assessment and review on phasing-in more stringent standards for criteria and other pollutants • Build capacity for regular review of AAQS
Maturing	**Management Process** • Establish a robust health statistics database based on health surveillance [See *Guidance Area 3 on Health and other impacts*] **Technical Process** • Regularly assess attainment and non-attainment areas • Conduct a comprehensive review of most policy-relevant science and literature on risks and exposures that are globally and locally available • Cooperate with academe and technical agencies to conduct risks/exposure assessments • Review AAQS regularly (at least every five years) and routinely monitor compliance • Gather inputs from the academic and scientific communities, and the private and public sectors to prepare policy-relevant issues that will frame the review

Developmental stages	Steps to follow
Fully developed	**Management Process** • Adopt international targets on air pollution • Align AAQS for criteria pollutants and other toxic pollutants with WHO AQGs and/or interim targets • Communicate costs and benefits of AAQS to the public **Technical Process** • Prepare cost-benefit analysis on the implementation of AAQS [See *Guidance Area 3 on Health and other impacts*] • Review AAQS regularly (at least every five years) or when important WHO AQGs are updated • Review linkages of AAQS with sector plans

Table 2.13 Steps to follow to implement roadmap for strengthening air quality monitoring

Developmental stages	Steps to follow
Underdeveloped	**Management Process** • Adopt AAQS (if there is none yet), to mandate routine AQ monitoring • Conduct AQ monitoring to support standards development • Define AQ monitoring objectives and data quality objectives • Identify capacities, skills and training needs for staff • Consider partnering with local university or research institute to support AQ monitoring activities **Technical Process** • Choose AQ monitoring equipment within available budget and manpower resources • Develop capacity for simple monitoring (e.g., manual samplers) and prioritize pollution hotspots • Build capacity for at least one station for air pollution monitoring of key pollutants
Developing	**Management Process** • Create project opportunities with other sectors (e.g., health, transport) to link AQ monitoring activities • Refine AQ monitoring objectives and data quality objectives • Identify capacities and skills and training to strengthen staff resources • Start reporting AQ data to public [See *Guidance Area 4 on Air quality communication*] • Collaborate with local or international academic organizations for AQ monitoring studies • Identify funding sources for AQ monitoring activities • Prepare AQ monitoring plans and guidelines • Provide sustainable training to address staff movements and technological developments **Technical Process** • Expand AQ monitoring network by adding more stations or pollutants monitored or improving frequency according to monitoring objectives and to support compliance monitoring to AAQS • Develop QA/QC plan, SOPs, and guidelines at the national level for AQ monitoring to guide cities • Develop QA/QC measures • Improve data management and AQ monitoring data use for health assessments • Build capacities for use of monitoring in AQ modeling – e.g. dispersion modeling [See *Guidance Area 2 on Emissions inventories and modeling*] and health assessments [See *Guidance Area 3 on Health and other impacts*]
Emerging	**Management Process** • Prepare plans to sustain AQ monitoring network, starting with financing of maintenance, equipment upgrade and human resource • Enhance reporting mechanisms of AQ data to the public to increase public awareness [See *Guidance Area 4 on Air quality communication*] • Collaborate with other countries' AQ monitoring activities • Ensure initiatives are in place to secure funding support from external sources **Technical Process** • Cooperate with meteorological agencies for sharing of expertise in AQ data interpretation and modeling • Enhance capacities for AQ modeling work [See *Guidance Area 2 on Emissions inventories and modeling*] • Make use of AQ data for health assessments [See *Guidance Area 3 on Health and other impacts*] • Make use of AQ data for assessing effectiveness of AQ and other related sector policies [See *Guidance Area 5 on Clean air action plans*] • Expand AQ monitoring network system to include more pollutants relevant for compliance and health assessments • Implement continuous skills training on AQ monitoring • Share technical expertise and knowledge with other Asian countries • Implement QA/QC procedures for AQ monitoring system
Maturing	**Management Process** • Sustain AQ monitoring network systems with proper planning and management • Develop strategies to access diverse financing sources to sustain operations • Network with neighboring countries and share data and technical knowledge through study visits **Technical Process** • Strengthen capacity for AQ modeling, including forecasting and health assessments • Review of AQ monitoring network system, including assessment of relevance of location/siting • Ensure adequate size and scope of monitoring system
Fully developed	**Management Process** • Collaborate with other countries to establish regional centers for AQ monitoring **Technical Process** • Pending availability of funds and capacity, explore or invest in studies using sophisticated or alternative AQ monitoring methods – e.g. monitoring supersites and remote sensors – for improved understanding of secondary PM mechanisms and regional transport of air pollution • Participate in studies and regional harmonization/cooperation work

Ambient air quality standards and AQ monitoring systems are two important AQM components that are closely interlinked. A simplified step-wise process to improve AAQS and AQ monitoring systems is discussed in **Annex I of the Information Sourcebook** and accompanied by case studies to better illustrate the recommended steps.

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