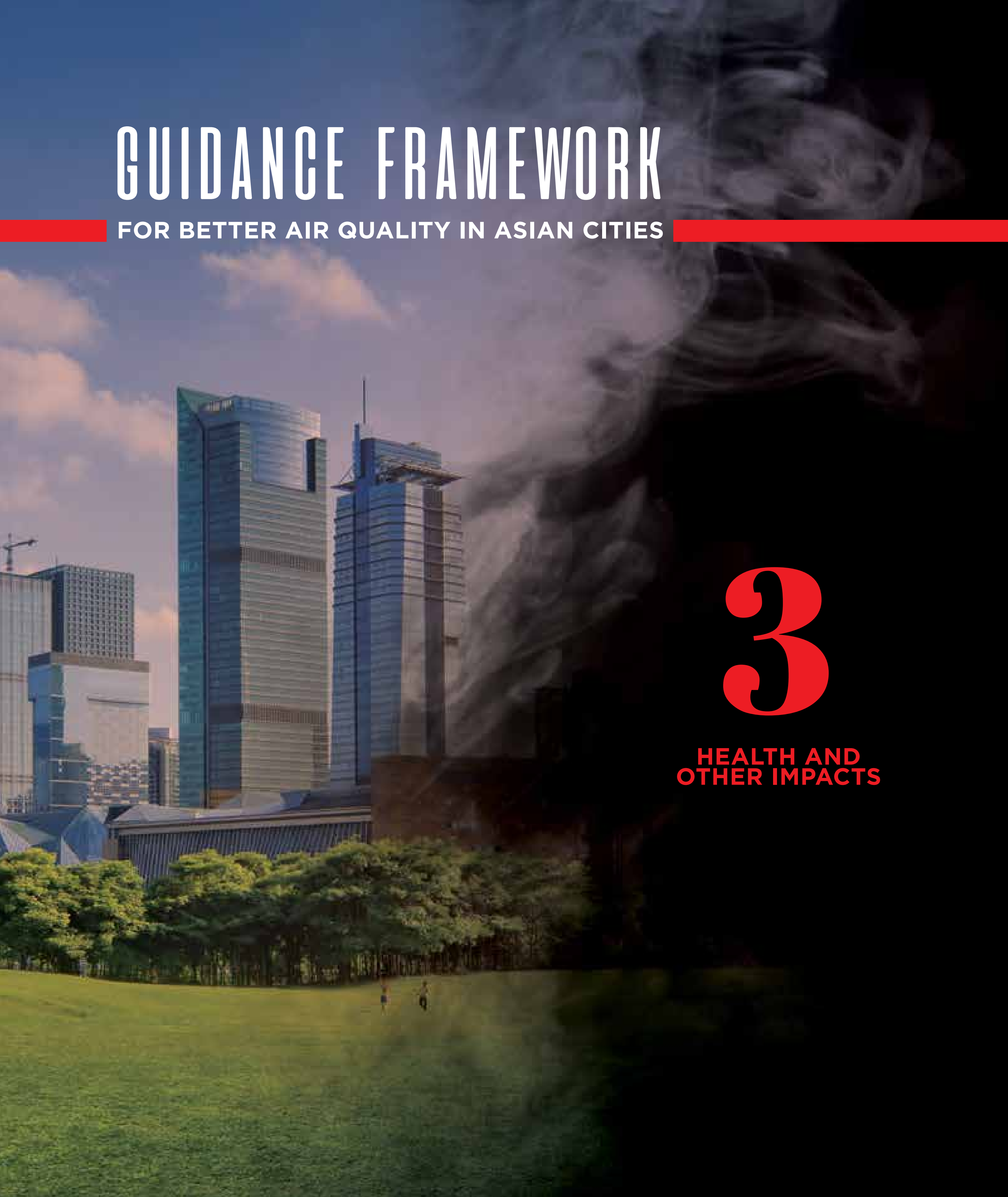
GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES



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HEALTH AND OTHER IMPACTS

GUIDANCE FRAMEWORK

FOR BETTER AIR QUALITY IN ASIAN CITIES

Guidance Area 3: Health and other impacts

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ABOUT THE GUIDANCE FRAMEWORK FOR BETTER AIR QUALITY IN ASIAN CITIES

The Guidance Framework is a voluntary and non-binding guidance document developed as an outcome of the biennial Governmental Meetings on Urban Air Quality in Asia, co-organized by Clean Air Asia and United Nations Environment Programme Regional Office for Asia Pacific (UNEP ROAP). It is an outcome of an extensive development process, which began in 2006 when the Long Term Vision for Urban Air Quality in Asia (LTV) was envisioned by representatives of environment ministries in the region. The LTV describes the desired state of urban air quality in Asian cities by 2030; the Guidance Framework serves as a guide for cities and countries to achieve this vision. In 2016, the Guidance Framework was launched as a pioneering approach to resolve air pollution challenges at the local- and national-levels. Centered on identified priority areas of concern in air quality management in the region, the Guidance Framework provides cities and countries with development capacity indicators and recommended steps and actions to improve air quality.

The Guidance Framework serves as a cornerstone document of Clean Air Asia's Integrated Programme for Better Air Quality in Asia (IBAQ Programme), which supports countries and cities in implementing the Guidance Framework through a range of targeted interventions, including knowledge-sharing platforms to strengthen regional collaboration, capacity building activities such as trainings, study tours and city twinning, and technical assistance at both the national and subnational levels.

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 261 organizations in 31 countries in Asia and worldwide, with nine country networks: China, India, Indonesia, Malaysia, 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 a 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. Policymakers, 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.

ABOUT UNEP
www.unep.org

The United Nations Environment Programme (UNEP) is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment. UNEP work encompasses assessing global, regional and national environmental conditions and trends; developing international and national environmental instruments; and strengthening institutions for the wise management of the environment. UNEP's mission includes to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

CONTENTS

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) in 2014 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.

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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

ABCs	Atmospheric Brown Clouds
AQM	Air Quality Management
BC	Black Carbon
CAAP	Clean Air Action Plan
CAHA	Climate and Health Alliance
CPCB	Central Pollution Control Board
CFCs	Chlorofluorocarbons
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
DPSEEA	Driving Force-Pressure-State-Exposure-Effect-Action
ECHP	European Centre for Health Policy
EPD (Hong Kong)	Environmental Protection Department
GAPF	Global Atmospheric Pollution Forum
GBD	Global Burden of Disease
GCEC	Global Commission on the Economy and Climate
GHG	Greenhouse Gas
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HFE	Fluorinated ethers
HIA	Health Impact Assessment
IARC	International Agency for Research on Cancer
IPCC	International Panel on Climate Change
MOEF (India)	Ministry of Environment, Forest, and Climate Change
NAAQS	National Ambient Air Quality Standards
NAMP	National Air Quality and Monitoring Program
NGO	Non-Governmental Organization
NH_3	Ammonia
NO_x	Nitrogen oxides
NO_2	Nitrogen dioxide
OECD	Organisation for Economic Co-operation and Development
O_3	Ozone
PFC	Perfluorinated Compounds
PM	Particulate Matter
PM_{10}	Particulate Matter (≤ 10 micrometers in diameter)
$PM_{2.5}$	Particulate Matter (≤ 2.5 micrometers in diameter)
SEI	Stockholm Environment Institute
SLCPs	Short-Lived Climate Pollutants
SO_2	Sulfur dioxide
UK	United Kingdom
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
WMO	World Meteorological Organization

The **exposure to ambient air pollution, particularly fine particulate matter** is estimated by WHO to have **caused 3.7 million premature deaths** worldwide in 2012.

CHAPTER 4

GUIDANCE AREA 3: HEALTH AND OTHER IMPACTS

4.1 Introduction

Ambient air pollution is a much more significant public health risk than previously assumed. This is one of the findings of two recent estimates on the global impact of air pollution on health —from the World Health Organization (WHO) in 2012 (WHO, 2014a) and from the Global Burden of Disease (GBD) project in 2010 (Lim et al., 2012).

The exposure to ambient air pollution, particularly fine particle or particulate matter ($PM_{2.5}$) is estimated by WHO to have caused 3.7 million[2] premature deaths worldwide in 2012. Most of the burden of air pollution is borne by the middle- and low-income countries in the WHO Western Pacific (WHO, 2014b) and South-East Asia regions – an estimated 1.6 million and 0.94 million deaths, respectively.

Over 76 million years of healthy life are lost due to air pollution according to the GBD's 2010 findings (Lim et al., 2012). The GBD ranks air pollution as the third most important risk of premature death in the world, after dietary risks and high blood pressure.

2 WHO's estimates' range is 3.188-4.291 million.

To **establish and/or strengthen** national and local programs that **monitor the health, environmental and economic impact** of air pollution consistently.

The GBD study shows that Asia gets the largest share of the ambient $PM_{2.5}$ -related deaths worldwide with an estimated 2.15 million deaths in 2010. Approximately 57 percent of these cases are in China and about 29 percent in India. This is also the case with premature deaths worldwide due to ground-level ozone (O_3) exposure, with Asia accounting for 83 percent of such deaths or 126,508 cases in 2010 (Figure 4.1).

More recently, in 2013, a group of experts working on behalf of WHO's International Agency for Research on Cancer (IARC) classified ambient air pollution in general and $PM_{2.5}$ in particular as carcinogenic (IARC Group 1) to humans (WHO/IARC, 2013a, b, c). This classification is based on sufficient evidence of carcinogenicity in humans and experimental animals, and strong evidence on the mechanisms (Brauer et al., 2012; Loomis et al., 2013; 2014). As a carcinogen, particulate matter (PM) has no threshold for the onset of effects.

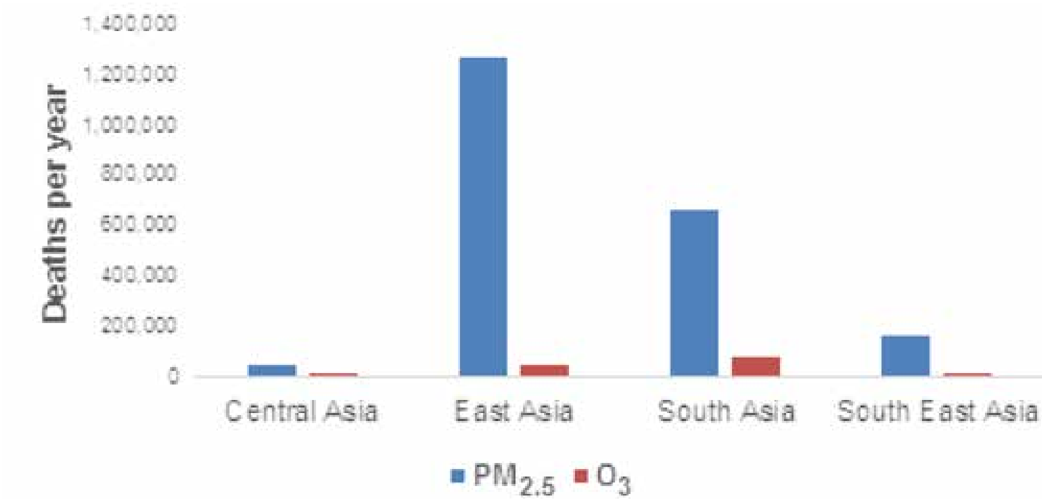

Figure 4.1 Regional distribution of premature deaths per year due to $PM_{2.5}$ and O_3

Source: Lim et al., 2012

4.1.1 Objective

To establish and/or strengthen national and local programs that monitor the health, environmental, and economic impact of air pollution consistently.

4.1.2 Importance of considering health and environmental impacts

Ambient and household air pollution has many significant impacts on human health and the environment. Many air pollutants have been classified as carcinogenic, in addition to causing a variety of respiratory and cardiovascular diseases. Impacts of air pollution on the environment include acidification of soil and freshwater systems, eutrophication of lakes and rivers, ozone layer depletion, and global climate change.

Understanding and estimating the impacts of air pollution as well as its economic costs to society are integral in the overall air quality management (AQM) framework. Any AQM framework is based on the Driving Force-Pressure-State-Exposure-Effect-Action (DPSEEA) framework depicted in Figure 4.2.

Analyzing the cost of air pollutant control measures *vis a vis* the benefits of avoided health and environmental impacts as a result of these measures is critical in improving the effectiveness of AQM. Without estimates on pollution damage costs, it is impossible to determine the cost effectiveness of air pollution prevention, mitigation, and control strategies. Identifying efficient and effective technologies and policy tools, needed for target setting and management strategy, also becomes unworkable.

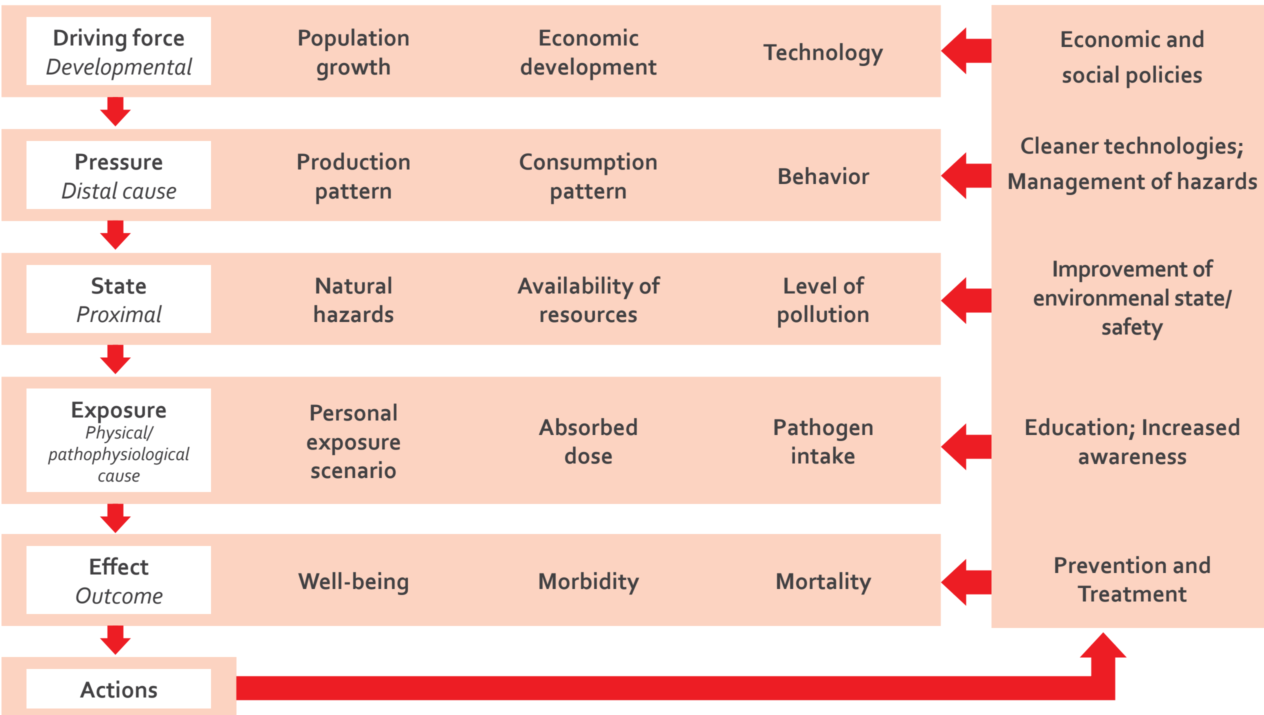

Figure 4.2 The DPSEEA framework[3,4]

Source: Adapted from WHO, 1995a

Understanding and estimating the impacts of **air pollution** as well as its **economic costs** to society are integral in the **overall air quality management** framework.

3 Absorbed dose: The amount of air pollutant absorbed, and therefore available to undergo metabolism, transport, storage, or elimination in the human body (WHO, 2000b).

4 Pathogen intake: The taking in of substances which can cause harm or disease (WHO, 2000a; Cyclopedic Medical Dictionary, 1997).

4.1.2.1 Health impacts of air pollution

The greatest impacts on human health tend to be focused on the effects of these common pollutants – $PM_{2.5}$, O_3, nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) – as well as toxic air pollutants and heavy metals.

Particulate matter
Evidence suggests that there is a close correlation between exposure to high concentrations of small particles and increased mortality or morbidity, both in the short- and long-term (Hirota & Martin, 2013; United States Environmental Protection Agency [USEPA], 2009; Hogg et al., 2004; WHO, 2013a,b; Brook et al., 2010; Chuang et al., 2007; Rückerl et al., 2006). Fine particulate matter, after it is inhaled, penetrates deep into the lung and the air sacs. The particles damage cells in the airways and affect the lung; this is associated with the exacerbation of asthma and chronic obstructive pulmonary disease (Riva et al., 2011; USEPA, 2009; Risom et al., 2005). The fine particulates cause further damage as they impact the heart and circulatory system.

$PM_{2.5}$-related deaths occur due to:

- cardiovascular disease, notably ischemic heart disease and stroke (WHO, 2013a,b);
- lung cancer (WHO, 2013a, b, c);
- chronic obstructive pulmonary disease (WHO, 2013a, b, c); and
- acute lower respiratory infection (WHO, 2013a, b; Roth et al., 2008; Lanata et al., 2004).

Non-fatal health impacts of exposure to $PM_{2.5}$ include non-fatal heart attacks, irregular heartbeat, aggravated asthma and decreased lung function, acute bronchitis, and increased respiratory symptoms. These can lead to absence from work and reduced school attendance, as well as increased hospital admissions and doctor's visits.

A component of $PM_{2.5}$ that should also be mentioned is black carbon (BC), which refers to elemental carbon-containing particles that are emitted from incomplete combustion of fossil fuels and biomass (Long et al., 2013). According to WHO, there is sufficient evidence for an association between daily variations in BC concentrations and short-term changes in all-cause and cardiovascular mortality, as well as cardiopulmonary hospital admissions (Janssen et al., 2012). For long-term BC exposure, cohort studies have provided sufficient evidence of relationships to all-cause and cardiopulmonary mortality. Exposure-relationships from both short- and long-term studies are much stronger for BC than for $PM_{2.5}$ and PM_{10} (Janssen et al. 2012). This statement does not mean that "any specific source, component, or size class of PM maybe excluded as a possible contributor to PM toxicity" (Hedley Index, 2013).

Given that ambient $PM_{2.5}$ -related deaths are largely concentrated in Asia, the risk of ambient PM ranks among the top health risks everywhere in Asia (Table 4.1).

Table 4.1 Risk factors ranked by attributable burden of disease, 2010

	Global	High-income Asia Pacific	East Asia	South East Asia	South Asia	Central Asia
High blood pressure	1	1	1	1	3	1
Tobacco smoking, including second-hand smoke	2	2	2	2	2	3
Alcohol use	3	3	6	6	8	2
Household air pollution from solid fuels	4	42	5	3	1	12
Diet low in fruits	5	5	3	4	5	5
High body-mass index	6	8	9	9	17	4
High fasting plasma glucose	7	7	8	5	7	7
Childhood underweight	8	39	38	13	4	25
Ambient particulate matter pollution	9	9	4	11	6	10
Physical inactivity and low physical activity	10	4	10	8	11	9

Source: Lim et al., 2012

Ground-level ozone
Ground-level ozone is less soluble in water. It is thus not scrubbed in the upper respiratory tract and reaches the lower respiratory tract where it dissolves in the fluid of the thin surface layer of lung cells. Free radicals and other oxidants in the fluid are assumed to react rapidly with the cell molecules and mediate the effects of O_3 exposure of the human lung. Ozone exposure is a major factor in asthma morbidity and mortality. Even short-term exposure can aggravate existing lung diseases and make the lungs more susceptible to infection.

Health effects of short-term exposure to O_3 include (USEPA, 2014a, 2013a; WHO 2013a, b):

- Increased all-cause mortality
- Increased cardiovascular mortality in adults younger than 75 years
- Increased hospital admission for heart diseases in adults older than 65 years
- Increased hospital admissions for respiratory diseases in adults older than 65 years
- Increased hospital admissions for chronic obstructive pulmonary disease
- Potentially increased hospital admissions for asthma
- Increased school absences

Nitrogen dioxide
Upon inhalation of NO_2, the human respiratory tract can absorb between 70-90 percent of the gas, and even greater levels when breathing from the mouth – e.g., during exercise. Nitrogen dioxide is increasingly deposited in the lower respiratory tract and can remain in the lung for prolonged periods (WHO, 2006). Short-term exposure to NO_2 is enough to cause aggravations in people with asthma and other

lung diseases. Above safe levels, NO_2 exposure can cause inflammation of the airways. Some studies have shown associations between NO_2 long-term exposure and mortality. However, present evidence is not sufficient to conclude that effects on mortality can be attributed to exposure to NO_2 itself (Institute of Occupational Medicine, 2004).

Health effects of long-term exposure to NO_2:

- Exacerbation of symptoms of bronchitis in asthmatic children (WHO, 2013b)
- Reduced lung function in children (WHO, 2013a; b)

Sulfur dioxide

The main anthropogenic source of SO_2 is the burning of sulfur-containing fossil fuels for domestic heating, power generation, and motor vehicles. Being highly soluble in water, inhaled SO_2 is readily absorbed in the human respiratory tract, in particular, while breathing from the mouth. Inhaled SO_2 can cause inflammation of the respiratory tract (WHO, 2013a).

Epidemiological studies have linked SO_2 long-term exposure to:

- Causation of changes in lung function
- Exacerbation of existing heart diseases
- Increased number of asthma attacks

WHO, in its most recent factsheet (WHO, 2014), believes that present evidence is sufficient to conclude that effects on mortality can be attributed to exposure to SO_2.

Toxic air pollutants and heavy metals

Examples of toxic air pollutants include benzene (in gasoline), benzo[a]pyrene (in tar and asphalt fumes, and diesel engine emissions), perchloroethlyene (in dry cleaning chemicals), methylene chloride (in solvents and paint strippers), asbestos, toluene, arsenic, and metals such as zinc, cadmium, mercury, chromium, nickel, and lead compounds.

People exposed to toxic air pollutants due to poisonous smog at ample concentrations and durations may have increased chances of cancer, reproductive and birth defects, immunological damages, and retarded neurological development. Some persistent toxic air pollutants accumulate in body tissues because unlike organic pollutants, toxic metals do not decay.

Toxic air pollutants such as benzene, benzo[a]pyrene, nickel and arsenic, in particular, are classified as carcinogenic; no safe level of exposure has been derived by WHO for these metals. While ammonia (NH_3) in itself is not classified as carcinogenic, it converts gaseous acids, especially sulfuric and nitric acids, to $PM_{2.5}$, which is carcinogenic (Martin, 2008). In a recent publication, Paulot & Jacob (2014) suggested that elimination of NH_3 emissions would achieve a greater health benefit than the reduction of the $PM_{2.5}$ national standard from 15 to 12 $\mu g/m^3$.

More detailed information about health impacts due to exposure to toxic air pollutants can be accessed at WHO (1995b) and USEPA (2007).

4.1.2.2 Environmental impacts of air pollution

Air pollutants are causing changes in the ecosystem and are indirectly affecting wildlife, in addition to directly affecting animal populations that are exposed to harmful air pollutants (United Kingdom Website (UK), 2014b). Extensive experimental studies to assess the potential threat from O_3 to agriculture conducted in Europe and North America have demonstrated crop losses due to O_3 impacts amounting to billions of dollars (Avnery et al., 2011a). The impact of air pollution on cultural heritage materials is also a serious concern because it can lead to loss of important parts of a county's history and culture.

Acid rain

Acid rain containing nitric and sulfuric acids, causes damage to forests and the acidification of soils and water bodies, potentially disrupting the food chain. Acid deposition may have various effects on crops, including significant yield loss in many species. Acid rain also accelerates the erosion of buildings, statues, and sculptures. Further information can be accessed from the USEPA (2012b), Phinney et al. (2004), and UK (2014a).

Eutrophication

Dry and wet deposition of airborne nutrients such as nitrates and phosphates can stimulate algal blooms. In turn, these blooms can cause fish kills and loss of plant and animal life because of oxygen depletion (United States Geological Survey, 2014).

Haze

Haze is caused by the scattering and absorption of sunlight by airborne fine PM (USEPA, 2012c). Haze degrades visual range, obscuring the clarity, color, texture, and forms of objects in cities and scenic areas. Haze has potential impacts on air quality, climate, and the hydrological cycle (Ramanathan et al., 2001).

Atmospheric brown clouds

Atmospheric brown clouds (ABCs) primarily consist of particles and pollutant gases, such as nitrogen oxides (NO_x), carbon monoxide (CO), SO_2, NH_3, and hundreds of organic gases and acids from indoor and outdoor air pollution due to biomass and fossil fuel burning (Ramanathan et al., 2008). Five ABC hotspots exist; three of them lie in East, South, and South-East Asia. The five ABC hotspots potentially have large impacts on regional and global climate, freshwater budget, agriculture, and health (Ramanathan et al., 2008; Ramanathan & Ramana, 2003).

Ozone layer depletion

Stratospheric ozone, particularly in the polar zones, is being gradually destroyed by chlorine- and bromine-containing substances referred to as ozone depleting substances. The Montreal Protocol on Substances that Deplete the Ozone Layer entered into force in 1989 to protect stratospheric ozone and, consequently, protect life from increased ultraviolet radiation at Earth's surface (United Nations Environment Programme [UNEP], 2011). These controls under the Protocol have proven effective for safeguarding public health[5]. Ultraviolet radiation can damage sensitive crops and reduce crop yields. Most ozone-depleting substances are also potent greenhouse gases (GHGs), contributing to global warming. There is strong evidence available on the effect of stratospheric ozone changes on Earth's surface climate (UNEP, 2010; USEPA, 2011a).

Crop and forest damage

Ground-level O_3 can reduce agricultural crop and commercial forest yields, diminish growth and influence survival of tree seedlings, and increase plant susceptibility to disease, pests, and other stresses. Wang & Mauzerall (2004) estimated a total US$5 billion loss per year for wheat, rice, maize, and soybean for China, South Korea, and Japan. Ghude et al. (2014) estimated India's crop loss for cotton, soybean, rice, and wheat to amount to 6 Mtons with a value of US$1.3 billion for 2005. These studies, however, may have substantially underestimated the effect O_3 has on crop productivity in Asia due to more sensitivity to O_3 of Asian-grown wheat and rice cultivars (Emberson et al., 2009).

Global climate change

The naturally occurring gases of the Earth's atmosphere trap some of the sun's heat in the troposphere. This "greenhouse effect" keeps the Earth's temperature stable. Human activities are producing too much of some of these GHGs (USEPA, 2014e). As a result, the Earth's atmosphere is trapping more of the sun's heat, causing the Earth's average temperature to rise (global warming). Global warming could have significant impacts on human health, agriculture, water resources, precipitation and draughts, forests, wildlife, and coastal areas. Table 4.2 presents some of the properties of GHGs.

5 Controls implemented under the Montreal Protocol have enabled the global community to avoid millions of cases of fatal skin cancer and tens of millions of cases of non-fatal skin cancer and eye cataracts. The U.S. estimates that, by the year 2065, more than 6.3 million skin cancer deaths will have been avoided in that country alone and that efforts to protect the ozone layer will have saved it an estimated US$4.2 trillion in healthcare costs over the period 1990–2065 (United Nations Development Programme, 2012). Moreover, in 2011, the United States Environmental Protection Agency estimated that more than 22 million Americans born between 1985 and 2100 would avoid suffering from cataracts as a result of the Montreal Protocol (UNEP, 2012).

Table 4.2 Sources and lifetimes of greenhouse gases

Compound	Sources	Lifetime [years]	Reference
CO_2	Fossil fuel and biomass burning	3–4	Gurjar, et al., 2010
CH_4	Rice paddies, livestock, natural gas leaks	12	IPCC, 2007
N_2O	Agriculture, fossil fuel combustion, wastewater management, industrial processes	114	USEPA, 2010; IPCC, 2007
CFCs	Air conditioners, refrigerators, sprays	45–1,700	IPCC, 2007
HFCs		1.4–270	
HCFCs		1.3–17.9	
PFCs		740–50,000	
HFEs		0.33–136	
Halons		16–65	

CO_2: Carbon dioxide; CFCs: Chlorofluorocarbons; HCFCs: Hydrochlorofluorocarbons ; HFCs: Hydrofluorocarbons; CH_4: Methane; PFCs: Perfluorinated compounds; HFEs: Fluorinated ethers

4.1.3 Link of air pollution and climate change; co-benefits

Many air pollutants such as PM, SO_2, NO_2, and CO have the same sources as GHGs. Major GHGs are CO_2, CH_4, and O_3. Ozone formation follows from various chemical transformations such as photochemical oxidation of organic vapors by organic peroxyl free radicals in the presence of NO_x, and CH_4 photo-oxidation via various sequences (Johnston & Kinnison, 1998). Greenhouse gases have to be reduced to mitigate climate change, while air pollutants have to be controlled to avoid direct effects on human and environmental health. Measures to mitigate climate change can reduce air pollution, and actions reducing local and regional air pollution can reduce GHG emissions. There is a need to jointly assess these interrelated policies. The co-control of air pollution and GHG emissions will be cost-effective and create co-benefits (Intergovernmental Panel on Climate Change [IPCC], 2007; Anenberg et al., 2012; Climate and Health Alliance (CAHA), 2012; HEAL, 2012; West et al., 2013; GCEC, 2014). The linkages between air pollution and climate and their relation to health and environmental impacts are depicted in Figure 4.3.

A United Nations Environment Programme/World Meteorological Organization (UNEP/WMO) report has compiled scientific studies that have shown that reductions of emissions of short-lived climate pollutants (SLCPs) can potentially prevent millions of premature deaths, prevent the loss of million tons of crops, and reduce global temperatures by 0.5°C [0.2°C–0.7°C] over the next four decades (UNEP/WMO, 2011). Several UNEP-recommended actions to reduce emissions of BC, organic carbon, $PM_{2.5}$, CO, NO_x, and CH_4 and case studies on co-benefits of linking air pollution and GHG reduction are provided in **Annex III-A and III-B of the Information Sourcebook.**

Measures to mitigate climate change **can reduce air pollution**, and **actions** reducing local and regional air pollution can reduce greenhouse gas emissions. There is **a need** to jointly assess these **interrelated policies**.

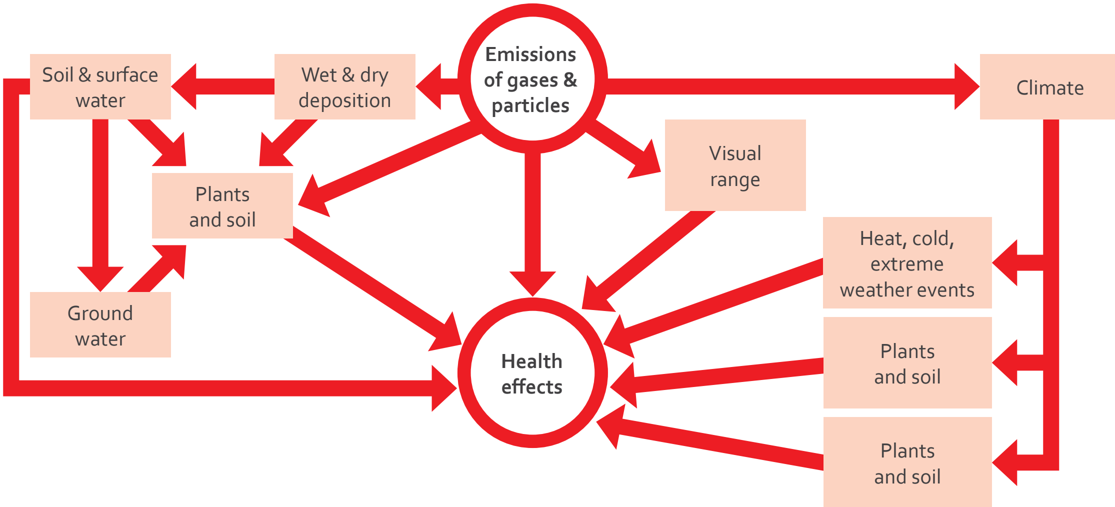

Figure 4.3 Linkages between air pollution, climate, and health impacts

Source: Stockholm Environment Institute (SEI), 2008

> **Health impact assessment** in a clean air action plan is a means of assessing the **positive and negative health impacts** of existing **air pollution abatement** policies, strategies, plans and projects.

4.1.4 Health impact assessment in clean air action plans

A clean air action plan (CAAP) is a long-term plan intended to improve air quality and public health by identifying measures to reduce emissions from sectors such as transport, industries, waste deposits, residential burning, among others [see *Guidance Area 5 on Clean air action plans*]. Health impact assessment (HIA) in a CAAP is a means of assessing the positive and negative health impacts of existing air pollution abatement policies, strategies, plans and projects. Many definitions of HIA exist (Birley, 1995; European Centre for Health Policy [ECHP], 1999; Lock, 2000; International Association for Impact Assessment, 2006), the main definition being that of the ECHP: "A combination of procedures, methods and tools by which a policy, program or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within a population" (WHO, 2007).

Health impact assessment is a valuable tool within a CAAP to develop policies, strategies, programs and projects for cleaner air by providing information for decision makers and addressing policymaking requirements. One of the objectives of an HIA study is to assess whether or not air pollution has an effect on human health. This tool brings policies and people together and involves all stakeholders. It is a proactive process that can mitigate health impacts due to air pollution. The HIA procedure within a CAAP is shown in Figure 4.4. A stepwise process for HIA development and implementation as well as case studies are provided in **Annex III-C of the Information Sourcebook.** The case of a multicity time-series study of short-term effects of air pollution on mortality under the Public Health and Air Pollution in Asia (PAPA) project is also provided in **Annex III of the Information Sourcebook.**

PHASE	PROCESS	DESCRIPTION
Policy and programme development for prospective assessments	Screening	Quickly establishes the 'health relevance' of air polution. Is HIA required?
	Scoping	Identifies key air pollutants & public concerns, establishes Terms of Reference, sets boundaries
	Appraisal	Rapid or in-depth assessment of baseline health status, adverse health impacts of air pollution using available evidence – who will be affected, significance, projection, mitigation
Policy implementation	Recommendations	Identifies strategies and measures to manage adverse health impacts
	Reporting	Communicates to stakeholders conclusions & recommendations to mitigate adverse health impacts
	Monitoring	Action, where appropriate, to monitor actual adverse health impacts to enhance existing evidence base

Figure 4.4 The procedure for health impact assessment in clean air action plans

Source: Adapted from WHO, 2015

4.2 Stages of health and environmental impact assessment

Strengthening the capacity for health and environmental impact assessment helps shape and define policies for improving air quality. Such capacity also helps in the assessment of the effectiveness of measures to protect human health and the environment. As a starting point, Table 4.3 presents indicators that would aid cities in identifying their current state of AQM development for health and environmental impact assessment.

The following served as key considerations in progressing through the stages:

- Availability of information for estimating health and other impacts
- Processes for estimating health impacts of air pollution
- Capacity for estimating health and other impacts of air pollution
- Presentation of results of health impacts assessment for policy development purposes

Table 4.3 Stages for the assessment of health and other impacts due to air pollution

Stages	Indicators
Underdeveloped	Absence of health surveillance system Unavailability of meteorological and air quality databases for emission-exposure-impacts modeling Absence of anecdotal observations of and information on health impacts by health authorities Lack of capacity for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to HIA • exposure assessment • health and environmental impact assessment Studies on socio-economic cost of pollution and benefits of pollution control are not available Cost effectiveness/cost-benefit analysis is not conducted
Developing	A health surveillance system is being developed Meteorological and air quality databases are being developed for emission-exposure-impacts modeling Initial observations on health impacts due to air pollution exposure exist Capacity is being developed for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to HIA • exposure assessment • health and environmental impact assessment Studies on socioeconomic cost of pollution and benefits of pollution are not available Cost effectiveness/cost-benefit analysis is not conducted

Stages	Indicators
Emerging	A health surveillance system starts to provide reliable data Meteorological and air quality databases are beginning to be established for emission-exposure-impacts modeling Routine observations on health impacts due to air pollution exposure are becoming more and more common Capacity is increasing and regularly enhanced by training for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to HIA • exposure assessment • health and environmental impact assessment Limited studies on socioeconomic cost of pollution and benefits of pollution control are available, mostly performed by academic/research institutions Cost-effectiveness/cost-benefit analysis is intermittently conducted by academic/research institutions Presentation of results of HIA, studies on socioeconomic cost of pollution, and cost-effectiveness/cost-benefit analysis considers its use in AQM policy development, implementation, and evaluation
Maturing	A health surveillance system is in place and is becoming a basis of HIA due to air pollution Meteorological and air quality databases are routinely used for emission-exposure-impacts modeling Systematic epidemiological studies on health impacts due to air pollution exposure are performed including exposure and health impact assessment studies of major facilities or areas (e.g., schools, hospitals, among others) and of vulnerable populations (e.g., children and the elderly), using rapid assessment techniques Capacity and understanding of issues is increased for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to HIA • exposure assessment • health and environmental impact assessment Studies on socioeconomic cost of pollution and benefits of pollution control are becoming available, performed by both academic/research institutions and the government Cost effectiveness/cost benefit analysis is conducted by academic/research institutions and the government Presentation of results of HIA, studies on socioeconomic cost of pollution, and cost-effectiveness/cost-benefit analysis systematically considers its use in AQM policy development, implementation, and evaluation

Stages	Indicators
Fully developed	A health surveillance system makes available reliable data and is always taken as the basis of HIA due to air pollution Meteorological and air quality databases are regulated to be routinely used for emission-exposure-impacts predictions Systematic epidemiological studies on health impacts due to air pollution exposure are performed including exposure and health impact assessment studies of major facilities or areas (e.g., schools, hospitals) and of vulnerable populations (e.g., children and the elderly), using sophisticated assessment techniques Capacity is sustainably enhanced for: • air pollution monitoring with cheap sensors or sophisticated analyzers with respect to HIA • exposure assessment • health and environmental impact assessment Studies on socioeconomic cost of pollution and benefits of pollution control are available, performed by academic/research institutions and the government. There is a process in place for estimating socio-economic costs adapted to local conditions Cost-effectiveness/cost-benefit analyses are routinely performed by academic/research institutions and the government following a localized system for estimating costs and benefits Presentation of results of HIA, studies on socioeconomic cost of pollution, and cost-effectiveness/cost-benefit analysis systematically considers its use in AQM policy development, implementation, and evaluation

4.3 Issues and challenges

While a number of Asian cities and countries have developed CAAPs over the last 15 years to address the challenge of air pollution, a number of considerable challenges remain to be resolved, especially in urban areas in Asia. This relates particularly to conducting HIA *vis a vis* air pollution. In addition, the valuation of the benefits of avoiding health impacts within CAAPs is often not performed.

Institutional

- **Insufficient human resources and institutional capability within governmental agencies possessing knowledge on the health and environmental impacts of air pollution,** and understanding the linkages between GHG mitigation and air pollution reduction in minimizing health and environmental impacts.
- **Limited understanding of governmental institutions of the importance of studies on health and environmental impacts caused by air pollution.** This understanding needs to get the support of all agencies and other stakeholders in providing data necessary for epidemiological studies.
- **Lack of collaboration, communication, and coordination between environmental authorities and health authorities** – preventing agencies from sharing of demographic, monitoring, mortality, and morbidity data needed for epidemiological studies.
- **Lack of understanding among government agencies of the linkage between source and emissions inventory, air quality monitoring, meteorological situation, and health and environmental impacts due to air pollutant exposure.** All these issues are important components of a CAAP, with health and environmental impacts as the most relevant as these could help bring about desired behavior change.
- **Lack of media information and awareness** on: (1) health and environmental impacts of air pollution, and of the health and economic benefits of actions to avoid or minimize the impacts due to air pollution; and (2) impacts of GHG emissions, their linkage to air pollution impacts, and the co-benefits of GHG mitigation and air pollutant emission reduction.
- **Lack of public awareness** that would enable public society groups/non-governmental organizations (NGOs) with interest in combating air pollution and pushing the government to act. These organizations can be interested to launch citizen science projects on air pollution exposure and effect assessment.

Management and Technical

- **Limited information on health impacts due to air pollution.** Policy and decision making process are limited and constrained by poor data and information on health impacts/effects, social and economic effects of the health risks. Limited connection with planning and policy development
- **Only a few Asian countries develop systematic CAAPs** to update or set emission and air quality standards based on health impacts/effects and monitor/enforce the compliance.
- **Limited health impact modeling** and/or short-term and long-term impact estimation by means of epidemiological health impact studies
- **Poor "public health surveillance programs**[6]—i.e. poor collection of mortality and morbidity information for selected health impacts, lack of cohort and time-series studies.
- **Poor early warning systems to protect the public against air pollution episodes**. These are needed in case of transboundary air pollution (haze episodes), emergency situations due to industrial malfunction, and meteorological events (such as strong inversions).
- **Lack of awareness and studies** on the following:
    - Short-term and long-term health and environmental impacts. Awareness is important to protect the public and the environment against the impacts of air pollution. Local studies are needed to assess the severity of health and environmental impacts.
    - Valuation of health and environmental impacts. Such studies are critical to get information about the benefits of avoiding health and environmental impacts as trade-offs to costs of abatement measures.
    - Linkage between air pollution health impacts and GHG mitigation measures. Awareness of the linkages is critical to understand the interrelationship between air pollution and GHGs.

6 Public health surveillance is defined as the ongoing, systematic collection, analysis and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to the appropriate individuals or institutions"(WHO, 1999)

- Risk communication and effective guidance to protect the population from the impacts of heavy pollution
- Valuation of co-benefits of air pollution health impacts and GHG mitigation measures. The co-benefits of simultaneous air pollution reduction and GHG mitigation in terms of health and environmental impacts are usually higher than those of reducing air pollutant emissions and mitigating GHG emissions separately.

Financial

In many Asian countries, lack of sufficient governmental funding prevents the development and implementation of health surveillance system and the conduct of epidemiological studies to assess relationships between exposure to air pollutants and health impacts. Funding is especially needed for studies on long-term exposure to air pollutants. Poor communities are constrained financially to introduce and apply protective and adaptation approaches.

In addition, the valuation of the benefits of avoiding health impacts as a consequence of CAAPs is often not performed. The opportunities of tapping into other sources of funding such as public-private-partnerships, grants or loans from international funding agencies, and citizen science or crowdsourcing approaches are often not known or, if known, not explored (Oxford English Dictionary, 2014)[7].

Despite these challenges, some Asian countries have assessed the local health consequences of air pollution and estimated their economic impact. Health studies in Bangkok and Hong Kong have provided some rationale to take air pollution abatement actions (Lee et al., 2013; Vichit-Vadakan & Vajanpoom, 2011; Hedley, 2009; Vassanadumrongdee & Matsuoka, 2005). The estimated premature deaths, hospital admissions, outpatient visits, and economic loss from air pollution in the Hedley Environmental Index system give such a strong incentive (Box 4.1). The USEPA has collaborated with national experts in several Asian cities to conduct systematic studies on the health and economic impacts of air pollution control policies (e.g. USEPA, 2014h).

Box 4.1
Hedley Environmental Index: measuring Hong Kong's air pollution cost

The Hedley Environmental Index (Hedley Index) closes the gap between generating scientific evidence and communicating the risks in terms of the number of deaths, the number of hospital bed-days, the number of doctor visits, the total economic loss, the loss of tangible cost – hospital admissions, outpatient visits (including travel cost), and work absence, and the loss of healthy life value (Hedley Index, 2014a). Using internationally established exposure-response relationships between air pollutants and health impacts of current levels of pollution, the Hedley Index is acting as a tool to assess the potential public health benefits for strengthened air quality standards in Hong Kong.

On the Hedley Index website (Figure 4.5), data on the five key air pollutant indicators $PM_{2.5}$, PM_{10}, NO_2, SO_2, and O_3 are reported from three roadside stations and 10 general monitoring stations run by the Hong Kong Environmental Protection Department (EPD). The data is then plotted real-time against the WHO's short- and long-term Air Quality Guidelines. To delve deeper into the issue, the historical series within a program called "Air Quality Tracker" adds a different function, allowing to review data beginning in 1998, and track the history of each pollutant (Hedley Index, 2014b).

The actual figures in the Hedley Index provide a rather conservative estimate, which does not yet account for air pollution's effects on vulnerable groups such as pregnant women and young children, the monetary losses of the long-term health burden, or the economic costs of Hong Kong's lost tourism.

7 Citizen science is also known as crowd science, crowd-sourced science, civic science, volunteer monitoring or networked science.

Figure 4.5 The Hedley Environmental Index Board

According to the Hedley Index, each year, air pollution kills more than 3,000 people in Hong Kong (Kwong, 2012). The Hedley Index is frequently cited and used as a teaching tool by policy researchers, media, and NGOs, and has become a key reference for Hong Kong EPD officials (Ng, 2012; Cheng & Luo, 2009).

The Hedley Index promoted the communication on air quality and its health impact as well as raised the awareness in Hong Kong. On December 30, 2013, Hong Kong EPD launched the Air Quality Health Index to replace the Air Pollution Index, which reports the short-term health risk of air pollution and helps the public take precautionary measures to protect health.

4.4 Roadmap for health and environmental impact assessment

Reliable information on health and environmental impacts is essential for AQM. To implement a roadmap for health and environmental impact assessment within AQM, a first step is to assess where a city is in the AQM developmental stages, then follow the recommendations to progress to the next stage. Table 4.4 gives the recommended steps to implement the roadmap and overcome the challenges outlined above.

Table 4.4 Recommended steps to implement a roadmap for health and other impacts assessment and overcome the challenges of air pollution impacts on health and the environment

Developmental stages	Steps to follow
Underdeveloped	**Management Process** • Start to conduct health and environmental impact assessment (WHO, 2004b; USEPA, 2011b) • Start to prepare an air quality monitoring system **Technical Process** • Learn from international experiences and studies on health impacts and consider the health factors in the policy, plan and strategy development process
Developing	**Management Process** • Ensure that health risk estimations are used to inform policy makers and are being considered in the policies and plan development • Prioritize identification of air pollution control plans and policies that consider impacts on health **Technical Process** Enhance capacity for: • estimating exposure (Global Atmospheric Pollution Forum (GAPF), 2011) • initial estimates of health risks and/or other impacts (WHO, 2004b) • an initial health surveillance approach (WHO, 2014d; Nsubuga et al., 2006)
Emerging	**Management Process** • Use information on health and other impacts to inform policy development • Integrate risk assessment into policies **Technical Process** Ensure: • growing capacity for simplified approaches to estimate exposure (WHO, 2004b) • improved understanding of the technical and economic feasibility of major pollution control measures (USEPA, 2011d; 2008b; Reis, 2005) Enhance capacity for estimates such as: • the health risks and/or other impacts (WHO, 2006) • the economic impacts, based on international studies (Organisation for Economic Co-operation and Development (OECD), 2014)

<table>
<tr><th>Developmental stages</th><th>Steps to follow</th></tr>
<tr><td>Maturing</td><td>Management Process
• Establish a robust health statistics database based on a health surveillance system to enable and facilitate health studies
• Translate study results into policy tools in a transparent manner
• Develop and implement communication strategies targeted at policy makers and the public
• Ensure that scenarios for future needs of AQM are developed (USEPA, 2012f)

Technical Process
Ensure that:
• exposure and HIA studies of major facilities or areas (e.g., schools, hospitals) and of vulnerable populations (e.g., children and the elderly) are conducted (Makri & Stilianakis, 2008)
• major studies on health impacts are systematically conducted (Rothman & Greenland, 1998)
• studies on other impacts of air pollution (e.g., on buildings and agriculture) are available (Emberson et al., 2003; Rao et al., 2014)
• studies on social economic cost of pollution and benefit of pollution control are available (OECD, 2014)
• cost-effectiveness/cost-benefit analysis are being conducted (USEPA, 2010b; Clean Air for Europe, 2012)
• emissions inventories and dispersion modeling are further developed (European Environment Agency, 2013)</td></tr>
<tr><td>Fully developed</td><td>Management Process
• Integrate health risk assessment into policies and strategies
• Develop and implement communication strategies with policy makers and the public as target audiences

Technical Process
• Conduct health and environmental impact studies regularly and systematically. Report results to influence policies. Link health and environmental impacts projections based on scenarios with policy changes in emissions-related sectors (e.g., transport). Conduct regularly and systematically exposure and HIA of major facilities or areas (e.g., schools, hospitals) and of vulnerable populations (e.g., children, elderly, and people with existing ailments and/or disabilities). Make available studies on other impacts of air pollution (e.g., on buildings and agriculture) as well as socioeconomic cost of pollution and benefit of pollution control. Conduct cost-effectiveness/cost-benefit analysis.
• Develop regulatory air quality simulation models to support the policymaking process</td></tr>
</table>

Municipal, provincial and national governments should recognize the need to consider health and environmental impacts as an important ingredient of AQM. In fact, if there were no impacts of air pollution, there would also be no need for action. In developing Asian countries, it is important to strengthen the political will and understanding of the social and economic costs of air pollution, which often surpass the costs of control measures [See *Guidance Area 6 on Governance*]. A strong governmental response is needed to mitigate the health and environmental effects of air pollution (Box 4.2). It is also important to strengthen the linkages among source inventory, emission, air quality monitoring, meteorological situation, and health and environmental impacts due to air pollutant exposure. To better understand these linkages, it is necessary to involve all relevant stakeholders in the development of action plans for health and environmental impact assessment as an integral part of CAAPs [See *Guidance Area 5 on Clean air action plans*]. Similarly, the collaboration, communication, and coordination between environmental authorities and health authorities on the municipal, provincial and national levels should be strengthened. Enhancing the institutional capability with respect to AQM issues through sustainable education and training and provision of sufficient human resources is also significant [See *Guidance Area 6 on Governance*].

Sufficient financial resources should be allocated for the following health and environmental impact studies. If reliable emissions and meteorological data exist, models can be used to estimate exposure [See *Guidance Area 2 on Emissions inventories and modeling*] and – with the application of established exposure-response relationships – corresponding health environmental impacts. This would be the low-cost option because appropriate models can be downloaded free of charge e.g. the USEPA website. If a health surveillance system is in place, epidemiological studies can be performed but the cost of such studies can be high to very high depending on the type of study, the number of cases and the planned duration of a study.

Financial resources should be made available for:

- emission-exposure-impact studies
- a health surveillance system (if it does not exist)
- short-term and long-term health and environmental studies
- studies on the valuation of health and environmental impacts
- studies on the linkage between air pollution health impacts and GHG mitigation measures
- studies on the valuation of co-benefits of air pollution health impacts and GHG mitigation measures

Municipal, provincial and national **governments should recognize** the need to **consider health and environmental impacts** as an important ingredient of **air quality management**. In fact, if there were **no impacts of air pollution**, there would also be **no need for action**. In **developing Asian countries**, it is important to **strengthen the political will** and understanding of the social and economic costs of air pollution, which often surpass the **costs of control measures**.

Box 4.2
Responding to the health effects of air pollution in India

Outdoor air concentrations of various air pollutants in Indian cities are continuing to be a major health concern in India because of their persistent high levels. The impact of long-term exposure to urban air pollution on the respiratory and other organ systems of the body was studied in Kolkata and Delhi, two highly polluted megacities in the country (Ray & Lahiri, 2010). Moreover, the health impacts of vehicular pollution during 2007 to 2010 have been investigated (Ray & Lahiri, 2012). Compared to rural controls, the urban population had a significantly higher prevalence of upper and lower respiratory symptoms, bronchial asthma, and lung function deficits. The adverse health consequences in the urban population were positively associated with PM_{10} levels in ambient air and with personal exposures to benzene. Long-term exposures to high levels of urban air pollution in these cities are adversely affecting the physical and mental health of citizens, especially of children and the elderly. In Kolkata, long-term exposure to air pollution arises mostly from vehicular exhausts.

Another study estimated the number of premature deaths in 14 Indian cities (Nema & Goyal, 2010). Based on the PM_{10} concentration levels of 2001, among the metro cities, the highest number of mortality cases is observed in Delhi (4889), followed by Kolkata (4303), Mumbai (1959), and Chennai (1272). India has set up institutions to respond to the air pollution and its health impacts. The Ministry of Environment, Forest, and Climate Change (MoEF) is the nodal agency in the Central Government for overseeing the implementation of India's environmental policies and programs. The MoEF initiated environmental epidemiological studies in different areas of indoor and outdoor pollution to identify and develop programs that shall create a database and suggest environmental mitigation measures.

The Central Pollution Control Board (CPCB) under MoEF is responsible for planning and executing comprehensive nation-wide programs for the prevention and control of air pollution. The CPCB is executing a nationwide National Air Quality Monitoring Program (NAMP). The NAMP is covering 545 operating stations spread over covering 225 cities/towns in 26 States and five Union Territories. A system for collecting real-time online data has been established and publishes air quality data from 35 continuously monitoring stations operated by various agencies (MoEF, 2014). The CPCB has stipulated National Ambient Air Quality Standards (NAAQS) since 1982. The NAAQS are based on health criteria and follow a land use based approach. The NAAQS have been revised in November 2009 in consultation with the civil society and experts, for 12 pollutants including SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3, Pb, As, Ni, CO, NH_3, benzene, and B(a)P. These standards/limits provide a legal framework for the control of air pollution and the protection of public health.

In January 2014, a Steering Committee on health related issues on Air Pollution was formed, with a view towards framing an action plan for mitigating the adverse health impacts of indoor and outdoor air pollution.

In June 2015 the Government of India launched the air quality index in New Delhi and urged the people to change their lifestyle in order to help protect the environment (Hindustan Times, 2015).

As: Arsenic; B(a)P: Benzo(a)pyrene; NH_3: Ammonia; Ni: Nickel; Pb: Lead

Source: CPCB, 1998; MOEF, 2014

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