Air Quality in Asia: Status and Trends

2010 Edition

Clean Air Initiative for Asian Cities (CAI-Asia) Center

Air Quality in Asia: Status and Trends

2010 Edition

April 2010

Clean Air Initiative for Asian Cities (CAI-Asia) Center

Unit 3510, 35th Floor, Robinsons-Equitable Tower
ADB, Avenue, Pasig City, Metro Manila, Philippines

Clean Air Initiative for Asian Cities (CAI-Asia) Center, 2010. “Air Quality in Asia: Status and Trends - 2010 Edition”. Pasig City, Philippines.

Disclaimer

The views expressed in this publication are those of CAI-Asia staff, consultants and management, and do not necessarily reflect the views of the Board of Trustees of the CAI-Asia Center. The CAI-Asia Center does not guarantee the accuracy of the data included in this publication and does not accept responsibility for consequence of their use.

Acknowledgment

This publication makes use of information published on the Clean Air Portal (www.cleanairinitiative.org) that was developed with support from the Asian Development Bank (ADB) through the Japan Special Fund together with CAI-Asia Partnership members.

Contact

CAI-Asia Center
Unit 3510, Robinsons-Equitable Tower, ADB Avenue,
Pasig City, 1605, Metro Manila, Philippines
Tel +63 2 395 2843
Fax +63 2 395 2846
center@cai-asia.org
www.cleanairninitiative.org

Photo © CAI-Asia Center

Introduction

Clean Air Initiative for Asian Cities (CAI-Asia)'s 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."

CAI-Asia recognizes that while information and knowledge on air quality management are increasingly generated in Asia, they are fragmented in different documents and websites. To ensure that decision-makers have better access to knowledge on clean air management that can assist in policy development, CAI-Asia has been releasing publications and presentations that provide a comprehensive and comparative assessment of the status and challenges of air quality management in Asia. Starting with only 20 cities in 2003, CAI-Asia now has compiled information on air quality and pollutant levels from over 200 Asian cities.[1]

"Air Quality in Asia: Status and Trends, 2010 edition" is now composed of two parts

- Status and Trends of Air Quality, which provides a snapshot of air quality levels in 2008 and trends of air quality from 1993 to 2008.
- Status of Air Quality Standards, which provides an overview of the ambient air quality standards adopted by developing Asian countries.

Analysis of air quality levels and ambient air quality standards in Asian cities, indicate that

- While some improvements in air quality have been achieved, levels of PM_{10} and SO_2 continue to exceed World Health Organization (WHO) air quality guidelines (AQG).
- There is not enough air quality data to assess $PM_{2.5}$ and ozone.
- Most Asian countries have already adopted National Ambient Air Quality Standards (NAAQS) for criteria pollutants (except for $PM_{2.5}$).
- Ambient air quality standards of most countries lag behind WHO AQG and US EPA (Environmental Protection Agency) NAAQS.

Based on this study, CAI-Asia advocates

- That countries without NAAQS, adopt ambient air quality standards to protect public health
- That cities monitor air quality levels to monitor compliance to NAAQS
- That air quality information be made widely available to public
- For a process of developing a roadmap on air quality standards in Asia moving towards achieving WHO guidelines

For more information, contact:
Clean Air Initiative for Asian Cities (CAI-Asia) Center
3510 Robinson's Equitable Tower, ADB Avenue,
Ortigas Center, Pasig City, 1605 Philippines
Tel: (63-2) 395-2843/(63-2) 395-2845
Fax: (63-2) 395-2846
Email: center@cai-asia.org

[1] The efforts in collecting air quality data from the different cities commenced during the implementation of the Air Pollution in the Major and Mega-cities of Asia project in 2003, in cooperation with UNEP and WHO. As of April 2010, CAI-Asia now has air quality data for 234 Asian cities.

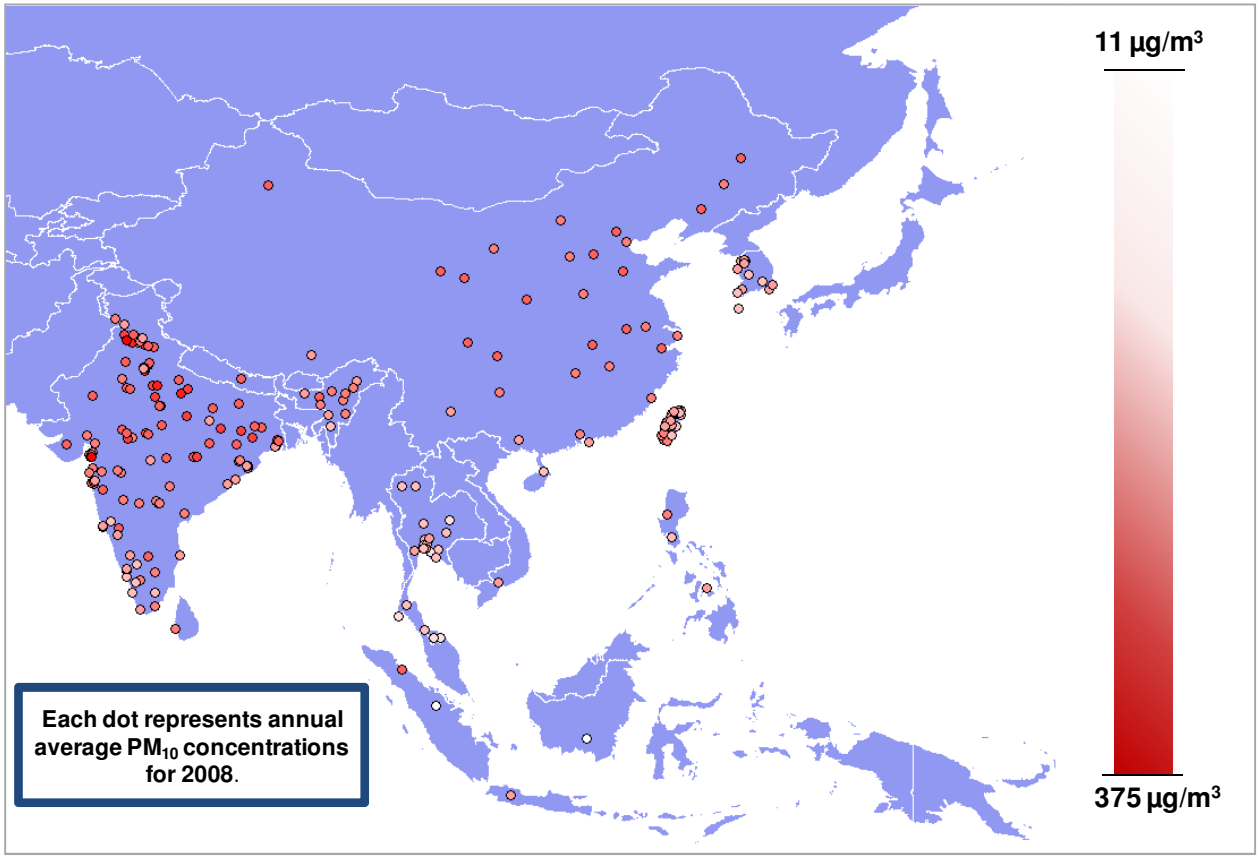
PM_{10} Concentrations in Asia – 2008

In 2008, CAI-Asia was able to collect annual average PM_{10} concentrations for 230 Asian cities. **Monitoring results reflects PM_{10} as a critical pollutant for most Asian cities.**

From these 230 cities, only two had annual average PM_{10} concentrations within the WHO AQG (20 µg/m^3) while about **58%** of these cities had annual PM_{10} levels exceeding even WHO Interim Target-1 (IT-1) of 70 µg/m^3.

The average of annual average PM_{10} concentrations of 230 cities is **89.5 µg/m^3—about 4.5 times higher than WHO AQG.**

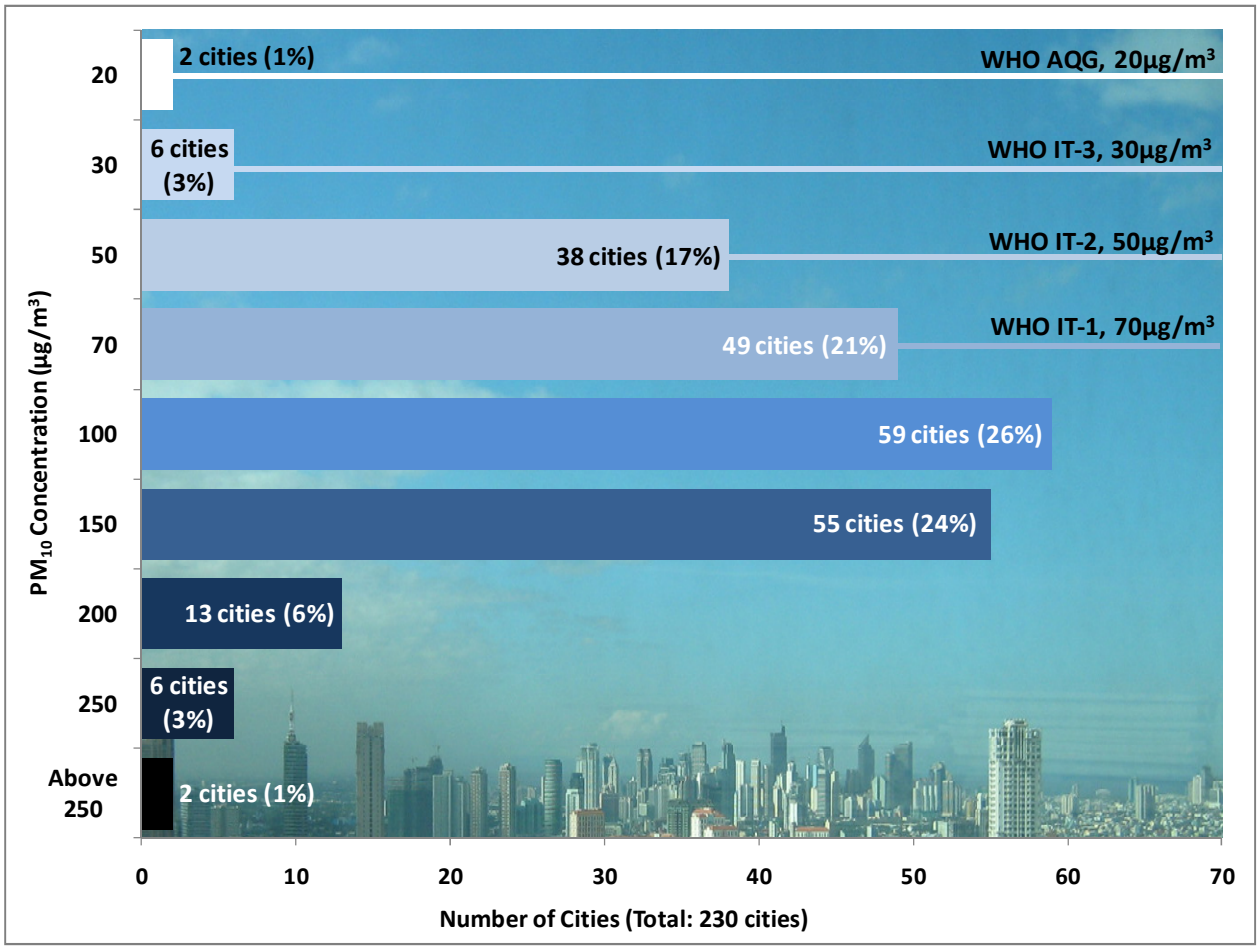
Figure 1 Annual Particulate Matter (PM_{10}) concentrations in 230 cities in Asia.



Note: Annual PM_{10} concentrations range from 11 (minimum) to 375 (maximum) micrograms per cubic meter (µg/m^3). PM_{10} = Particles with aerodynamic particle diameters of 10 micrometers or less.

Source: CAI-Asia Center, 2010.

Figure 2 Distribution of Asian Cities relative to 2008 PM_{10} concentration.



WHO = World Health Organization; AQG = air quality guideline; IT = interim target; $\mu g/m^3$ = microgram per cubic meter; PM_{10} = Particles with aerodynamic particle diameters of 10 micrometers or less.

Source: CAI-Asia Center, 2010.

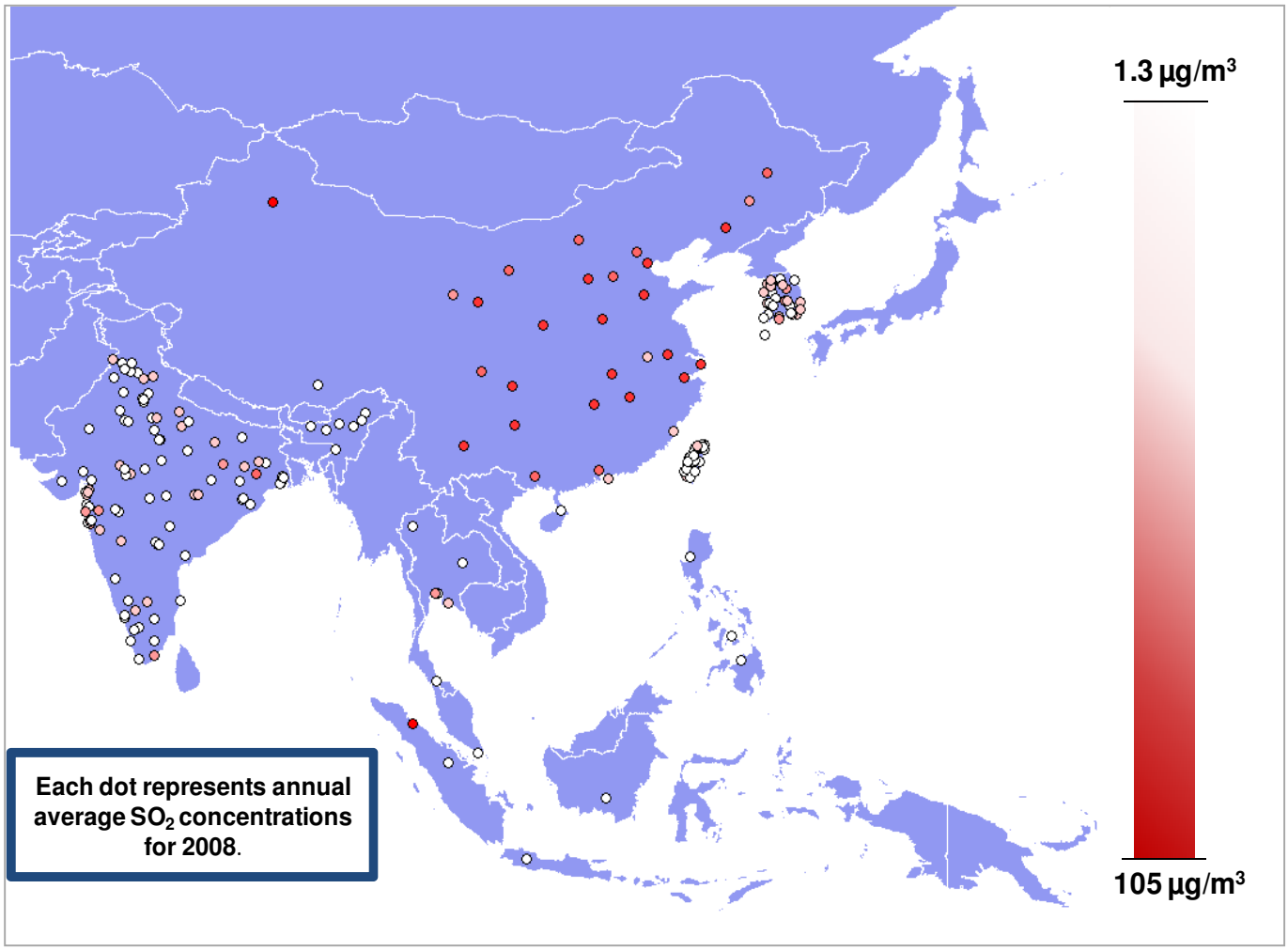
SO_2 Concentrations in Asia – 2008

SO_2 monitoring data for 213 Asian cities show that **SO_2 levels are still a problem for some Asian cities, particularly those in or are within the vicinity of industries**.

Average of annual average SO_2 concentrations of 213 Asian cities is **18.7 µg/m^3.** The WHO does prescribe an annual guideline for SO_2, but rather, prescribes a 24-hour AQG – 20 µg/m^3. Based on the 2005 Global Update of AQG by WHO, an annual AQG for SO_2 was not established because the 24-hr AQG is already low and achieving the 24-hr AQG ensures that the annual average SO_2 concentration will even be lower.

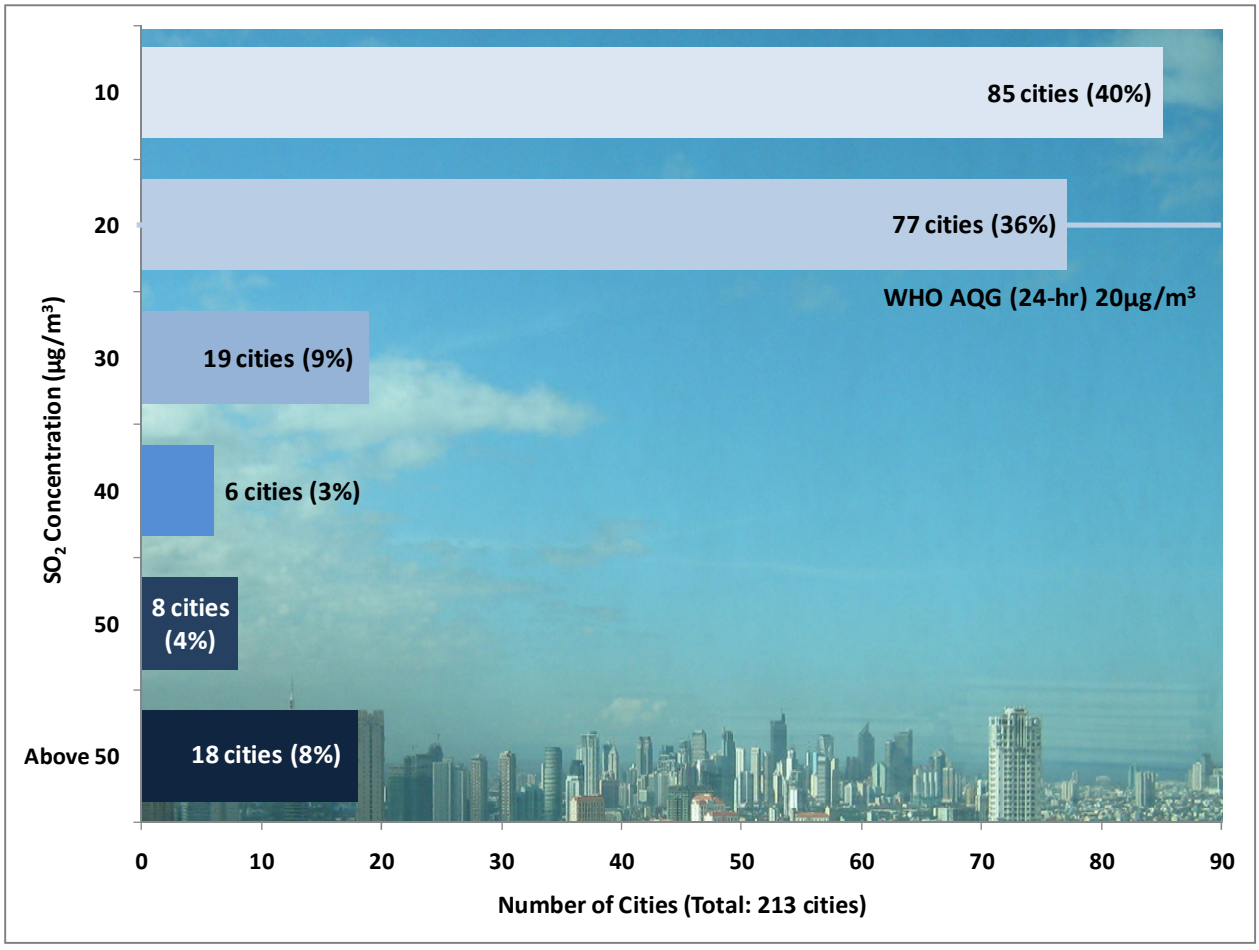
About 40% of the cities had annual average SO_2 levels equal or lower than 10 µg/m^3. However, **24% of cities' annual average SO_2 concentrations do not meet even the 24-hr WHO AQG.**

Figure 3 Annual Sulfur dioxide (SO_2) concentrations in 213 cities in Asia.



Note: Annual SO_2 concentrations range from 1.3 (minimum) to 105 (maximum) micrograms per cubic meter (µg/m^3). Source: CAI-Asia Center, 2010.

Figure 4 Distribution of Asian Cities relative to 2008 SO_2 concentration.



WHO = World Health Organization; AQG = air quality guideline; µg/m^3 = microgram per cubic meter; SO_2 = Sulfur dioxide

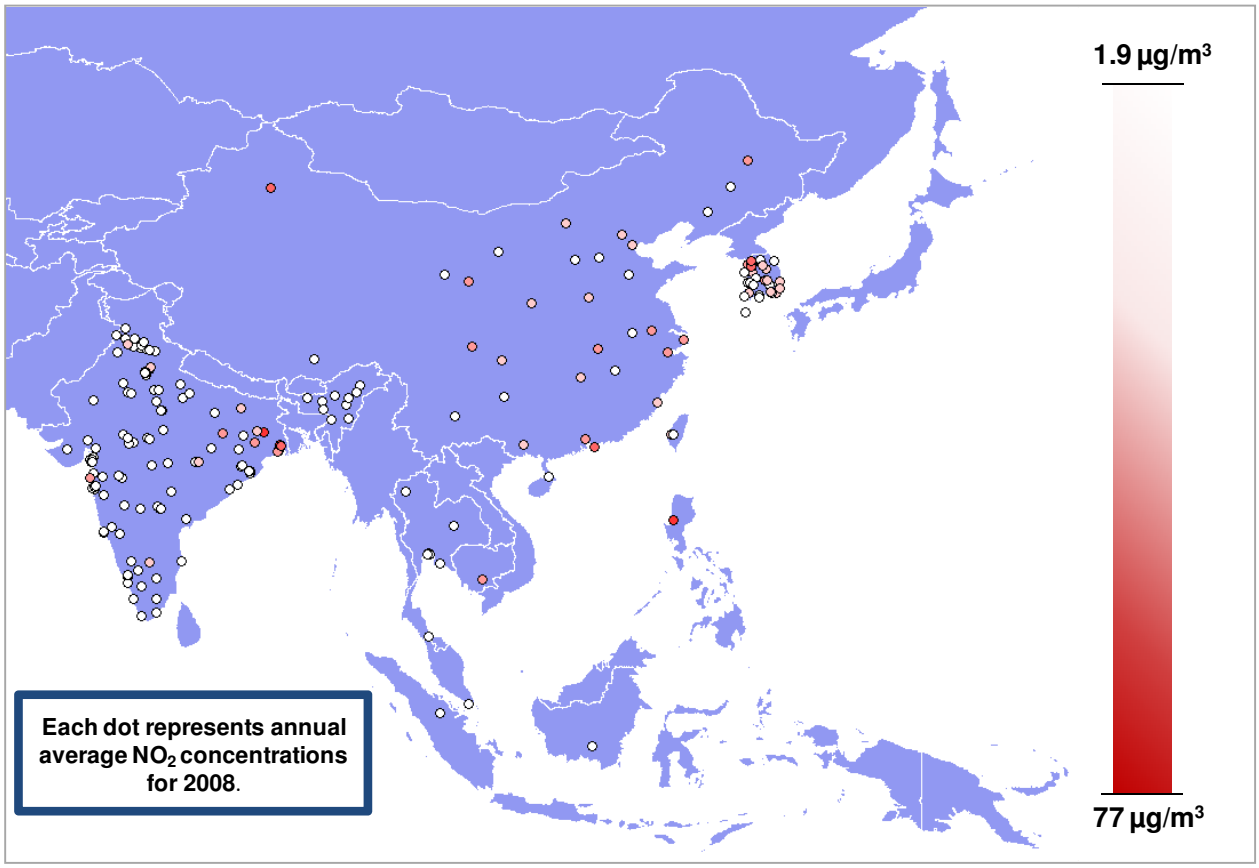
Source: CAI-Asia Center, 2010.

NO_2 Concentrations in Asia – 2008

In 2008, annual average NO_2 monitoring data for 234 Asian cities show that **NO_2 levels are relatively low and well within the WHO AQG** (40 µg/m^3) for most cities. **73%** of the 234 cities have annual average NO_2 concentrations below the WHO AQG.

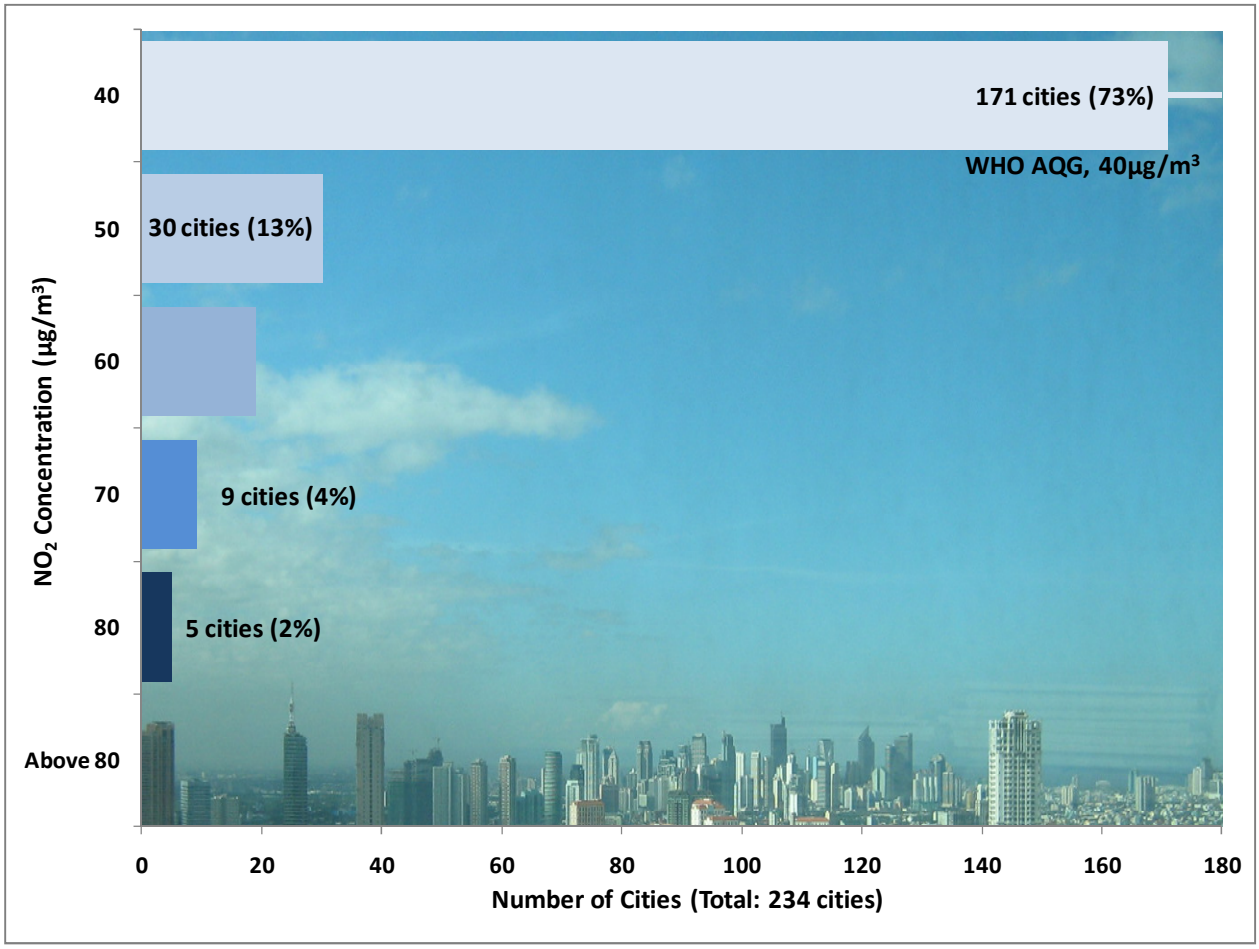
The average of annual average NO_2 concentrations for 234 Asian cities is 30.7 µg/m^3—within the WHO AQG.

Figure 5 Annual Nitrogen dioxide (NO_2) concentrations in 234 cities in Asia.



Note: Annual NO_2 concentrations range from 1.9 (minimum) to 77 (maximum) micrograms per cubic meter (µg/m^3).
Source: CAI-Asia Center, 2010.

Figure 6 Distribution of Asian Cities relative to 2008 NO_2 concentration.



WHO = World Health Organization; AQG = air quality guideline; µg/m^3 = microgram per cubic meter; NO_2 = Nitrogen dioxide

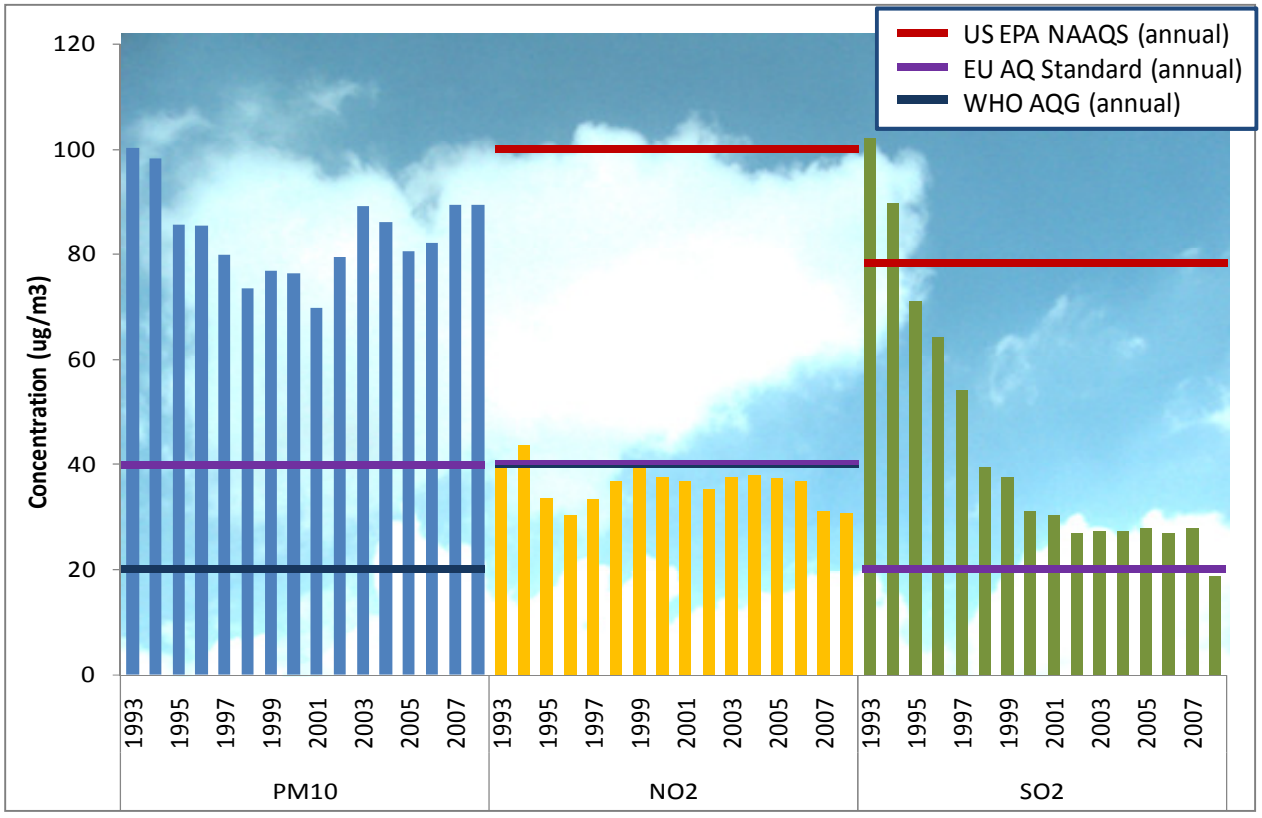
Source: CAI-Asia Center, 2010.

Air Quality Trends

Understanding the air quality trends/tendency for Asia is a difficult task—with one major challenge is the limitations experienced by many Asian cities in air quality monitoring and reporting capacity. Nonetheless, CAI-Asia Center has been collecting available air quality monitoring data for over 200 Asian cities over the years to have an indication on the trend of air pollution in Asian cities. Upon analysis of these data, CAI-Asia has found that—

- **PM_{10}** is still a major pollutant is Asian cities—with the average of annual average PM_{10} concentrations over three times above the WHO guidelines since 1993.
- Since 1995, most Asian cities have reported relatively low **NO_2** levels, with annual average concentrations well within the WHO AQG.
- Regarding **SO_2** levels, although there has been a marked decrease from 1993 to 2000, a number of Asian cities have annual average SO_2 concentrations do not meet even the 24-hr WHO AQG.

Figure 7 Average of Annual Average Annual Ambient AQ in Selected Asian Cities (1993-2008).



AQ = air quality; µg/m^3 = micrograms per cubic meter; US EPA = United Stated Environmental Protection Agency; NAAQS = National Ambient Air Quality Standards; EU = European Union; WHO = World Health Organization; AQG = air quality guidelines; PM_{10} = Particles with aerodynamic particle diameters of 10 micrometers or less; NO_2 = Nitrogen dioxide; SO_2 = Sulfur dioxide.

Source: CAI-Asia, 2010. [Note: Air quality data is compiled by CAI-Asia Center from official sources (publications, personal communications) for 243 Asian cities – as of April 2010.]

Status of Air Quality Standards

The adoption of ambient air quality standards and monitoring of their compliance is one of the main policy tools to protect the health of public from the adverse effects of air pollution. In 2009, CAI-Asia Center conducted a survey to understand the status of National Air Quality Standards in Asia.

Development of National Ambient Air Quality Standards

In Asia, governments, whether at country or city level, have adopted a range of air quality standards, most of which are based on the prevailing international guidelines, such as WHO AQG and US EPA NAAQS, at the time of development. Ideally, countries or cities should develop standards after considering prevailing exposure levels, meteorological and topographical conditions, socio-economic levels, natural background concentration, and population susceptibility, among others.

Ambient air quality standards are set to protect public health and the environment from the harmful effects of air pollution. The standards come in different forms based on different factors. Short-term standards aim to protect population from acute exposure to pollutant whereas long-term standards aim to protect population from long-term exposure to the pollutant.

Air Quality Monitoring and Reporting

To monitor compliance to the standards, authorities often, at the city level, install air quality monitoring systems. In addition, air quality monitoring systems also aid in assessing effectiveness of air quality policies. Asia has seen improvements in capacities for air quality monitoring and reporting. More cities are now able to report on their air quality levels. However, air quality reporting remains to be widely variable in Asian cities. Some cities report actual air quality levels versus some which report with use of air quality indices. Some cities also report air quality information real-time while others continue to do this on ad hoc basis.

PHOTO BELOW Mobile air quality monitoring station in Metro Manila. This is operated by the Environmental Management Bureau – National Capital Region (EMB-NCR).

PHOTO LEFT Automatic air quality monitoring station in Cebu City. This is operated by EMB – Region 7.

World Health Organization Ambient Air Quality Guidelines

The WHO assists countries in reducing the health effects of air pollution by providing guidance to countries in setting their NAAQS through the WHO Ambient AQG. The WHO AQG, first published in 1987, identify pollutant levels below which exposure to a pollutant for a given averaging time either does not constitute a health risk or the least health risk.

In 2005, the WHO updated the AQGs by setting guidelines for PM_{10} and $PM_{2.5}$. The 2005 Global Update also indicated that reducing levels of PM_{10} could decrease mortality in polluted cities by as much as 15% every year. Interim targets were also provided for some pollutants. The ITs are targets which the countries can adopt as they progressively move towards the WHO AQGs.

The 2005 version also lowered the recommended limits of many pollutants, including O_3 and SO_2, making them much more stringent than the national standards currently applied in many parts of the world.

Pollutant	Averaging Time	WHO Guidelines	US EPA NAAQS[c]
$PM_{2.5}$	Annual mean	10[a]	15
	24-hour mean	25[a]	35
PM_{10}	Annual mean	20[a]	-
	24-hour mean	50[a]	150
Ozone (O_3)	8-hour mean	100[a]	147[d]
	1-hour mean	-	235[d]
Nitrogen (NO_2)	Annual mean	40[a]	100
	1-hour mean	200[a]	-
Sulfur dioxide (SO_2)	Annual mean	-	78[e]
	24-hour mean	20[a]	365[e]
	10-minute mean	500[a]	-
Lead (Pb)	Annual mean	0.5[b]	-
	3-month mean	-	1.5
Carbon monoxide (CO)	1-hour mean	30,000[b]	40,000
	8-hour mean	10,000[b]	10,000

$PM_{2.5}$= particles less than 2.5 micrometers in aerodynamic diameter; PM_{10}= particles of 10 micrometers or less in aerodynamic diameter; WHO=World Health Organization; EPA=Environmental Protection Agency; NAAQS=National Ambient Air Quality Standards

[a]WHO, 2006. WHO Air Quality Guidelines for particulate matter, ozone, Nitrogen dioxide and Sulfur dioxide. Global Update 2005. Summary of Risk Assessment.
http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf

[b]WHO, 2000. "Guidelines for Air Quality." http://whqlibdoc.who.int/hq/2000/WHO_SDE_OEH_00.02_pp1-104.pdf

[c]National Ambient Air Quality Standards http://www.epa.gov/air/criteria.html

[d]Conversion factor for ppb to µg/m^3: 1.962

[e]Conversion factor for ppb to µg/m^3: 2.616

Existence of NAAQS in Asia

Most Asian countries have NAAQS, but there are still few without standards

Most Asian countries have already adopted NAAQS (Table 1), with some countries regularly reviewing and updating their standards to take into account current conditions of the country and recent scientific information.

Thailand, for instance, has updated their standards for four times since they first established their standards in 1981. India also recently revised their standards wherein they established $PM_{2.5}$ and O_3 standards.

Recent developments were also observed in Viet Nam. Effective 2010, Viet Nam's NAAQS (TCVN) was revised into national technical regulations (QCVN), making compliance mandatory. Hong Kong Special Administrative Region (SAR) is also currently undergoing review of their Air Quality Objectives (AQO).

Nonetheless, there are a number of Asian countries still without NAAQS—Afghanistan, Bhutan, Lao People's Democratic Republic (PDR) and Pakistan (Table 1). There is currently no information whether these countries are planning to adopt NAAQS in the near future.

Asian countries slowly establishing $PM_{2.5}$ standards

Countries have developed standards for a range of pollutants. With recent scientific findings highlighting the significant health impacts of PM2.5, WHO and several developed countries, such as US and EU have established $PM_{2.5}$ guidelines (for WHO) and standards (for US and European Union [EU]).

Asian countries are slowly moving towards developing $PM_{2.5}$ as well, but there is still a long way to go. Of 19 Asian countries included reviewed; four have $PM_{2.5}$ standards (Table 1). Further, based on survey results, only Thailand had concrete plans to develop $PM_{2.5}$ standards in the next couple of years.

Status of Air Quality Standards

Table 1 Summary of Ambient Air Quality Standards in Select Asian Countries (µg/m^3)

Countries	$PM_{2.5}$		PM_{10}		SO_2		NO_2		O_3		CO ('000)		Pb
	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	1-Hr	8-Hr	1-Hr	8-Hr	Annual
Afghanistan	-	-	-	-	-	-	-	-	-	-	-	-	-
Bangladesh	65	15	150	50	365	80	-	100	235	157	40	10	0.5
Bhutan	-	-	-	-	-	-	-	-	-	-	-	-	-
Cambodia	-	-	-	-	300	100	100	-	200	-	40	20	-
China: Grade I	-	-	50	40	50	20	80	40	160	-	10	-	1
China: Grade II	-	-	150	100	150	60	120	80	200	-	10	-	1
China: Grade III	-	-	250	150	250	100	120	80	200	-	20	-	1
Hong Kong SAR	-	-	180	55	350	80	150	80	240	-	30	10	-
India*	60	40	100	60	80	50	80	40	180	100	4	2	0.5
India**	60	40	100	60	80	20	80	30	180	100	4	2	0.5
Indonesia	-	-	150	-	365	60	150	100	235	-	30	-	1
Lao PDR	-	-	-	-	-	-	-	-	-	-	-	-	-
Malaysia	-	-	150	50	105	-	10	-	200	120	35	10	-
Mongolia	-	-	-	-	30	-	40	-	120	0	-	-	-
Nepal	-	-	120	-	70	50	80	40	-	-	-	10	0.5
Pakistan	-	-	-	-	-	-	-	-	-	-	-	-	-
Philippines	-	-	150	60	180	80	150	-	140	60	35	10	1
Republic of Korea	-	-	100	50	131	52	113	56	196	118	28.6	10.3	0.5
Singapore	35	15	150	-	365	80	-	100	-	147	40	10	-
Sri Lanka	50	25	100	50	80	-	100	-	200	-	30	10	-
Thailand	-	-	120	50	300	100	-	-	200	140	34.2	10.3	-
Viet Nam	-	-	150	50	125	50	-	40	-	120	30	10	0.5

China: Grade I = applies to specially protected areas, such as natural conservation areas, scenic spots, and historical sites; **China: Grade II** = applies to residential areas, mixed commercial/residential areas, cultural, industrial, and rural areas; **China: Grade III** = special industrial areas**; India*** = NAAQS for Industrial, Residential, Rural and Other Areas**; India**** = NAAQS for Ecologically Sensitive Areas (notified by Central Government); **SAR** = Special Administrative Region; **PDR** = People's Democratic Republic; **Pb** = lead; **PM_{10}** = Particles with aerodynamic particle diameters of 10 micrometers or less; **$PM_{2.5}$** = Particles with aerodynamic particle diameters of 2.5 micrometers or less

Ozone (**O_3**) Conversion factor for ppb to µg/m^3: 1.962
Sulfur dioxide (**SO_2**) Conversion factor for ppb to µg/m^3: 2.616
Carbon monoxide (**CO**) Conversion factor for ppb to µg/m^3: 1.145
Nitrogen dioxide (**NO_2**) Conversion factor for ppb to µg/m^3: 1.880

Source: CAI-Asia Center, 2010. [Collected from various sources]

Comparison of NAAQS with WHO AQG, US EPA NAAQS and EU AQ Standards (Per Pollutant)

$PM_{2.5}$

Only a few Asian countries have $PM_{2.5}$ standards, and of these countries, none have standards equivalent to the WHO AQG. Still, $PM_{2.5}$ standards generally close to a WHO interim target. Annual PM2.5 standards of Singapore and Bangladesh, for instance, are at WHO IT-3 (15 µg/m^3).

PM_{10}

All the surveyed Asian countries' standards, including US EPA's PM_{10} standards for 24-hour and annual averaging period are more lenient than WHO guidelines with some even more lenient than WHO IT-1. A large number of the countries meet WHO IT-1 for both 24-hour and annual averaging periods.

SO_2

All the surveyed Asian countries, including US EPA and EU, have 24-hr average SO_2 standards higher than WHO AQG. About 64% of the countries surveyed were higher than WHO IT-1. Most of the countries have annual SO_2 standards despite WHO not having a guideline for this.

NO_2

Only four of 18 countries surveyed had annual NO_2 standards equivalent to the WHO AQG. Most of the countries have 24-hour NO_2 standards even though WHO does not have a guideline for this.

O_3

Of the 19 Asian countries surveyed, two have 8-hr average O_3 standards same with the WHO AQG. Remaining countries with 8-Hr average O_3 standard meet the WHO IT-1. Still, 59% of the countries do not have 8-hr average O_3 standards.

CO

Most of the surveyed Asian countries, including US EPA and EU, have CO standards for 1-hour and 8-hour averaging period within WHO guidelines with a few being more stringent than the WHO AQG.

Pb

Around a third of the countries surveyed have Pb standards for annual averaging period similar to the prescribed WHO AQG (0.5µg/m^3), another third of the countries have more lenient standards and the last third of the countries do not have Pb standards for the annual averaging period.

Figure 8 24-Hr $PM_{2.5}$ Standards in Asian countries vs. WHO AQG and US EPA NAAQS.

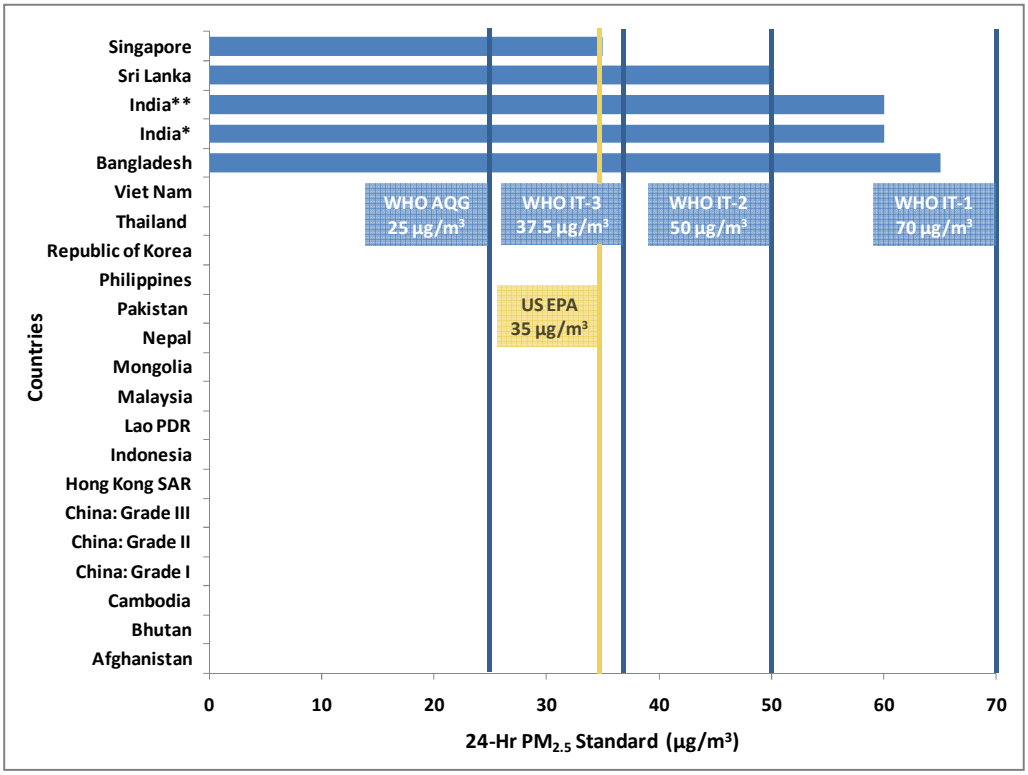


Figure 9 Annual $PM_{2.5}$ Standards in Asian countries vs. WHO AQG, US EPA and EU NAAQS.

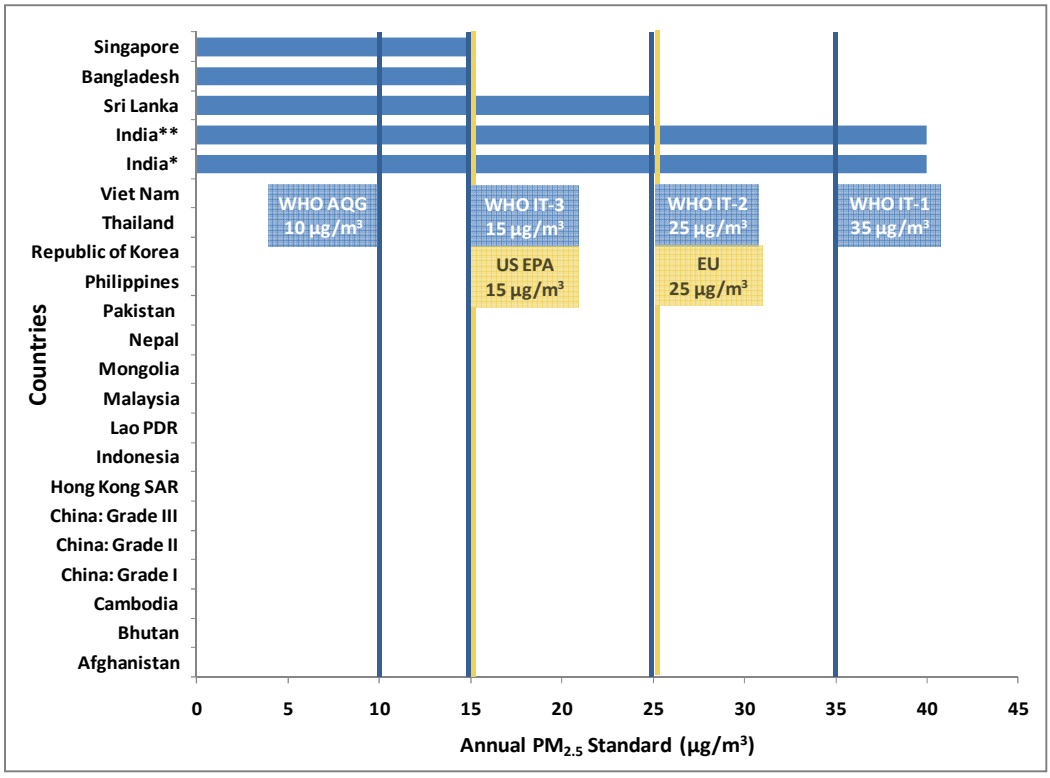


Figure 10 24-Hr PM_{10} Standards in Asian countries vs. WHO AQG, US EPA and EU NAAQS.

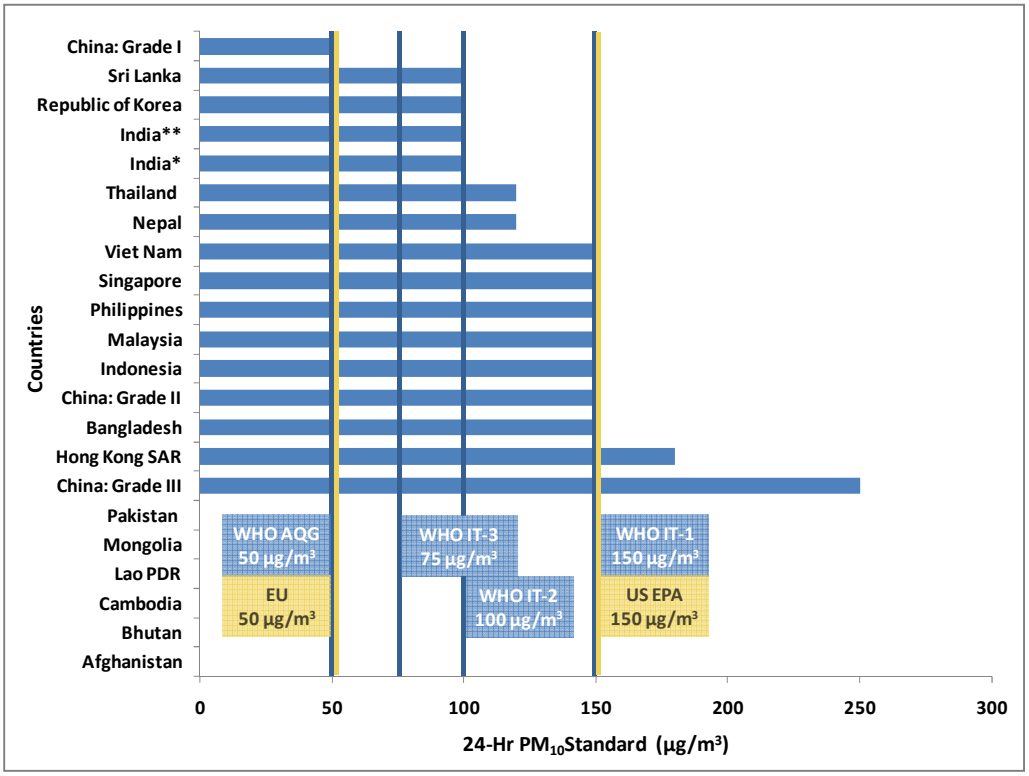


Figure 11 Annual PM_{10} Standards in Asian countries vs. WHO AQG and EU NAAQS.

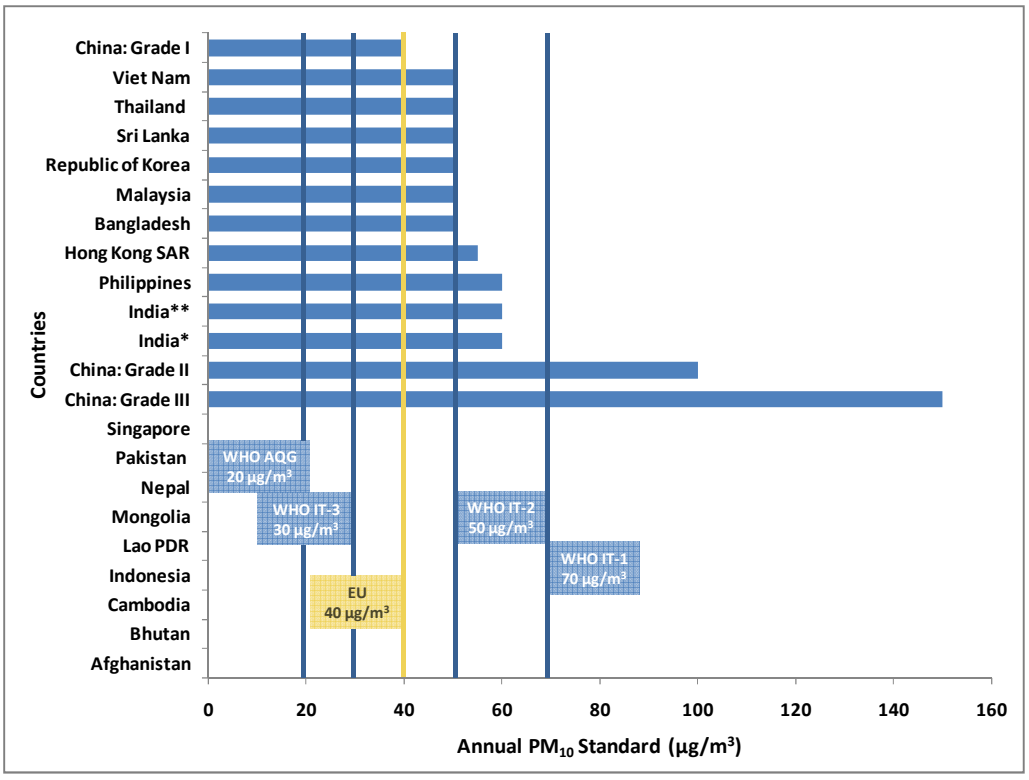


Figure 12 24-Hr SO_2 Standards in Asian countries vs. WHO AQG, US EPA and EU NAAQS.

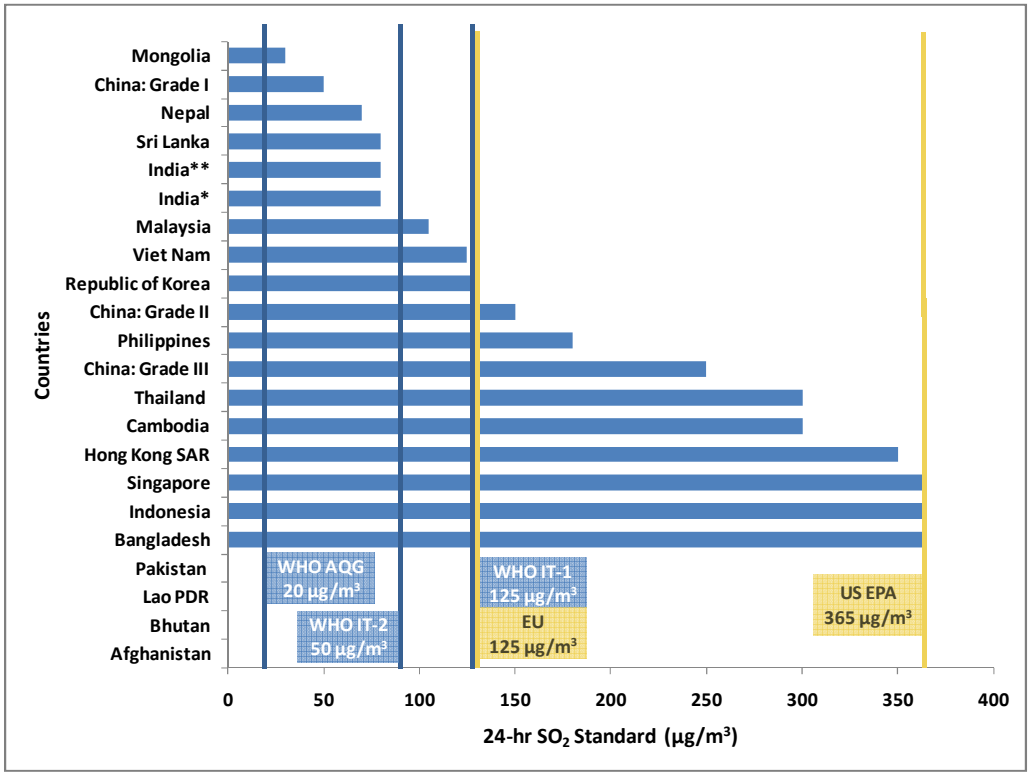


Figure 13 Annual SO_2 Standards in Asian countries vs. US EPA NAAQS.

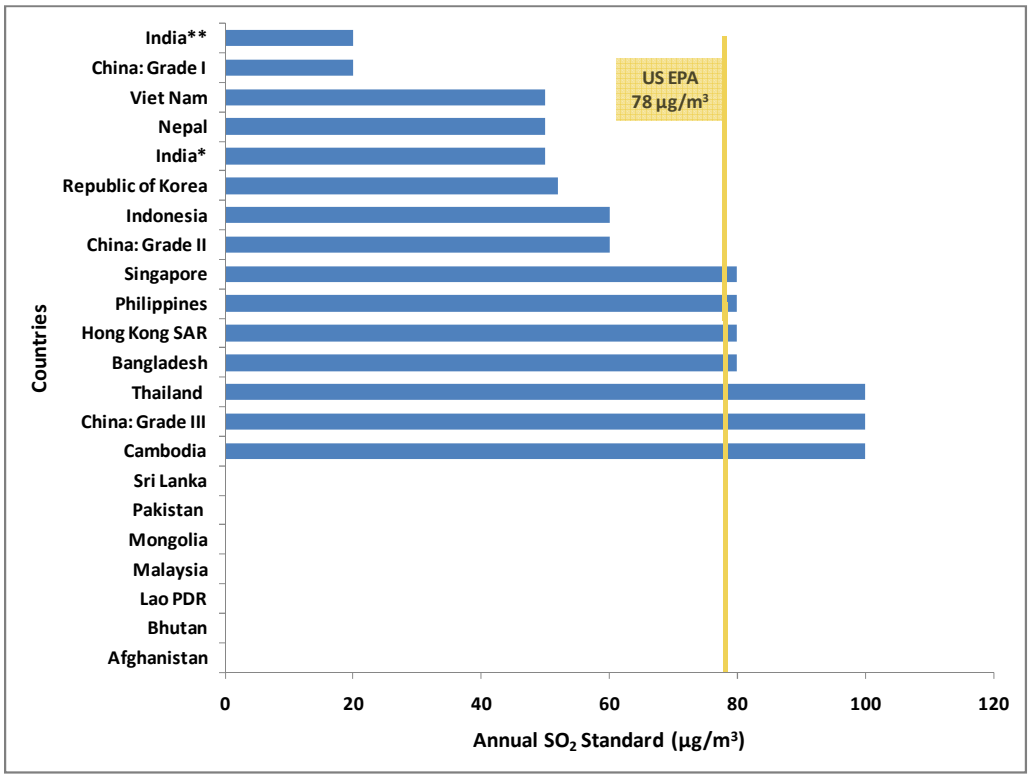


Figure 14 24-Hr NO_2 Standards in Asian countries.

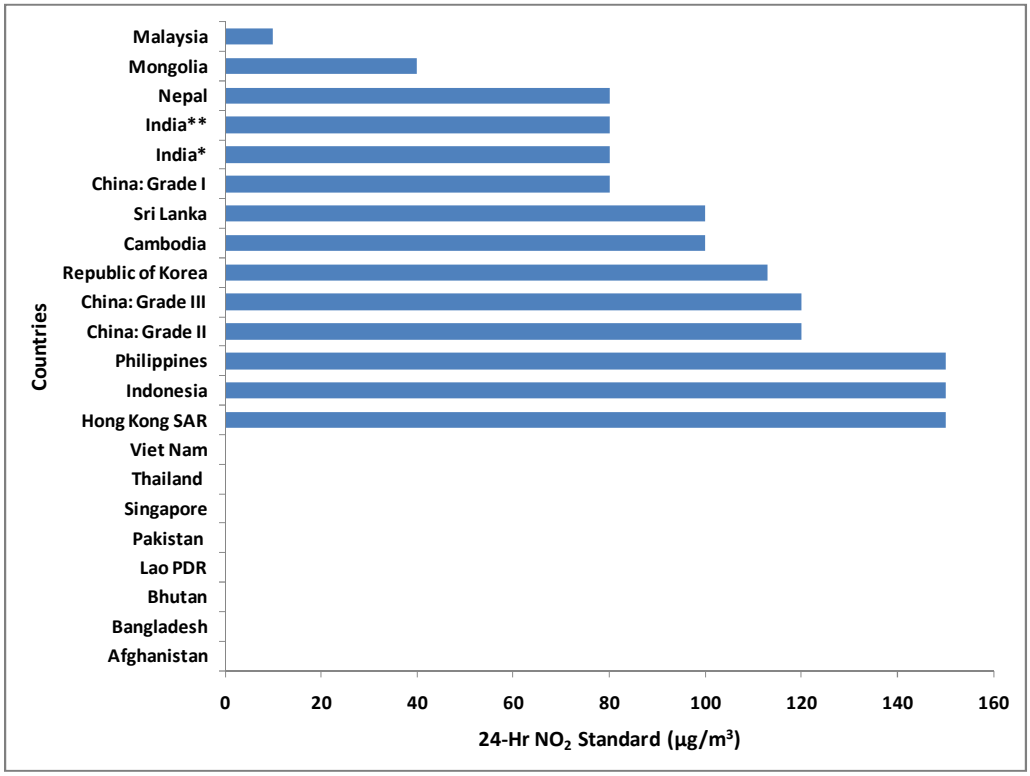


Figure 15 Annual NO_2 Standards in Asian countries vs. WHO AQG, US EPA and EU NAAQS.

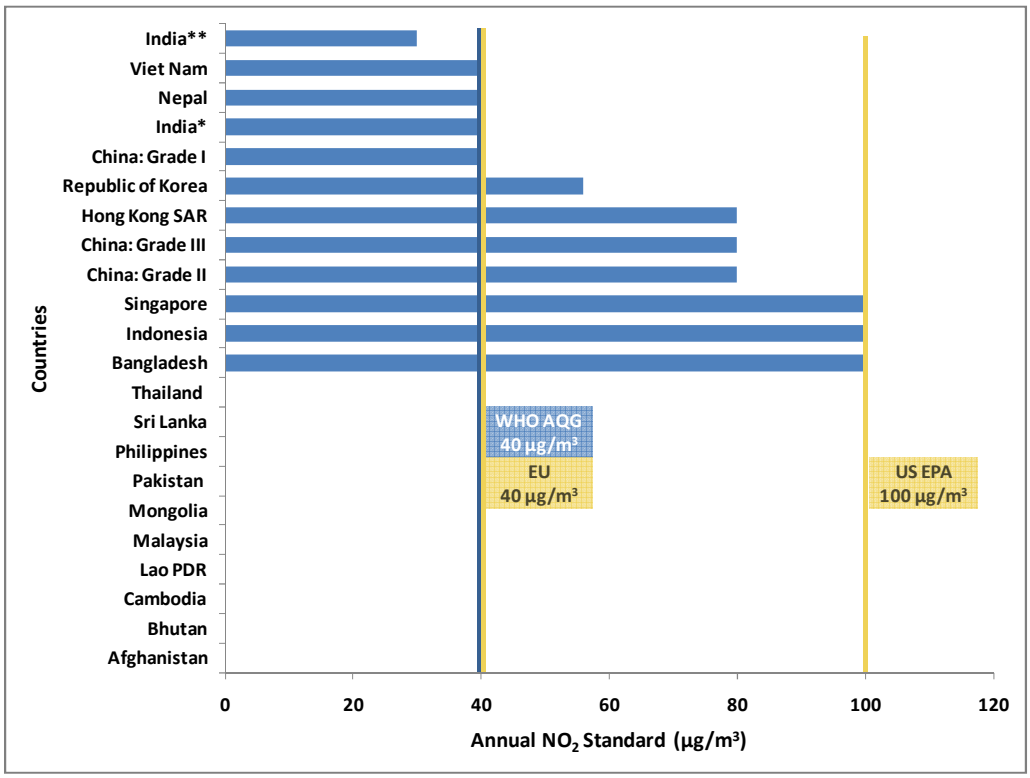


Figure 16 1-Hr O_3 Standards in Asian countries vs. US EPA NAAQS.

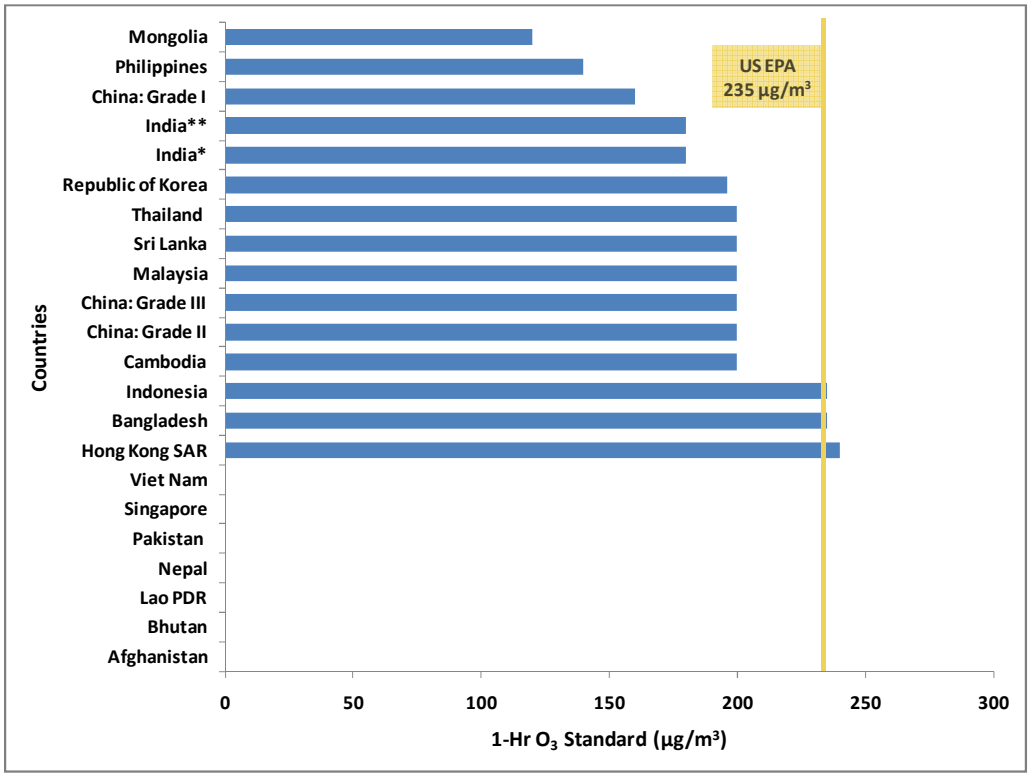


Figure 17 8-Hr O_3 Standards in Asian countries vs. WHO AQG, US EPA and EU NAAQS.

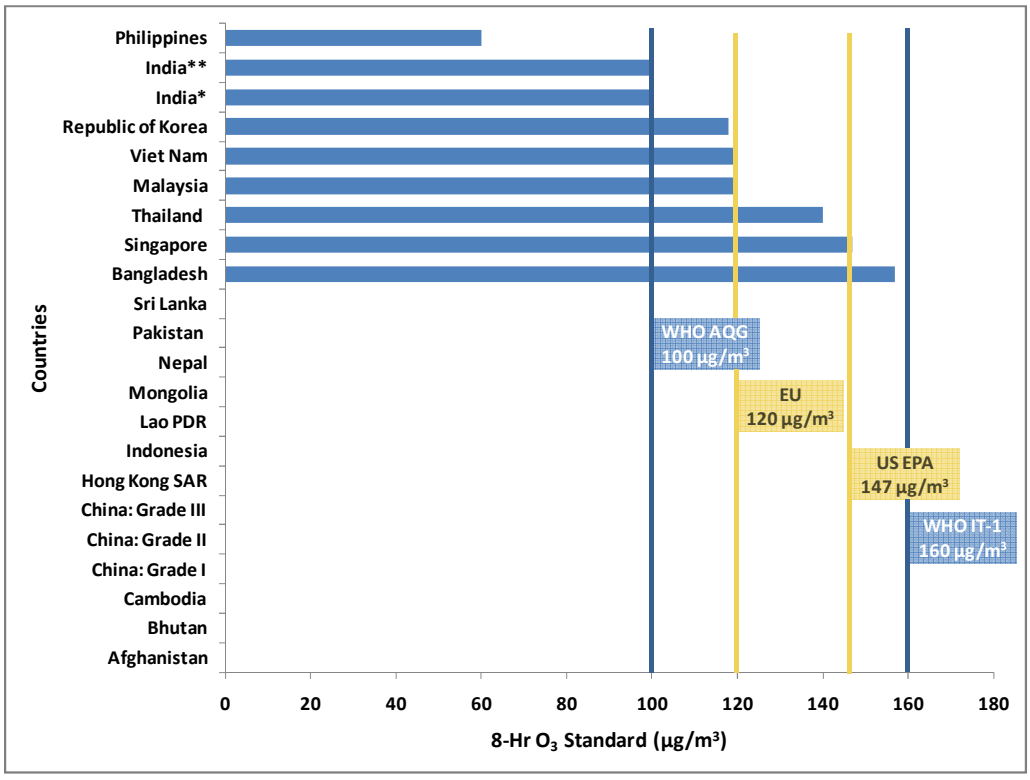


Figure 18 1-Hr CO Standards in Asian countries vs. WHO AQG and US EPA NAAQS.

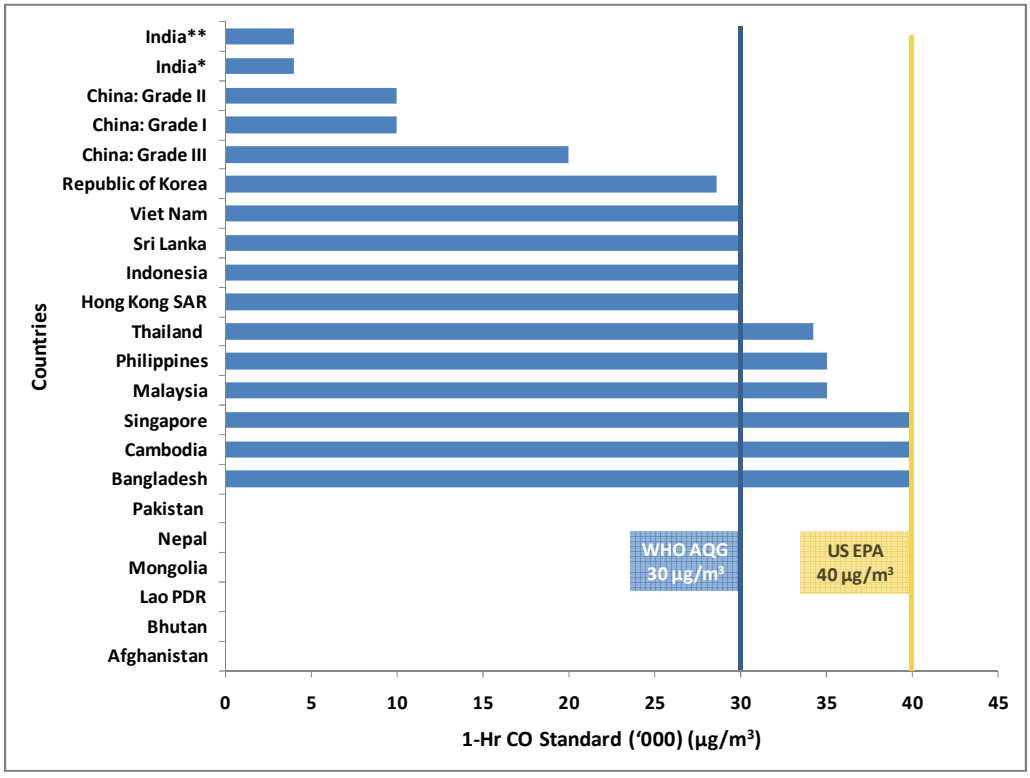


Figure 19 8-Hr CO Standards in Asian countries vs. WHO AQG, US EPA and EU NAAQS.

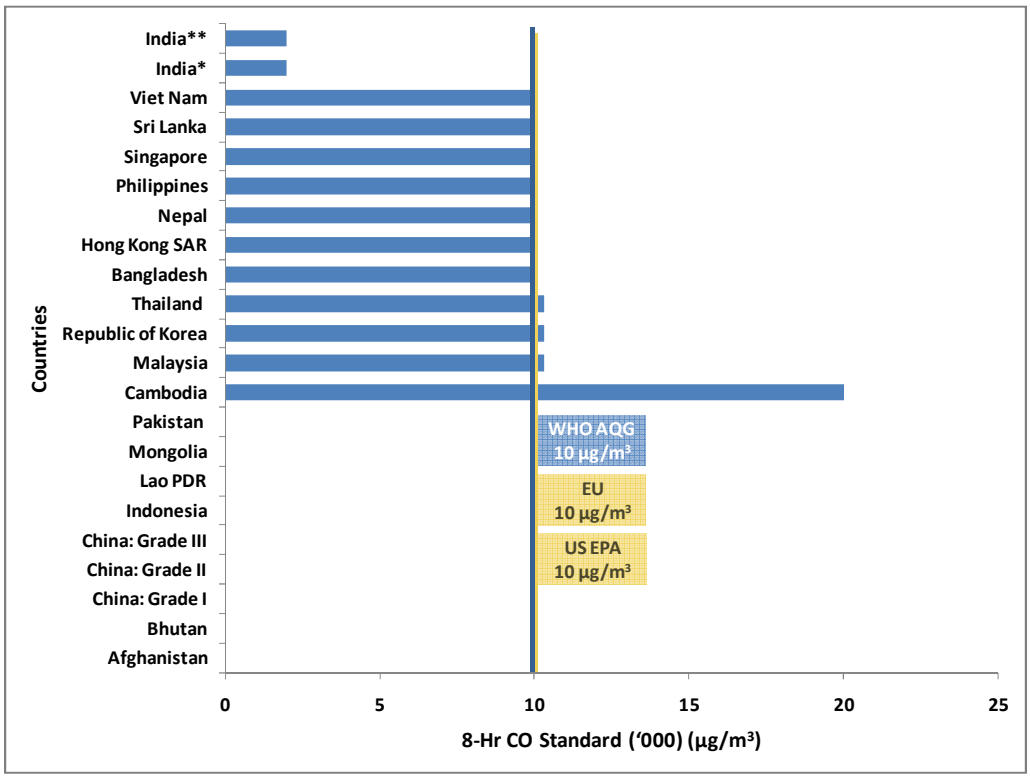
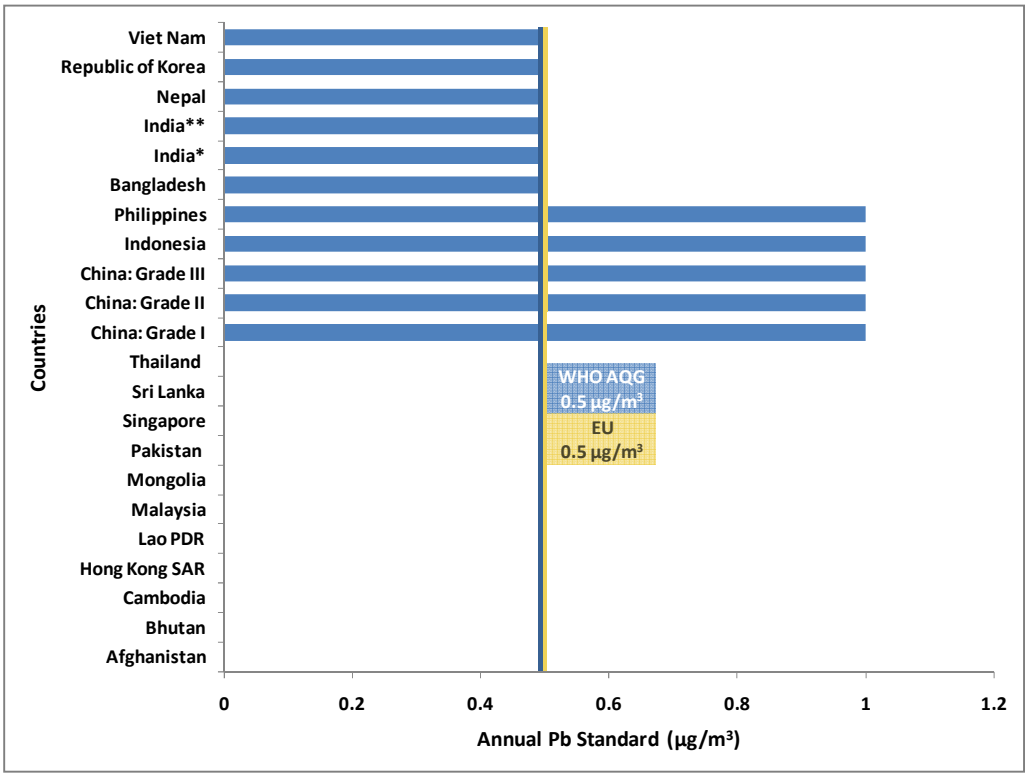


Figure 20 Annual Pb Standards in Asian countries vs. WHO AQG and EU NAAQS.



Notes for Figure 8 to Figure 20.

China: Grade I = applies to specially protected areas, such as natural conservation areas, scenic spots, and historical sites; **China: Grade II** = applies to residential areas, mixed commercial/residential areas, cultural, industrial, and rural areas; **China: Grade III** = special industrial areas**; India*** = NAAQS for Industrial, Residential, Rural and Other Areas**; India**** = NAAQS for Ecologically Sensitive Areas (notified by Central Government); **SAR** = Special Administrative Region; **PDR** = People's Democratic Republic; **Pb** = lead; **PM_{10}** = Particles with aerodynamic particle diameters of 10 micrometers or less; **$PM_{2.5}$** = Particles with aerodynamic particle diameters of 2.5 micrometers or less; **µg/m^3** = micrograms per cubic meter; **WHO** = World Health Organization; **IT** = interim target; **AQG** = air quality guidelines; **US EPA** = United States Environmental Protection Agency; **EU** = European Union.

Ozone (**O_3**) Conversion factor for ppb to µg/m^3: 1.962
Sulfur dioxide (**SO_2**) Conversion factor for ppb to µg/m^3: 2.616
Carbon monoxide (**CO**) Conversion factor for ppb to µg/m^3: 1.145
Nitrogen dioxide (**NO_2**) Conversion factor for ppb to µg/m^3: 1.880

Source: CAI-Asia Center, 2010. [Collected from various sources]

3510 Robinson's Equitable Tower, ADB Avenue,
Ortigas Center, Pasig City, 1605 Philippines
Tel: (63-2) 395-2843/(63-2) 395-2845
Fax: (63-2) 395-2846
Email: center@cai-asia.org
Website: www.cleanairinitiative.org