Air Pollution Reduction Strategy for Bangladesh

Final Report

Prepared by
Department of Environment
Government of Bangladesh

In association with
Department of Civil Engineering
Bureau of Research, Testing and Consultation
Bangladesh University of Engineering and Technology

October 2012

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Executive Summary

Air pollution, especially in the large cities, is a major environmental concern in Bangladesh. In response to a call by the Department of Environment of the Government of Bangladesh, this report describes the current state of air quality, major sources of air pollution, past policies implemented and suggests future strategies to reduce air pollution in Bangladesh. Around 50 strategies were initially selected, of which 26 are finally recommended after evaluation of the strategies. The criteria for evaluation were likely impact, time to introduce, time to benefits, technical and implementation effectiveness, cost effectiveness and co-benefits. The recommended strategies are presented below (detail inside the report). The strategy choices were based on a *qualitative* multi-criteria evaluation because of lack of information for quantitative benefit-cost modeling. It is strongly recommended each of the strategies is quantitatively evaluated before final implementation.

Table ES 1. Recommended strategies for air pollution reduction in Bangladesh

	Strategy	Area of application
A	Improve public transport	Large cities
B	Strengthen vehicle inspection and maintenance	All, especially large cities
C	Ban vehicles older than 20 years	Commercial vehicles, large cities
D	Encourage Diesel to CNG switch through incentives	All diesel vehicles, especially, truck & buses in large cities
E	Emissions (age) based annual registration fees	All vehicles
F	Stringent emissions standards	All new vehicles
G	Emissions based import tariff	All new vehicles
H	Comprehensive land use plan for industry locations	All industries, especially new ones
I	Cluster management	Cluster of highly polluting industries
J	Emissions (technology and fuel) based license fee	All kilns
K	Technology standards	All kilns
L	Alternate construction material	All country, especially large cites
M	Ensure adequate power supply	All country
N	Emissions standards	All new plants
O	Emissions standard for diesel generators	All new generators
P	Inspection & maintenance of diesel generators	All existing generators
Q	Technology specification	Existing steel mills, cement and glass factories
R	Inspection and maintenance	Existing steel mills, cement and glass factories
S	Emissions standards	All new and existing plants
T	Import control for quality of coal	Whole country, primarily brick and power industries
U	Better construction practices on site & during transport	All construction sites
V	Air pollution mitigation plan and its enforcement	Large construction projects
W	Timely road maintenance	All roads
X	Landscaping and gardening	All exposed soil in urban areas
Y	Encourage fuel switch	Urban slums and rural areas
Z	Improved cooking stoves	Rural areas

In addition, it is important to consider the following for effective implementation of air pollution reduction strategies:

1. Regulatory and fiscal reform to enable the strategies effectively
2. Awareness and motivation about air pollution across sectors
3. Research and development to address the knowledge and information gaps so that future strategies can be based on quantitative modeling
4. Co-operation and coordination among various stakeholders, from regulators to businesses to the general public
5. Capacity building and knowledge retention
6. Institutional reform to ensure coordination and governance

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List of Acronyms

µg	micro gram (measurement unit)
ADB	Asian Development Bank
AQ	Air Quality
AQS	Air Quality Standards
BAEC	Bangladesh Atomic Energy Commission
BC	Black Carbon
BDT	Bangladeshi Taka
BPC	Bangladesh Petroleum Corporation
BRTC	Bureau of Research, Testing and Consultation
BTK	Bull's Trench Kiln
BUET	Bangladesh University of Engineering and Technology
CAC	Command and Control
CAMS	Continuous Air Monitoring Stations
CH4	Methane
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
dL	deci Litre (measurement unit)
DoE	Department of Environment
FCK	Fixed Chimney Kiln
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gases
GoB	Government of Bangladesh
GSC	Gravity Settling Chamber
HHK	Hybrid Hoffman Kiln
HK	Hoffman Kiln
IAP	Indoor Air Pollution
ICS	Improved Cooking Stoves
I&M	Inspection and Maintenance
IF	Internal Fuel
L	Litre
M$	Million US Dollar
MBI	Market Based Instrument
MoEF	Ministry of Environment and Forest
NO_2	Nitrogen Dioxide

NO_x	Oxides of Nitrogen, includes NO_2
O_3	Ozone
Pb	Lead
PM	Particulate Matter
PM_{10}	Particulate matter with an aerodynamic diameter less than 10 µm
$PM_{2.5}$	Particulate matter with an aerodynamic diameter less than 2.5 µm
ppm	parts per million
SLCF	Short-Lived Climate Forcer
SLCP	Short-Lived Climate Pollutant
SO_2	Sulphur Dioxide
SO_x	Oxides of Sulphur, includes SO_2
SPM	Suspended Particulate Matter, includes PM_{10}
TSP	Total Suspended Particles
UNEP	United Nations Environment Programme
USEPA	United States Environmental Pollution Agency
VCBK	Vertical Shaft Brick Kiln
WB	World Bank
WHO	World Health Organization
ZK	Zigzag Kiln

Acknowledgements

The Bureau of Research, Testing and Consultation (BRTC) of the Bangladesh University of Engineering and Technology thanks the Department of Environment (DoE) of the Government of Bangladesh for entrusting it with the task of preparing the air quality reduction strategy for Bangladesh. The interactions with the DoE were smoothly and quickly handled by Mr. Quazi Sarwar Imtiaz Hashmi. Mr. Hashmi also arranged the stakeholders meeting where the draft version of the report was presented for getting feedback from experts in the area. Prof. Nooruddin Ahmed, Prof. A. H. Khan, Dr. Md. Khaliquzzaman, Dr. Hafiza Khatun, Dr. Bilkis Begum, Mr. Md. Sirajul Islam Molla, Mr. Mylvakanam Iyngararasan, and the UNEP all provided valuable insight through written comments on the draft report, which has improved the work significantly. BRTC gratefully acknowledges their contribution.

Chapter 1
INTRODUCTION

1.1 Background

Air pollution, especially in the large cities of Dhaka and Chittagong, is a major environmental hazard in Bangladesh. The impact of poor ambient air quality on human health, agricultural production and damage to materials has been well documented in developing and developed countries. Governments of all developed countries have been very active in controlling air pollution in order to ensure a good quality of life for their citizens. Developing countries like Bangladesh have also taken note of the air pollution issues, and often guided by the multinational agencies like the World Bank (WB), Asian Development Bank (ADB), United Nations Environment Programme (UNEP), have taken measures or have made plans to reduce and control air pollution.

The Department of Environment (DoE), the Government Agency entrusted with safeguarding the environment in Bangladesh, sought proposals to develop an 'Air Pollution Reduction Policy for Bangladesh' under the framework of the Malé Declaration on Control and Prevention of Air Pollution and Its Likely Trans-boundary Effects for South Asia'. The DoE, with the assistance from the Malé Declaration Secretariat based at UNEP and the Stockholm Environmental Institute (SEI), selected the Department of Civil Engineering at Bangladesh University of Engineering and Technology (BUET) as the consultant to produce the report. BUET provides consulting services to nationally important projects under its Bureau of Research Testing and Consultation (BRTC) framework.

The Department formed a two member BRTC consultant's team, comprised of Dr. M. Ashraf Ali, Professor and Dr. Zia Wadud, Associate Professor to conduct the work, and a contract was signed accordingly between BRTC, BUET and the DoE.

1.2 Methodology

The proposed methodology for developing the air pollution reduction policy/strategy follows the general USEPA guidelines (USEPA 2011). There are four main steps in developing an air pollution control strategy.

1. *Determine priority pollutants:* The pollutants of concern depend not only on the health (or reduced agricultural output), but also on the severity of the air quality problem in the region.
2. *Identify control measures:* For specific emissions source categories, the appropriate controls for the priority pollutants are identified. This segment primarily deals with the technological solutions.
3. *Incorporate the control measures into a strategy/policy*: Once the control measures are identified, a regulatory program is proposed such that the control strategies are formalized. This section primarily deals with policies aimed at adoption of the technologies mentioned above.
4. *Involve the public:* It is important to involve the community and other affected parties, during the development of the policy or strategy. Early consultation reduces later challenges.

For the first step, it is important to have a comprehensive spatially and temporally disaggregated emissions inventory identifying the contribution of different emission sources. Unfortunately no such emissions inventory is available, although DoE has developed an aggregate emissions inventory under the Malé Declaration for 2000. Unfortunately, this inventory does not capture the required spatial or temporal resolution, and there are issues with the activity data and emissions factors. In order to link steps 2 and 3, there are three primary considerations: Environmental, Engineering and Economic. Both, the cost of individual control measures (technologies), and the cost of the strategy (regulation, command and control, market based instruments, etc.) are important in this regard. However, there is a lack of quantitative information in order to carry out a quantitative evaluation of the strategies.

The dearth of information about ambient air pollutants concentration trends, emissions inventory, existing technological landscape and costs of control, the above methodology has been modified and the following describes the simplified work breakdown carried out in this study by the consultants, as outlined in the original proposal:

1. Determine the current status of air pollution in Bangladesh, with emphasis on highly polluted cities;
2. Review of the emissions inventory compiled by the DoE and suggest modifications, if necessary;
3. Based on 1 and 2, identify the key air pollutants that require action;
4. Review of international literature on air pollution control strategies (technologies) and their effectiveness from environmental and engineering perspectives;
5. Collect existing relevant air pollution strategies, policies, laws, standards and regulations in Bangladesh;
6. Review the evidence (based on published literature) of the impact of previous policies, strategies on air quality in Bangladesh and of potential co-benefits of strategies with respect to GHG emissions;
7. Collect government plans and projections on industrial and transport developments over the next few years, especially on coal based power plants, highways, public transportation and brick industries;
8. Review of international literature on policies and strategies to reduce air pollution and their effectiveness and economic efficiency;
9. Based on 5 to 8, identify the key control strategies for Bangladesh and potential policies to help implement the strategies;
10. Incorporate feedback from stakeholders and update the report;
11. Prepare the draft final report for Client's feedback;
12. Prepare final report incorporating feedback from Client/ Reviewers.

1.3 Scope

An ideal approach to developing an air pollution reduction strategy is to develop an impact-pathway model for evaluation of policy impact as explained in Fig. 1.1. Such a modeling approach can quantify the exact benefits resulting from any of the candidate strategies in monetary terms, which can then be assessed against the cost of the strategy to guide policy choice. Although the consultants have some experience in such modeling in the context of Bangladesh, especially in

the transport and brick emissions area, there are still large uncertainties in input data (of emissions factors, emissions activity, temporal and spatial distribution, resolution of information, trans-boundary transport etc.), which renders such modeling exercises less useful in the context of Bangladesh. The consultants believe that the policymaking in Bangladesh should move toward a modeling and evidence based framework, but that the knowledge is not quite there yet. Under these circumstances qualitative evaluation and expert stakeholders' opinions were given more emphasis than quantitative modeling.

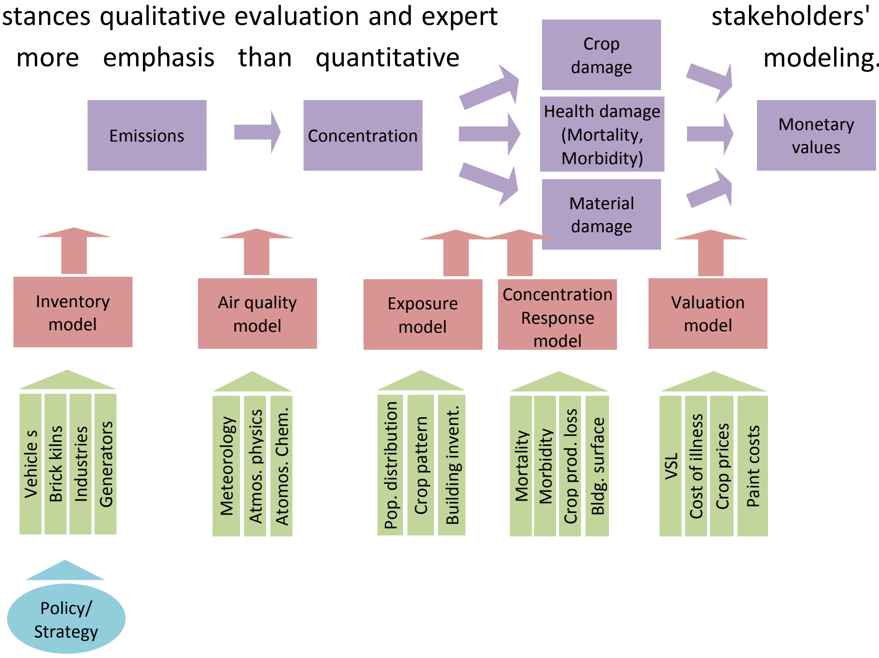


Fig. 1.1 Impact pathway for air quality policy benefits evaluation

Also, although the original title of the work deals with air pollution reduction 'policy', it is important to highlight the change from the original call for the proposal document and the use of the word 'strategy' instead of 'policy'. This distinction is important since policy statements generally depict one overarching vision or goal, while strategies are pathways to achieve that vision or goal. The consultants thus focused on strategies, rather than on the overarching policy goal. This also meant that the barrier to air pollution management and actions to overcome them were beyond the scope of current work. Also detailed description of other policy relevant issues were beyond the scope and are only briefly discussed.

Therefore, this document focuses on the strategies to reduce air pollution and not on action plans or other air quality management issues. The simplified work break down described in the previous section arises from these limitations in scope directly.

1.4 Structure of the Report

The report is divided into nine chapters. After this introduction,Chapter 2 presents the current status of ambient air pollution in order to understand the key pollutants that need to be reduced. Chapter 3 discusses the major sources of pollutant emissions, and Chapter 4 discusses the impact of air pollution in Bangladesh. Chapter 5 documents the past measures undertaken in Bangladesh to reduce air pollution, and their successes and failures. Chapter 6 discusses the approaches to

pollution control, with some discussion on the market based and command and control policy approaches to control air pollution. This chapter also presents some international case studies of successful and not-so-successful approaches to pollution control. Chapter 7 identifies the potential strategies to reduce air pollution in Bangladesh, sets the evaluation criteria and then recommends the strategies applicable for Bangladesh. Chapter 8 briefly discusses other relevant issues to implement the strategies, and Chapter 9 presents the conclusions of the study.

Chapter 2
AMBIENT AIR QUALITY IN BANGLADESH

This chapter presents the current status of air quality in Bangladesh. The chapter describes the status of each the six criteria air pollutants, pollutants that are generally controlled by air quality standards in many countries and the current ambient air quality standard in Bangladesh.

Air Quality Management and Standards

The history of air quality management in Bangladesh is relatively recent. Ambient air quality standards were first introduced in Bangladesh in 1997 under the environmental conservation rules (ECR) 1997. The Air Quality Management Project (AQMP) implemented by the DoE during 2000-2007 with support from the World Bank was the first major project aimed at air quality management in Bangladesh. The objectives of the AQMP included reducing vehicular emissions in the metropolitan areas, setting standards, enforcing pilot programs towards cleaner technologies, as well as implementing air quality monitoring and evaluation. This led to the revision of the ambient air quality standards of Bangladesh in July 2005 (see Table 2.1, Appendix). Other notable projects aimed at air quality management include certain components of the Clean And Sustainable Environment (CASE) Project supported by the World Bank, the Bangladesh Air Pollution Management (BAPMAN) Project, and the Implementation of Malé Declaration. The BAPMAN project supported by NORAD is primarily an institutional capacity building project where the Norwegian Institute of Air Research (NILU) is providing the necessary knowledge, tools, and guidance to Bangladesh counterparts for maintaining an Air Quality program in a sustainable manner. The overall objective of the CASE project is to catalyze the adaptation of Sustainable Environment Initiatives (SEIs) in key polluting sectors (urban transport and brick making) with a focus to abate air pollution and generate co-benefits through introducing energy efficient technology in brick sector and lay the foundation of introducing mass transit projects such as Bus Rapid Transit in Dhaka.

Table 2.1 Ambient air quality standards in Bangladesh from July 2005 and their comparison with WHO and US standards (Source: ADB 2006)

Pollutant	Averaging time	Bangladesh standard ($\mu g/m^3$)	WHO guideline ($\mu g/m^3$)	US standard ($\mu g/m^3$)
Carbon Monoxide (CO)	8 hour	10,000 (9 ppm)	10,000	10,000
	1 hour	40,000 (35 ppm)	30,000	40,000
Lead (Pb)	Annual	0.5	0.5	0.15
Nitrogen Oxides (NO_x)	Annual	100 (0.053 ppm)	-	-
Suspended Particulate Matter (SPM)	8 hour	200	-	-
Coarse Particulates (PM_{10})	Annual	50	20	-
	24 hour	150	50	150
Fine Particulates ($PM_{2.5}$)	Annual	15	10	15
	24 hour	65	25	35
Ozone (O_3)	1 hour	235 (0.12 ppm)	-	235
	8 hour	157 (0.08 ppm)	100	157
Sulphur Dioxide (SO_2)	Annual	80 (0.03 ppm)	-	78
	24 hour	365 (0.14 ppm)	20	365

Lead (Pb)

The presence of lead (Pb) in ambient air can have especially harmful effect on the development of fetuses and children (Tong et al. 2000). Pb was identified as a major health hazard in Bangladesh as early as 1980s (Khan et al. 1980) when an average blood Pb concentration of 55±18 µg/dL was observed in a group of 100 adults in Dhaka.[1] In early 1990s, tests confirmed the presence of Pb in ambient air in Dhaka, and petrol additives were identified as a major source. Subsequent advocacy by various groups led to total phase out of Pb from petrol in Bangladesh by mid 1999, which had reduced Pb concentration in ambient air significantly.

At present, air quality standard in Bangladesh for Pb concentration in ambient air is 0.5 $\mu g/m^3$. Recent test results show that Pb concentration in ambient air in Dhaka comfortably achieves the standard (Begum and Biswas 2008). In fact, these results show that the current ambient Pb concentration nearly meets the USEPA standard (0.15 $\mu g/m^3$), however, caution must be exercised in interpreting the numbers since these tests considered the Pb contained within the fine PM ($PM_{2.5}$) only. Comparison of these results with earlier ones shows that the total ambient Pb concentration can be approximately 57% more when Pb in coarse PM ($PM_{2.5\text{-}10}$) is also considered (see Table 2.2). The current share of Pb in coarser particles could actually be higher since the current Pb in ambient air possibly does not come from fuel combustion, which generally produces fine particles. This indicates that Pb concentration in ambient air is likely to be larger than the current USEPA standard, but possibly is still reasonably below the Bangladesh standard. It should be noted that Pb is not continuously measured at the CAMS established by the DoE in different cities of the country.

Table 2.2 Ambient Pb concentration in Dhaka

Year	Study 1 Pb in $PM_{2.5}$ ($\mu g/m^3$)	Study 2 Pb in $PM_{2.5}$ ($\mu g/m^3$)	Study 2 Pb in PM_{10} ($\mu g/m^3$)	Ratio of Pb in PM_{10} to Pb in $PM_{2.5}$
1994		0.312±0.485	0.522±0.614	1.67
1997	0.265±0.549	0.256±0.532	0.461±0.775	1.80
1998	0.370±0.644	0.370±0.636	0.507±0.669	1.37
1999	0.225±0.370	0.225±0.370	0.342±0.420	1.52
2000	0.106±0.179	0.106±0.179	0.160±0.192	1.51
2001	0.130±0.163			(average 1.57)
2002	0.227±0.784			
2003	0.166±0.467			
2004	0.198±0.611			
2005	0.102±0.207			
Reference	Begum & Biswas 2008	Biswas et al. 2003	Biswas et al. 2003	

Apart from the possibility of Pb in road dust (Pb has a long life) other potential sources of Pb in Bangladesh can be paint, fabric and leather dyeing (hence textile and leather industries), metal smelters and battery industries. It is highly unlikely that Pb would be an important pollutant outside large cities with significant industrial establishments. Although a moderate level of blood Pb was reported in Dinajpur (see later in Table 4.2), it was possibly due to the presence of a few fabric dyeing industries. Since blood Pb level in the urban residential and rural area are generally

[1] Centre for Disease Control in the US defines 10 µg/dL of Pb in blood as elevated Pb level.

below the 'elevated' level, unlike industrial areas (Table 4.2), it is clear that the Pb pollution in the industrial areas is higher than the test location (within Dhaka University, near a large park).[2] This indicates efforts should continue to identify hotspots of Pb pollution, take necessary measures to reduce emissions and revisit the ambient Pb standard.

Particulate Matters

It is widely accepted that particulate matter is the major pollutant of concern internationally and in Bangladesh (ADB 2006, UNEP 2012). Numerous epidemiological and toxicological studies in developed countries related elevated particulate concentration (especially $PM_{2.5}$) with an increased risk of premature mortality. Various regulatory impact studies (e.g. USEPA 2007) also shows that among the criteria air pollutants, $PM_{2.5}$ has the most harmful impact on health. In recent times, the adverse effects of black carbon (BC), a major component of soot, has attracted much attention (WHO 2012, UNEP 2011). Black carbon and other particulates are emitted from many common sources, such as diesel cars and trucks, residential stoves, forest fires, agricultural open burning and some industrial facilities.

The current AQS for Suspended Particulate Matter (SPM), Coarse Particulate Matter (PM_{10}) and Fine Particulates ($PM_{2.5}$) is presented in Table 2.1. Although Bangladesh was one of the first few countries in Asia to enact a $PM_{2.5}$ standard for ambient air, the achievements on the compliance of this and other particulate related standards are poor. Consistent and coherent source for time series information on SPM or PM concentrations in ambient air are also not available, since the Continuous Air Monitoring Station (CAMS) of the Department of the Environment (DoE) at Shangshad Bhaban in Dhaka started operating in 2002 (partially operative during 2007-2010); the other CAMS in Dhaka (at BARC) has been operating since 2008. A CAMS has also been operating in Chittagong since 2006 and two more in Khulna and Rajshahi since 2008. There are also several satellite monitoring stations (SAMS) at Narayanganj, Tongi, Sylhet and several locations in Dhaka, where only PM samples have been collected sporadically. Bangladesh Atomic Energy Commission (BAEC), since 1993, and Bangladesh University of Engineering and Technology have also been taking snapshot measurements of the ambient PM concentrations over time. There are issues regarding the quality assurance in the data generated and also breaks in the time dimension. The DoE also takes occasional measurements of SPM at different towns in Bangladesh.

Because of larger emission sources (higher motorization rate, larger population, larger number of industries) and high impact possibilities (large population exposure), Dhaka is the most important city in terms of air pollution. Figs. 2.1 and 2.2 present the ambient PM_{10} and $PM_{2.5}$ concentration at the CAMS monitor near Shangshad Bhaban, Dhaka. It is clear from the figures that the ambient air fails to meet the AQS for both the pollutants at both the averaging periods (24 hr and annual) in Dhaka. The seasonal pattern is also clearly visible: since winters are dry with no wet deposition possible, it is expected that the ambient PM concentrations would be higher during November to March. The air quality is further aggravated during the winter due to the seasonal operations of the many thousand brick kilns, both near Dhaka and throughout the country. Also, temperature inversions during the winter hinder vertical mixing and dilution of the pollutants. On the other hand, during much of the monsoon, $PM_{2.5}$ and PM_{10} concentrations in the ambient air in Dhaka

[2] Lead concentrations in commercial areas were even larger than in industrial areas (Ahmed et al. 2006).

remains well below the AQS for 24 hour averaging periods, although $PM_{2.5}$ tends to exceed the AQS more frequently than PM_{10}. It should be noted that the CAMS monitor at Sangshad Bhaban in Dhaka is located in a semi-residential area, and pollution hot spots within Dhaka can have significantly poorer air quality, which is observed at the second CAMS at Farmgate.

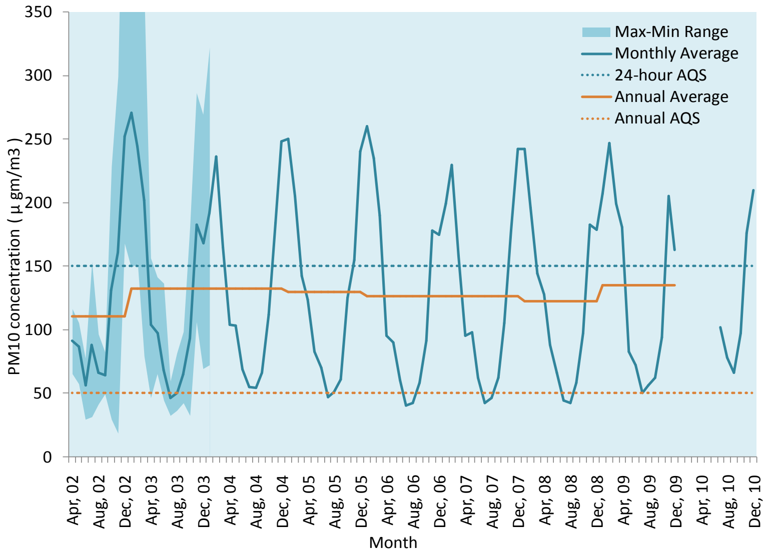


Fig. 2.1 CAMS data for PM_{10} at Dhaka, along with AQS (Source: DoE)

Although there is limited time series data to conduct a proper trend analysis, it does appear that the particulates concentration in Dhaka did not increase significantly in the recent years, despite a large increase in vehicle numbers during that period. Conversion of vehicles to run on CNG has largely contributed to the reduction of PM emissions and the relatively stable ambient concentrations. However, even this stable annual average ambient concentration of particulates is more than twice the AQS for coarser particulates and more than five times the AQS for finer particulates during dry season. Such a high exposure to $PM_{2.5}$ is especially alarming since research clearly shows that prolonged exposure to $PM_{2.5}$ has almost ten times the adverse impacts on premature mortality than short term acute exposures.

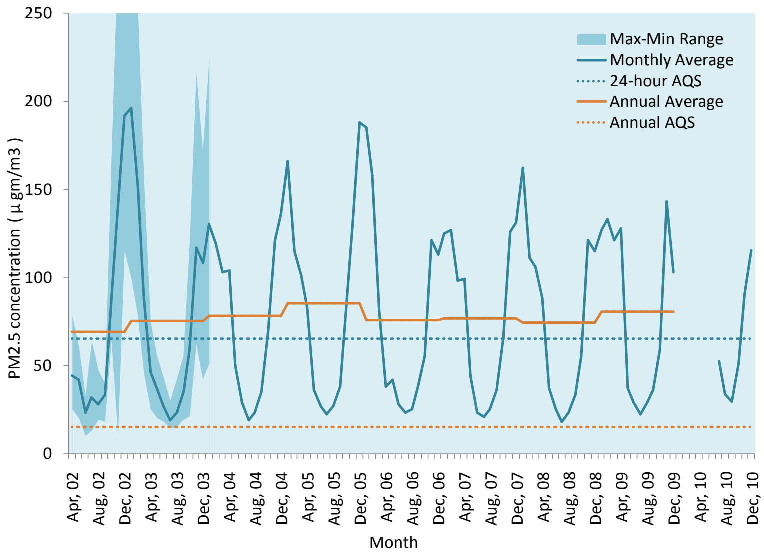


Fig. 2.2 CAMS data for $PM_{2.5}$ at Dhaka, along with AQS (Source: DoE)

There is a large spatial variation in concentrations of particulates among different cities or areas within Bangladesh and also within the same city. Figs. 2.3 and 2.4 present the CAMS data for four large cities in Bangladesh for PM_{10} and $PM_{2.5}$ respectively for 3 years (CAMS data for Chittagong, Rajshahi, and Khulna are available only recently). Despite a lack of data during the winter months, the seasonal pattern can easily be inferred in all cities. Although Rajshahi has smaller number of vehicles and industries than Chittagong, its air quality is slightly worse than Chittagong's. Windblown dust from the sand dunes of the Padma could be responsible for higher PM recorded at the Rajshahi CAMS. Proximity to the sea and stronger wind possibly influence air quality in Chittagong. Somewhat surprisingly, particulates concentrations in Khulna are larger than in Dhaka, which requires further investigation.[3] In all of the comparative statements, it must be recognized that the data are for a single monitor in each city, and the location of the monitor can be crucial. Figs. 2.3 and 2.4 clearly reveal that long term (annual) particulate air pollution is of serious concern in these major cities too. Although there is a lack of data, particulates concentration during the winter months comfortably exceeds the 24-hour AQS.

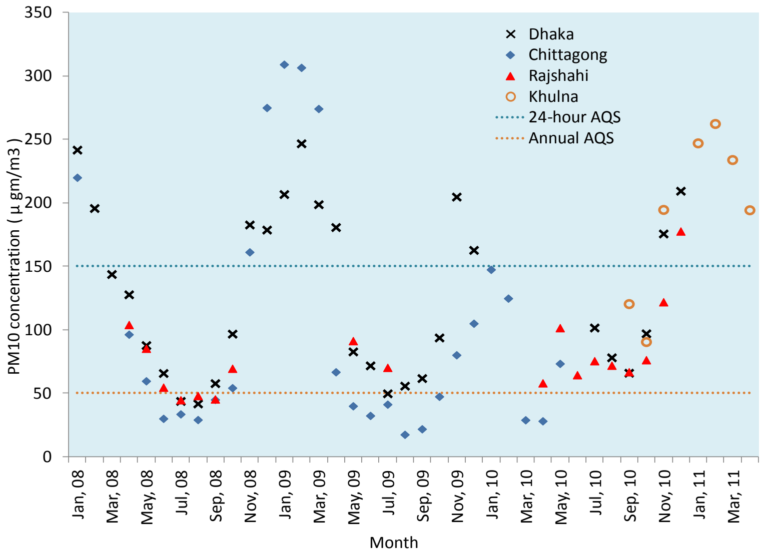


Fig. 2.3 CAMS data for PM_{10} at four major cities, along with AQS (Source: DoE)

Table 2.3 collates the concentrations of particulates (and other pollutants) at various locations in Bangladesh from different other studies (non CAMS), although the concentrations between different studies and different time periods may not be strictly comparable. However, it is clear that total SPM (or PM_{10}) exceeds the national AQS for SPM (or PM_{10}) for almost all the cases. Note that most of the measurements were taken during the winter, which is dry and, therefore, dusty. The very high SPM measures at the two locations in Chittagong are industrial and commercial hubs of the city, while Bogra, Rajshahi, Sirajganj and Pabna are located in the northeastern part of the country which is meteorologically drier than the rest. Even the less urbanized Sunamganj had a large SPM concentration during the winter. Lack of information on size wise distribution of the particulates in these locations does not allow further analysis of their potential sources.

[3] The CAMS at Khulna has opened very recently, and there may be some calibration issues.

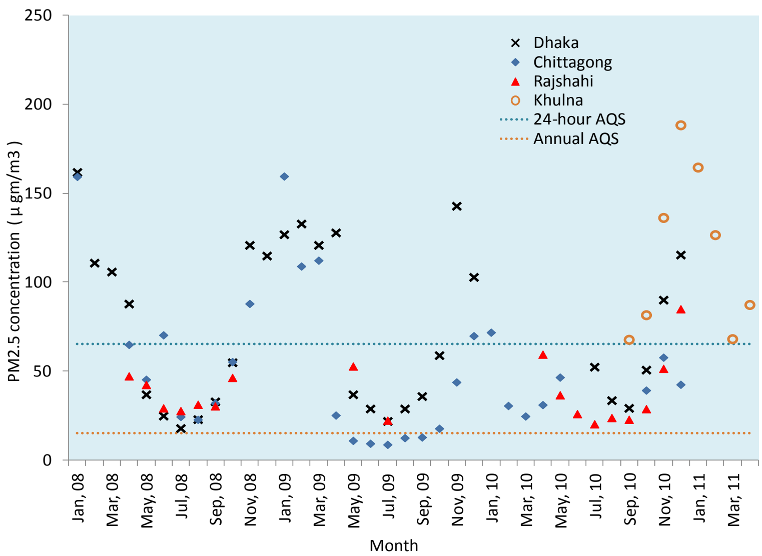


Fig. 2.4 CAMS data for $PM_{2.5}$ at four major cities, along with AQS (Source: DoE)

Table 2.3 Particulate concentration at different parts in Bangladesh (source: ADB 2006, other unpublished sources)

City	Time of measurement	TSP
AQS (annual)		200
Bogra	2003-2004	170-531
Rajshahi	2004	329-680
Sirajganj	2003	400-420
Pabna	2004	500-829
Chittagong Khulshi	Oct 2002 – Mar 2003	213.1-317.8
Nasirabad	Mar 2003	904
Agrabad	Apr 2004	804
Chandgaon	Sep 2002 – Feb 2003	172.6-208.4
Sunamganj (diff locations)	Feb 2010	243.2-365

Modeling exercises in the late 1990s show that the major road intersections were the hotspots for air pollution in Dhaka (Karim 1999). This is expected since motor vehicles are a major source of air pollution in large cities throughout the world and Dhaka is no exception. Source apportionment studies on collected PM samples undertaken by Bangladesh Atomic Energy Commission (BAEC, Begum et al. 2004, 2005, 2007, 2009) also confirm that motor vehicles are the major PM source in Dhaka and Chittagong (Figs. 2.5 and 2.6). Re-suspended soil (road dust or crustal soil) are another major source among the larger fraction of particulates. For fine particulates, brick kilns and biomass burning can be a large source, especially in areas away from Dhaka. A recent study also identified transboundary transport of pollutants from India as a *significant* source of background particulate concentration in Bangladesh (Begum et al. 2010). In summary, motor vehicles (especially diesel ones), brick kilns, biomass burning (especially in rural areas), re-suspended dust (from construction activities, roads), metal smelting and cement factories are the major sources of particulate emissions in Bangladesh.

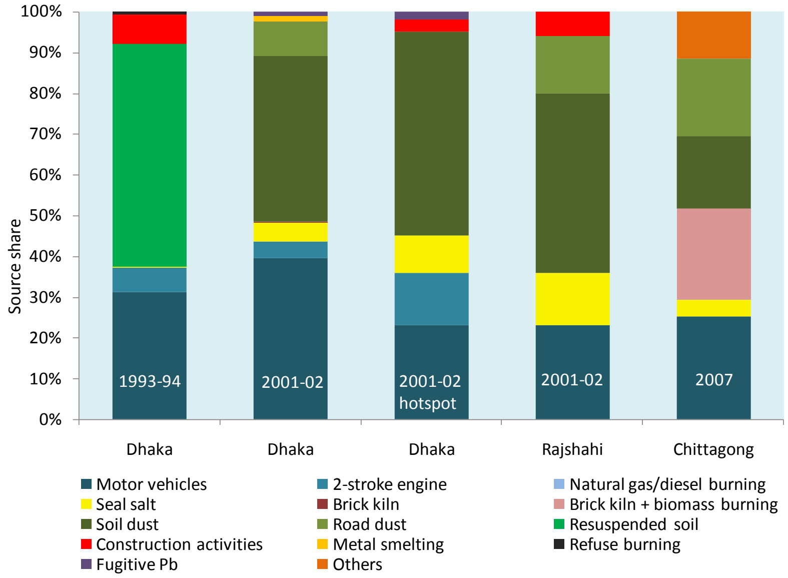


Fig. 2.5 Source apportionment for $PM_{2.5\text{-}10}$ at various locations in Bangladesh (source: BAEC)

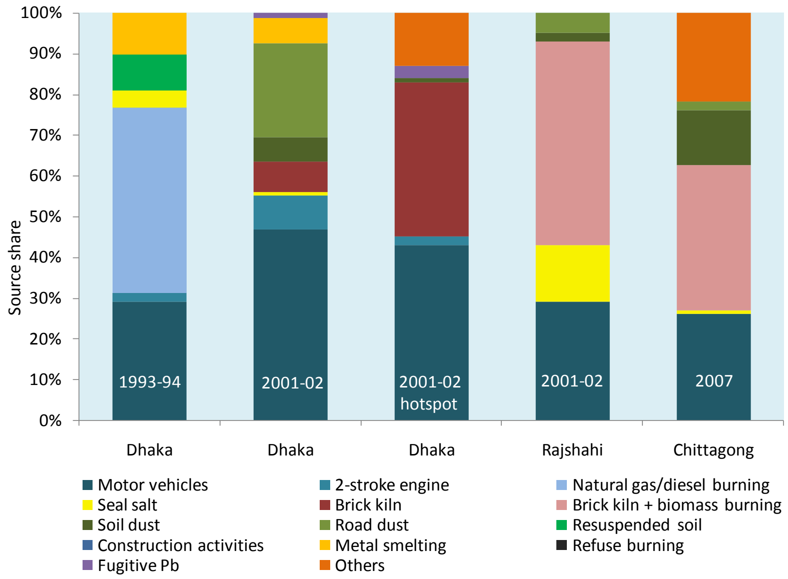


Fig. 2.6 Source apportionment for $PM_{2.5}$ at various locations in Bangladesh (source: BAEC)

NO_2

Nitrogen Dioxide (NO2) has some health impacts and is a well known precursor to acid rain, which can reduce agricultural production and damage the environment (UNEP, 2012). NO_2 is also a precursor for the formation of particulates and O_3 in the atmosphere, which are both known to increase premature mortality. NO_x monitoring data from CAMS in the three large cities are not as extensive as the particulates data, but those available are summarized in Fig 2.7. Lack of a proper time series, and data gaps even within the 3-year period, make it difficult to ascertain the trend of ambient NO_2. However, it appears the annual average ambient concentrations for NO_2 are below the national AQS for all the cities, indicating that NO_x is not a pollutant of serious concern at the moment. Major sources of NO_x emissions are motor vehicles, power plants and other combustions sources. Once again, recorded NO_x ambient concentration in Rajshahi is larger than in Chittagong, despite Chittagong having a larger number of potential NO_x sources. As noted

earlier, close proximity of a major busy highway to the Rajshahi CAMS could be responsible for this.

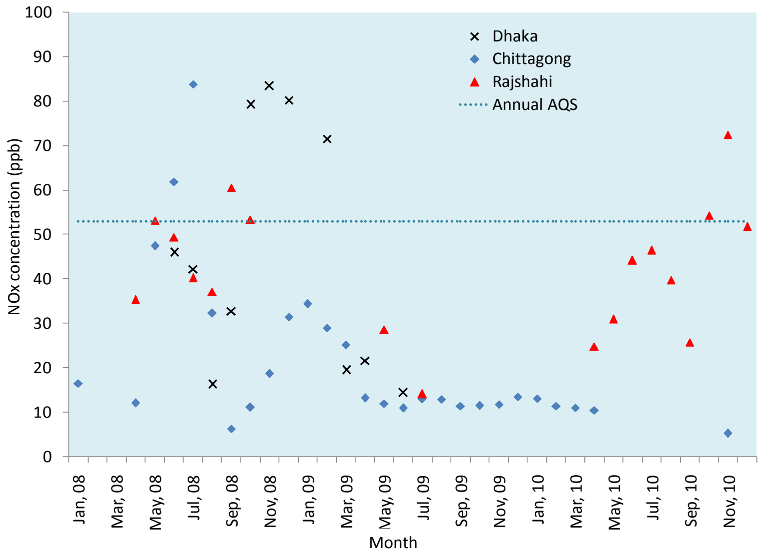


Fig. 2.7 CAMS data for NO_x at three major cities, along with AQS (Source: DoE)

Hot spot areas can still exceed the AQS for NO_2 and other pollutants, as can be seen in Table 2.4 which presents ambient concentrations of NO_x, SO_x, O_3 and CO near Sonargaon Hotel, which is located at one of the busiest intersections of roads in Dhaka.

Table 2.4 Concentration of criteria air pollutants at a Dhaka hotspot, mid 90s (Source: Islam 2005)

Pollutants	28 day average concentration (ppb)	Maximum concentration (ppb)	AQS (ppb)
NO_2	130	400	53 (annual)
SO_2	150	1470	140 (24 hour)
O_3	20	280	80 (8 hour), 120 (1 hour)
CO	4690	14800	9000 (8 hour), 35000 (1 hour)

SO_2

Sulphur dioxide (SO_2) has health impacts as a gas and also acts as a precursor to the formation of particulates and acid rain in the atmosphere. SO_2 emissions occur primarily from combustion of sulphur containing fuel (coal, diesel). In Bangladesh, diesel vehicles and brick kilns are the most important sources because of the presence of sulphur in commercially available diesel and coal. Similar to NO_x, ambient SO_2 concentration from the CAMS monitors of three cities are presented in Fig. 2.8. Clearly the current ambient concentrations are significantly lower than the AQS and ambient SO_2 is not of significant concern at the moment. It is possible that SO_2 concentrations exceed the AQS at pollution hot spots (Table 2.4), but at the moment, comprehensive data on hot spots remains unavailable.

O_3

Ozone (O_3) in high concentrations at the ground level can be a significant health hazard, resulting in premature mortality. O_3 can also reduce agricultural productivity significantly by hindering

plant growth (GEO5, 2012). Unlike particulates, NO_x or SO_2, O_3 is not directly emitted by any source, but is produced in the atmosphere when emissions of volatile organic compounds and NO_x from different sources react in the presence of sunlight. O_3 concentrations in three large cities in Bangladesh are presented in Fig. 2.9. It is clear that the average concentrations are below the AQS, however, the AQS for O_3 works in a different way than those of particulates. O_3 concentrations show diurnal variation and it is important that the ambient concentration does not exceed the AQS beyond a certain number of times. Hourly or 8 hourly O_3 data is therefore more useful than the averages presented here.

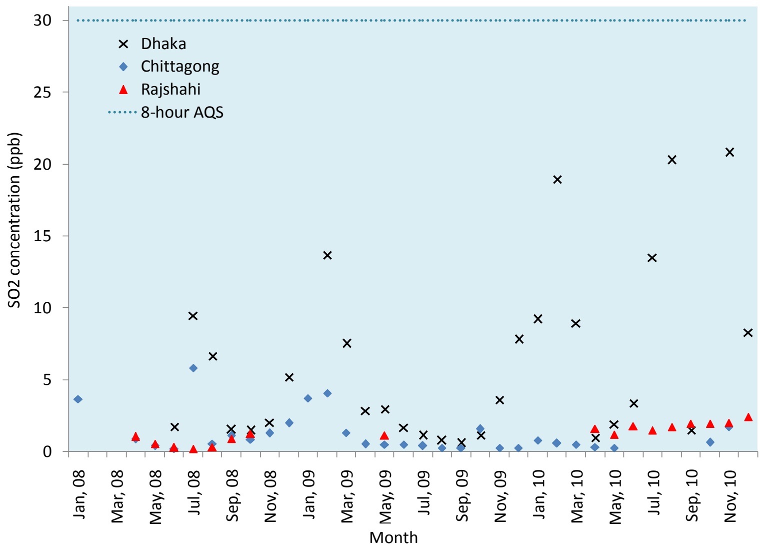


Fig. 2.8 CAMS data for SO_2 at three major cities, along with AQS (Source: DoE)

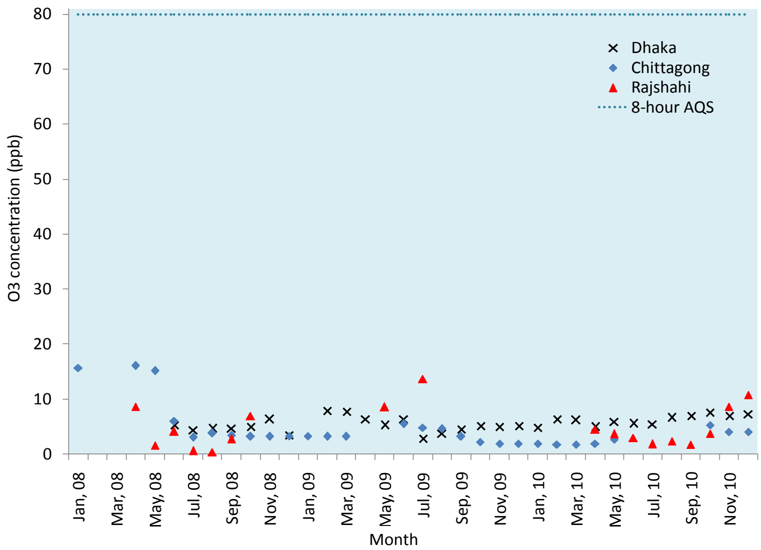


Fig. 2.9 CAMS data for O_3 at three major cities, along with AQS (Source: DoE)

Although it is possible that O_3 concentrations could exceed AQS at certain places (Table 2.4), which is not captured through Fig. 2.9, the very low averages give confidence that the probability of exceeding the AQS is very low. Note also that two stakeholders considered that the O_3 monitors were not placed at the locations of maximum O_3 concentrations and therefore too

much reliance on the data from the current monitors may not be wise. Even if this argument is true, considering the relatively less potency of O_3 with respect to PM, O_3 remains a less important pollutant than PM.

CO

Carbon Monoxide CO is produced due to incomplete combustion and, exposure at very high levels can cause death. Major sources of CO in urban areas are motor vehicles. Ambient CO concentrations from the CAMS at three cities in Bangladesh (Fig. 2.10) reveal no significant concern regarding outdoor CO pollution. However, CO pollution can be significant in indoor atmosphere, especially in the rural areas where use fuel wood and other solid fuels are used for cooking.

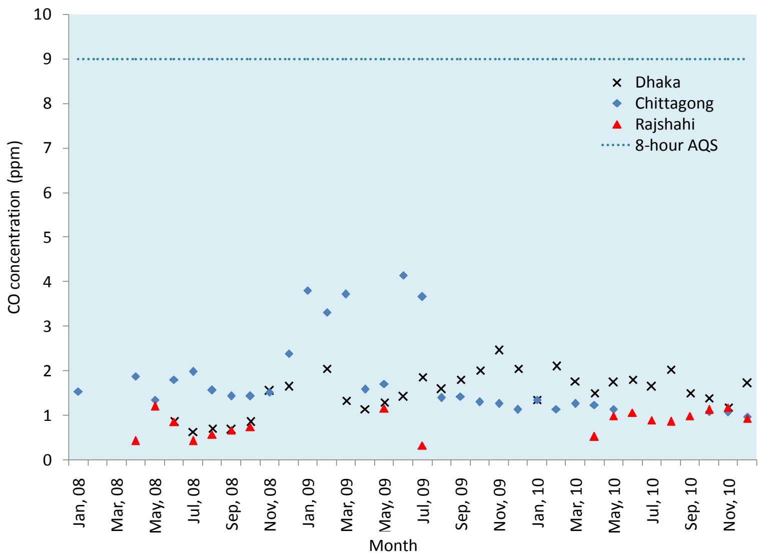


Fig. 2.10 CAMS data for CO at three major cities, along with AQS (Source: DoE)

Indoor Pollutants

Indoor air pollution (IAP), resulting primarily from combustion of biomass (e.g., firewood, animal dung, crop residue) and fossil fuels (e.g., kerosene) in traditional cooking stoves in rural areas and urban slums, is a major concern in Bangladesh as well as many other developing countries. IAP causes acute respiratory infections, which is major cause of death of young children in developing countries. Through respiratory infections, IAP has been estimated to cause between 1.6 and 2 million deaths per year in developing countries (Smith et al., 2004), primarily affecting children in poor households. In fact, women and children in the developing countries are disproportionately exposed to polluted air due to use of biomass/ fossil fuels for cooking and heating (World Bank, 2010). It has been argued (Dasgupta et al., 2006b) that in biomass using households in Bangladesh, IAP may be much worse than outdoor pollution, and health risks may be severe for household members who are exposed to IAP for long periods during the day.

Typical pollutants generated from burning of solid biomass fuel include particulate matter, CO, and a wide range of organic pollutants including benzene, formaldehyde, and PAHs. In Bangladesh, only limited data are available on indoor air quality (e.g., Dasgupta et al., 2009; Khaliquzzaman et al., 2007; Dasgupta et al., 2006a, 2006b; Dana, 2002; Alauddin and Bhattacharjee, 2002). Dana (2002) found that concentration of SPM in kitchen environment in Gazipur and Dhaka slum areas ranged from 4,040 to 39,192 $\mu g/m^3$. Alauddin and Bhattacharjee (2002) found concentration of SPM in a poorly ventilated rural kitchen (5,032 $\mu g/m^3$) in Dhamrai, Manikganj to be much higher than that in a well-ventilated rural kitchen (3,670 $\mu g/m^3$). The same study also found significantly higher levels of VOCs in the poorly ventilated kitchen compared to that in the well-ventilated kitchen. Dasgupta et al. (2006a) reported that household level PM_{10} concentrations in Bangladesh frequently reached 300 $\mu g/m^3$, although spikes of up to 4,864 $\mu g/m^3$ have been observed,. Under average conditions, Bangladeshi households using “dirty” fuels can experience 24-hour average PM_{10} concentrations as high as 800 $\mu g/m^3$ (Dasgupta et al., 2006b), against an acceptable level of 150 $\mu g/m^3$ (USEPA, 2006).

Dasgupta et al. (2006a) reported significant regional variation in indoor air quality depending on local differences in fuel use and, more significantly, construction practices that affect ventilation. In fact, Dasgupta et al. (2006b) reported that non-fuel characteristics are so influential that some households using “dirty” biomass fuels have PM_{10} concentrations comparable with those in households using clear fuels. Dasgupta et al. (2006a; b; 2009) also reported that pollution generated in cooking areas diffuses almost immediately into living areas, and as a result hourly pollution levels in cooking and living areas are quite similar; in 236 Narshingdi households, the average 24-hour PM_{10} concentration was 260 $\mu g/m^3$ for cooking areas 210 $\mu g/m^3$ for living areas, while average outdoor concentration was 36 $\mu g/m^3$.

Chapter 3
SOURCES OF AIR POLLUTION IN BANGLADESH

In order to control air pollution, it is necessary to understand the sources of the pollution, since all pollution control approaches aim to reduce emissions in order to control ambient concentration of pollutants. This chapter describes the major sources of various air pollutants in Bangladesh.

3.1 Pollutant specific sources

Globally, the major sources of the individual air pollutants are briefly listed in Table 3.1. Considering the different structure of the economy and meteorology, not all of these sources are important for Bangladesh, and the major sources in Bangladesh are described in the next section.

Table 3.1. Major sources of criteria air pollutants (Source: USEPA, with minor modifications)

Pollutant	Sources
Carbon Monoxide (CO)	Motor vehicle exhaust, kerosene, power plants with internal combustion engines or wood/biomass burning stoves.
Sulphur Dioxide (SO_2)	Coal-fired power plants, brick kilns, petroleum refineries, sulphuric acid manufacture, and smelting sulphur containing ores.
Nitrogen Dioxide (NO_2)	Motor vehicles, power plants, and other industrial, commercial, and residential sources that burn fuels (e.g. diesel generators).
Ozone (O_3)	Vehicle exhaust and certain other fumes (hydrocarbons). Formed from other air pollutants in the presence of sunlight.
Lead (Pb)	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.
Particulate Matter (PM)	Diesel engines, motor vehicles, power plants, brick kilns, industries, windblown and road dust, wood/ biomass stoves, open burning.

3.2 Trend of Major Sources in Bangladesh

3.2.1 Motor Vehicles

Combustion of fuels in motor vehicles is, undoubtedly, the most important source of air pollution in the largest of the urban centres, i.e. in Dhaka and Chittagong. Fuel combustion not only produces fine particulates directly, which have severe health effects, but also emits NO_x and SO_x, which are important precursors to producing further particulates in the atmosphere.[4] NO_x and HC emitted from vehicles can also undergo transformation in the atmosphere to produce ozone (as well as a range of other secondary pollutants), another pollutant with direct adverse health impacts. Also, vehicles emit closer to the human population and thus have a direct effect on human health in urban areas.

Dhaka and Chittagong, and Bangladesh in general, have a very low vehicle ownership by international standards. Even in comparison to neighbouring India and Pakistan, vehicle ownership in Bangladesh is very small. However, the growth rate in the number of motor vehicles

[4] NOx and SOx react with NH_3, which is in abundant supply in Bangladesh because of its vast agriculture sector, to produce fine particles of NH_4NO_3 and NH_4SO_4

in Dhaka, and in Bangladesh, in recent years is quite high (around 8% on an average for the past 5 years). This is a joint result of a robust economic growth, giving rise to a larger middle class and a lack of good public transport system in Dhaka city. For long distance and freight also, road is now the major mode of transport, eclipsing rail or water, which are generally more energy efficient. Fig. 3.1 shows the growth in motor vehicles in Bangladesh and in Dhaka city over the last 20 years. High congestion in the roads of Dhaka and Chittagong not only increases emissions to the atmosphere, but also increases exposure of in-vehicle users as well as pedestrians.

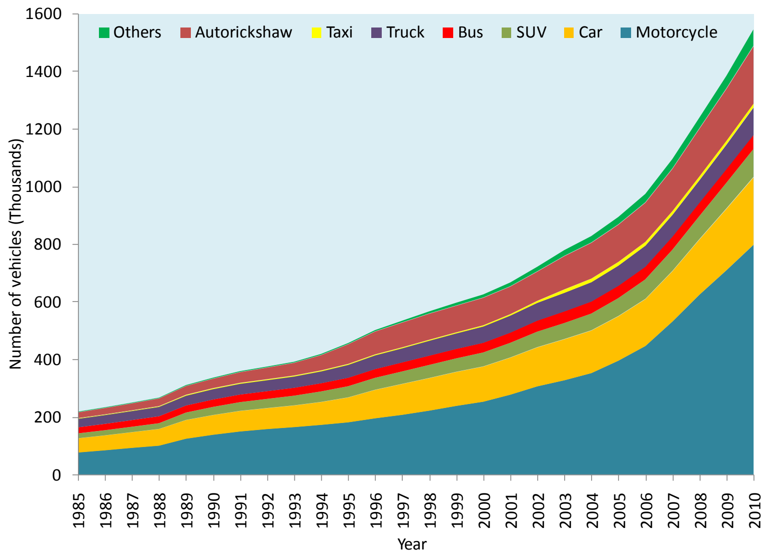


Fig. 3.1 Vehicle growth in Bangladesh during 1985-2010 (source: BRTA)

Bangladesh does not have any vehicle manufacturing industry and all the vehicles are imported from abroad. Among the personal vehicle fleet, most are pre-used cars imported from Japan. Since these vehicles were originally built to strict Japanese emissions standards (mostly Euro IV equivalent), their emission performances are quite good as found in the road side measurements by the DoE. A series of measurements in 2011 show that less than 5% of the gasoline/CNG fueled car fleet in Dhaka fail to meet CO emissions standard. Since 2002, conversion of most personal vehicles to run on CNG has possibly made the on road personal vehicles less polluting in terms of particulates, although ultrafines emissions may have increased. However, the emissions performance of converted vehicles can vary widely, depending on the emissions performance of the original vehicle, quality of conversion and maintenance. Also, there exists no information on pre and post conversion emissions performance of the vehicles.

Although the number of buses, minibuses, human haulers and trucks are much smaller in comparison to the personal vehicle fleet, these vehicles contribute more to the total particulate emissions. The DoE (2011) roadside measurements found that more than 60% of the diesel fleet fail to meet free acceleration smoke emissions standard. The primary reasons are an older vehicle fleet with mostly pre-Euro era engines, use of diesel fuel and poorer maintenance of commercial vehicles. Reducing emissions from these vehicles through improved vehicle inspection and maintenance or phasing out of the vehicles from urban centres can have large immediate health benefits in Bangladesh.

An important parameter in particulates from motor vehicles is the sulphur content in the fuel. High sulphur content can be particularly harmful for diesel vehicles. At present the sulphur

content in motor fuel in Bangladesh is significantly high as compared to many other countries. Table 3.2 presents the sulphur content of various fuel types by Bangladesh Petroleum Corporation (BPC), the sole agency responsible for liquid fuel supply in the country. The very high sulphur in fuel leads to the formation of secondary particulates. There is some scope for reducing the formation of secondary particulates through reducing fuel sulphur content although it was mentioned in the stakeholders meeting that the majority of diesel PM emissions is carbonaceous and thus diesel de-sulphurization may not have large benefits. Also, low sulphur diesel works with Euro II or later engines, thus reducing diesel sulphur content without phasing out older diesel engines through stricter vehicle emissions standards will not be beneficial.

Table 3.2 Fuel sulphur content in different fuel types in Bangladesh (Source: Islam 2005)

Fuel	Acronym	Bangladesh (ppm)
Motor gasoline	MS	1,000
Motor gasoline	HOBC	1,000
High speed diesel	HSD	5,000
Low sulphur diesel	LSHSD	3,000
Light diesel oil	LDO	18,000
High sulphur furnace oil	HSFO	35,000
Kerosene	SKO	4,000
Jet fuel	JETAI	3,000
Liquefied Petroleum Gas	LPG	200

Under the current circumstances, vehicle numbers will significantly increase in the future with concomitant pressure on the air quality, especially in the larger cities. Even if strong policies are undertaken to discourage personal vehicle growth (through appropriate land use policies, installation of extensive public transport system in Dhaka and Chittagong, increasing personal vehicle usage costs, etc.), it appears that vehicle growth cannot be stopped and, at best, can only be slowed. This indicates successively stricter emissions standards, better institutional capacity to monitor and enforce standards, retrofitting diesel vehicles with particulate filters and switching to cleaner fuel (low sulphur diesel and CNG) would all be necessary to keep the air pollution from vehicles under control. It should be noted that high sulphur diesel is phased out in the international market, and the Chittagong refinery, once upgraded, will also have a sulphur content lower than 500 ppm. Therefore there is a good likelihood that the diesel sulphur content will be reduced in Bangladesh without additional interventions.

3.2.2 Brick Kilns

Brick kilns are a major source of air pollution throughout Bangladesh (Fig. 3.2). Brick kilns are major sources of PM, SO_x, CO, VOC (VOCs are precursors to O_3) and acidic gases (e.g. HF, HCl etc.). Brick making is also one of the largest GHG emissions source in Bangladesh, with large CO_2 emissions from the combustion of coal and wood.

Bangladesh has only limited natural sources of stones and construction of infrastructure and buildings often depends on the supply of locally produced bricks. The construction sector has been growing at a rate of 8.1% to 8.9% a year during the last decade, with concomitant growth in demand for bricks (IIDFCL 2009). It is estimated that around 15 billion bricks are produced annually in Bangladesh from around 5,000 brick kilns (Hossain 2008), although some recent

Fig. 3.2 Brick kilns in Bangladesh are a major source of air pollution and GHG emissions

estimates put the number at 8,000 (Prothom Alo 2012). Among the brick kilns, 75% are Fixed Chimney Kilns (FCK), while around 16% are still Bulls Trench Kilns (BTK), which are highly polluting. The rest (only 9%) are Zigzag and Hoffman Kilns (ZK and HK), which are better in their emissions performance. Almost all the brick kilns use coal as the primary fuel, although unofficial estimates mention that around 25% of the fuel used in 2007 was still wood (20% in 2012, mentioned in stakeholders meeting, Fig. 3.3).

Fig. 3.3 Wood storage for brick kilns (source: Daily Star)

The sulphur content in imported coal from north-east India is often around 5%, whereas there is a ban on importing coal with a sulphur content larger than 1% to be enforced by the Ministry of Commerce. The ban, however, is overturned at the request of brick manufacturers every year (since coal from north east India is the cheapest) and there is essentially no control on sulphur content of the coal used in the brick kilns. These coals also have high clinker and ash content, which contributes to high PM emissions.

Brick making is an important industry in Bangladesh, with an annual turnover of around BDT 450 billion in 2006-2007 (1% of GDP). Since brick making is still a labour intensive process, approximately 1 million people directly or indirectly depend on the industry for their livelihood. However, the industry is still not an organized one, and apart from the few HKs and ZKs, all other kilns are in operation only during the winter aggravating the already poor air quality.

The industry as a whole uses traditional and old technology and is inefficient in its energy use. On average, the brick kilns in Bangladesh use around 23 tons of coal to produce 100,000 bricks, whereas in China the amount is only 7.8 to 8 tons (although slightly smaller sized bricks, IKEBMI 2007). While cost benefits analysis generally shows that switching to the advanced brick burning technologies are financially viable and socially very desirable in the long run, large capital investment initially is a significant drawback.

It is worthwhile to note that Hoffman Kilns (HK) using natural gas as the fuel are the cleanest of all brick kilns in terms of AQ impacts, but they have not gained much popularity in Bangladesh, despite the country having significant resources in natural gas. The reasons for the unpopularity are the larger capital and operating costs of the HKs, lack of a nationwide gas supply network and primarily the unreliability of gas supplies even where the network is available. Unavailability of gas has encouraged the closure of some of these clean HKs.

With the unavailability of stone, brick industries are expected to supply the major share of construction materials in Bangladesh in the future. It is argued in the Stakeholders meetings that a sizable share of the brick is exported to India as well leading to air pollution externalities in Bangladesh. It is therefore of utmost importance that opportunities are created through policy measures, so that the industry embraces technologies to reduce emissions - both local air pollutants as well as GHGs. Although HKs are the least emitting of all brick kilns, it is unlikely that natural gas will be available for brick kilns (see power section). Among coal fueled kilns, Hybrid Hoffman Kilns (HHK) and Vertical Shaft Brick Kilns (VSBK) appear to be the most promising, although their higher capital costs can be onerous to the numerous small entrepreneurs. Proper Market Based Instruments (MBIs) linked to pollution levels can be useful in keeping the economic costs of the technology adoption down and assist in the transition. For example, gravity settling chambers in FCKs may be able to reduce the emissions at a much lower cost than HHKs or VSBKs. Lack of capacity and willingness to enforce can be significant hindrance for effective implementation of the MBIs. In another approach, there have been recent initiatives in constructing some pilot HHK through Global Environment Facilities (GEF) taking advantage of the carbon credits generated by such projects.

3.2.3 Industries

While the brick industry requires a separate section because of its large contribution to air pollution, contribution from other industrial sources are not negligible. The major polluting industries in this regard are the cement, steel, parboiling rice mills, and glass plants. All three are directly linked to building and infrastructure construction (as is brick), which is a natural consequence of the state of growth in Bangladesh. Since such growth is expected in the future, it is important to control emissions from these sources in order to keep the air quality at a reasonable level. There are currently gaseous emissions standards governing emissions from these industries, but enforcement is so lax that only a few people are aware of their existence.

3.2.4 Biomass Burning

The World Health Organization (WHO) estimates that 2.4 billion people worldwide rely on burning biomass fuels (e.g., fuelwood, animal dung, crop residues) for cooking and heating their homes. Biomass is extensively used in rural areas of Bangladesh, primarily for cooking. Biomass

contributes to more than half of the total primary energy needs in Bangladesh. Biomass burning, especially in traditional cooking stoves, results in significant air pollution, which is harmful especially to the women and young children who often spend most of their time in the kitchen with a high level of particulates concentration. In rural Bangladesh, majority of people rely on solid biomass fuel; and firewood, crop residue dung, and tree leaves accounts for about 97% of total household energy use (Asaduzzaman et al., 2007).

Outdoor biomass burning generally takes place during the winter after a crop harvest. This adds to the winter fogs to create dense smog in rural areas of Bangladesh. While immediate health impact may not be of serious concern, smog can be a driving hazard and has been blamed for a quite a few road accidents and fatalities in the highways of Bangladesh. It is also a fairly common practice to burn refuse, which can be potentially harmful, especially if there are other harmful elements in the refuse (e.g. PVC, heavy metal, batteries etc.). Burning of accumulated dry leaves is also fairly common in cities and rural areas during the winter (as a means of disposal of these "solid wastes"). While localized effects can be significant in cities, the impact in rural areas and meso-scale effects may not be that large.

Fig. 3.4 Women burning plastic in Bangladesh
(Source: http://knowledge.allianz.com/?729/energy-efficiency-recycling-hidden-resource)

3.2.5 Construction and Vehicular Activities

Dust is one of the major problems in most urban areas and some rural areas in Bangladesh, especially during the dry seasons (i.e. winter, spring, late autumn). While coarse suspended particulates are not as lethal as their finer counterparts, they can still be a health hazard, especially increasing incidences of morbidity among the population. Construction and vehicular activities primarily give rise to dust in urban areas. Large urban metropolises (Dhaka and Chittagong and, to a lesser extent, the divisional and the district headquarters) have benefited from a boom in the real estate sector, but this also equates to an increase in construction activities. Since there are no specific guidelines or rules on storage and transport of construction materials, it is very common that the construction sites are all very dusty. Even the roads catering for the construction traffic are also dusty because there are no requirements of covering the construction material during transport. In addition, most of the construction (especially excavation and soil transport which are particularly dust generating) take place during the winter,

which is dry and further conducive to air pollution. A special case in point is the recent construction of the BSMMU extension near Shahbag (see Fig. 3.5).

Road traffic also adds to the air pollution in addition to its contribution through combustion exhausts. Vehicular movements on unpaved roads generate a large amount of coarse suspended matter. Even on paved roads, which are often of poor quality and suffer surface damages during the monsoon, vehicular movements generate coarse particulates during the winter. Traffic also causes resuspension of the settled dust on the road. Transport of bulk material in vehicles without proper cover can also result in spills and dust.

Fig. 3.5 Air pollution at Shahbag area due to a large construction in BSMMU and related material transportation (Source: The Daily Star and The Independent)

Roads are also responsible for emissions during its construction and maintenance phases through open processing of asphalts. In large cities, these activities now take place at nights and thus direct exposure to non-construction people is limited. In the next few years, some very large transportation projects will take place in Dhaka, which would be responsible for additional dust emissions and increase short term acute exposure to air pollution.

3.2.6 Power Sector

Although electricity utilities are a major source of air pollution in many developed and developing countries, their contribution to air pollution in Bangladesh has not been large. As opposed to the USA, Australia, China or India, where coal is the major primary source to produce electricity, Bangladesh has only one coal-fired power plant. Most of its electricity is produced from natural gas, which is much cleaner than coal, both in terms of local air pollution and global air pollution (i.e. GHG emissions). Fig. 3.6 presents the share of different primary energy sources used in electricity production in Bangladesh during 2006 and 2011. It is clear that natural gas is the major primary source with more than three-fourths of all electricity generated from natural gas.

At present, a major air pollution concern in the power sector is the small, particularly because of the prevalence of natural gas power plants, but numerous small to medium diesel generators currently supplement the infrequent grid electricity supply in the residential, industrial and commercial sectors. These small diesel generators currently do not have to meet any emissions

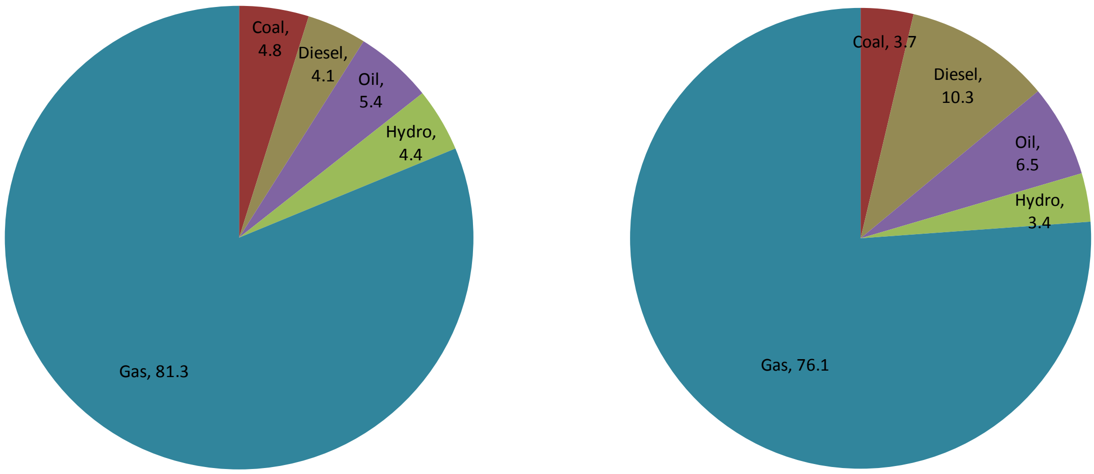


Fig. 3.6 Percentage share of fuels used for power generation in (a) 2006 and (b) 2011 (Data source: Bangladesh Power Development Board 2007)

standards and their total emissions may be significant (no reliable data available), and they also emit much closer to the people in comparison to large scale power plants, with potentially large health impacts. Diesel generators can also be a large growth sector in the future if reliable electricity supply cannot be ensured.

While the power industry (apart from the diesel generators mentioned above) is not a major air polluting source at present, there is a potential for it to become a large one in the near future. Bangladesh currently faces severe shortage of electricity in all sectors of the economy. In order to support and sustain a healthy GDP growth and to enhance the standard of living in future, electricity production needs to be increased significantly. With an apparent slowing down of natural gas production, this leaves the country with primarily coal or petroleum (diesel, furnace oil, etc.) as the next potential fuel for electricity production. Both of these fuels emit more pollutants per unit of electricity production as compared to natural gas. The government has recently sanctioned the setting up of fuel oil based power plants in the private sector (for quick generation of power), and the share of diesel and furnace oil in electricity production has increased in 2011 (Fig. 3.6). These small and medium capacity (20~100 MW) fuel oil based power plans use internal combustion engines and if operated without flue gas desulferization, these could give rise to serious air pollution in the vicinity of the plants.

The government is also trying to expand coal-based power generation involving both public and private sectors. Recently the BPDB has entered into an agreement with NTPC of India to set up two imported coal-based power plants in Chittagong (1,320 MW) and Khulna (2,640 MW), with a total capacity of 3,960 MW. In December 2011, the Government also signed a deal with a private company for setting up of three coal-based power plants (in Chittagong, Khulna and Munshiganj) with a total capacity of 1,086 MW. These plants will also be run with imported coal. More coal-based power plants utilizing local coal are likely to be established in the future. A recent round table discussion on energy policy also showed an inclination toward open-pit mining of coal in the country in order to ease the electricity supply crisis (Daily Star Round Table in October 2011). Open pit mining of coal beds, if implemented, will further add to local air pollution on top of the combustion emissions. Therefore, at the moment, it appears that coal and fuel oil will increase

their share in electricity production in future, with coal accounting for a large share because of its significant cost advantages. Coal and petroleum based power plants can be large sources of CO_2, SO_2, NO_x and particulate emissions, and increase in secondary O_3 formation.

It is estimated that, despite stringent emissions control rules, coal fired power plants in the USA are responsible for more than 15,000 premature deaths (Wadud and Waitz 2011). Considering the much higher population densities in Bangladesh and proximity of any power plants to the human habitat, it is possible that the impact of coal fired plants will be quite large in Bangladesh. Therefore, the policy makers should set proper emissions guidelines (already some standards exist) and enforce them in power plants and/or fuel quality guidelines for imported coal and diesel ahead of time in order to control emissions from these potentially new and harmful sources. It should be noted that the Government is putting emphasis on renewable energy, especially solar energy. Apart from mandatory provision for installation of solar panels on the top of residential/commercial buildings, the Government plans to generate 500 MW of power from solar energy by 2014.

3.3 Emissions Inventory

Emissions inventories document the sources of pollutant emissions and the share of various sources in total pollutant load emitted to the atmosphere. Emissions inventories thus give an indication of the relative importance of various emissions sources, and help identify the sources requiring intervention in order to control air pollution. However, over reliance on emissions inventories is not advised because the final impact on population does not depend only on the quantity of emissions but also where the pollutants are emitted. Clearly, high PM emissions in a deserted area are less harmful than lower emissions in a densely populated city. Even the direction of wind or timing of emissions can be as important as the emissions inventory in determining the impact of pollution. Because of all these factors, comprehensive air quality modeling (which requires the input from emissions inventory as well as spatial and temporal distribution of emissions and meteorology information) is more important than emission inventories alone. However, emission inventories are often the first step at developing an air quality model and also give an indication of the important polluting sources.

The only comprehensive emissions inventory for Bangladesh has been developed by the DoE under the framework of the Malé Declaration for year 2000. There are two major limitations of the Malé Declaration emissions inventory. Firstly, the inventory is for year 2000, and relative importance of emissions sources have significantly changed since then, e.g. CNG conversion of vehicles, phasing out of two stroke three-wheelers, penetration of diesel generators – all took place after 2000. However, the emission inventory for 2005 is currently under construction. Secondly, the underlying data on emissions factors, number of emissions sources and their activity are possibly unreliable (even the 'well-documented' vehicle registration data does not include the vehicle scrappage information in Bangladesh). Also, the emissions factors were based on expert-judgment from abroad, rather than from emissions testing in-country. Despite the limitations, the emissions inventory does indicate that the two most important sources requiring attention are brick kilns and motor vehicles.

There are various other sectoral emissions inventories available, especially for motor vehicles. Once again, the underlying emissions factors, vehicle numbers and activities data are unreliable.

Therefore this report does not put much emphasis on the existing emissions inventories while determining the key pollutants and their sources. However, it is important to note that development of a reliable emissions inventory for large cities and the whole country must be a priority for proper evidence-based policy making in future.

Chapter 4
EFFECTS OF AIR POLLUTION

Air pollution has adverse impacts on human health, material, agricultural production, ecosystems and regional and global climate, thus adversely affecting quality of life and economic output. It is also important to understand the relative importance of various pollutants with respect to impact. This chapter briefly describes the effects of various criteria air pollutants in general and in the context of Bangladesh.

4.1 Documented Impacts of Air Pollution

The criteria air pollutants which are regulated by the national AQS have been selected primary based on their adverse effects on human health. The primary health effects and additional effects of these pollutants are presented in Table 4.1 below. Most of the evidence base for these health impacts is from developed countries, where physiological and toxicological studies confirmed the adverse impacts of the pollutants. Extensive research efforts during the past decades have resulted in successful quantification of some of these health impacts with respect to a change in the ambient pollutant (Hurley et al. 2005). However, due to limitations of epidemiologic studies in Asia, assessments of health impacts of air pollution in Asian population rely to a large extent on extrapolation of the results of Western studies, which involves considerable uncertainties. The Health Effect Institute (HEI) initiated the Public Health and Air Pollution in Asia (PAPA) program in 2002 to reduce uncertainties about the health effects of exposure to air pollution in the cities of developing countries. A number of studies and publications from the PAPA program (HEI ISOC 2004, HEI ISOC 2010) provide very useful information on health effects of air pollution in Asian cities. Based on meta-analysis of results of Asian time-series studies in 82 reports published through August 2007, HEI-ISOC (2010) concluded that short-term exposure to PM_{10} would increase daily mortality from all natural causes by 0.27 percent per 10 $\mu g/m^3$ increase in pollutant concentration; an effect similar to that reported in meta-analyses and multi-city studies in Europe, North America, and Latin America. The PAPA studies also provided unique picture of the short-term impact of particulate matter on mortality in four large metropolitan areas in East and Southeast Asia: Bangkok, Hong Kong, Shanghai, and Wuhan (HEI ISOC 2010). In the combined analysis of city-specific results, a 10 $\mu g/m^3$ increase in PM_{10} concentration was found to be associated with an increase of 0.6 percent in the daily rate of death from all natural causes, estimates similar to or greater than those reported in multi-city studies in the United States and Europe. The study in Wuhan found that the estimated relative risk may increase by a factor of 5 at extremely high temperatures, as compared with temperatures typical of temperate zones; the studies in Hong Kong and Shanghai found evidence of higher relative risks among the economically disadvantaged and those with least education, respectively, corroborating the results of some earlier studies in Western cities. Preliminary data from two Indian cities, Delhi and Chennai, also showed increased rates of all-natural cause of mortality in association with short-term exposure to PM_{10} (HEI ISOC 2010).

Table 4.1 Health impact of the criteria air pollutants (source: USEPA, with minor modifications)

Pollutant	Health Effects	Other Welfare Effects
Carbon Monoxide (CO)	Headaches, reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, death.	Contribute to the formation of some secondary pollutants.
Sulphur Dioxide (SO_2)	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO_2)	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g. cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O_3)	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage, leading to premature mortality.	Plant and ecosystem damage. Material (rubber) damage
Lead (Pb)	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects, leading to premature mortality.	Visibility impairment, atmospheric deposition, aesthetic damage.

In recent times, short-lived climate pollutants (SLCPs) or short-lived climate forcers (SLCFs) - black carbon (BC), tropospheric ozone, and methane - have drawn much attention due to their impact on both air quality and climate. Atmospheric lifetime of BC and tropospheric ozone varies from days to weeks, while that of methane is about 12 years. Black carbon and tropospheric ozone cause health and climate impacts; tropospheric ozone also causes damage to crop yields and ecosystem structure and function. Methane, a potent greenhouse gas, is also one of the precursors of tropospheric ozone and thus contributes to air pollution (UNEP, 2011). For some methane sources, emission control measures, if implemented, would also reduce other co-emitted substances such as the more reactive volatile organic compounds that contribute to local formation of ozone, as well as toxics, such as benzene, carbon tetrachloride and chloroform (UNEP, 2011). Ozone, a secondary air pollutant, is a powerful oxidizing agent and affects human health, for example by causing oxidative stress in lungs. At the same time, it is the main gaseous pollutant affecting the yield of many crops and it also has impacts on diversity and growth of plant communities (UNEP, 2011).

Black carbon (BC) results from incomplete combustion of fossil fuels, wood and other biomass; and hence is emitted, along with other particulate matter, from many common sources (e.g., vehicles, agricultural burning, and residential stoves). Short-term epidemiological studies have provided evidence of an association between BC concentration with short-term changes in health (all-cause and cardiovascular mortality, and cardiopulmonary hospital admissions); it has been suggested, based on short-term health studies, that BC is a better indicator of harmful particulate substances from combustion sources (especially traffic) than undifferentiated particulate matter (WHO 2012). Toxicological studies suggest that BC may not be a major toxic component of fine PM, but it may operate as a universal carrier of a wide variety of chemicals of varying toxicity to the lungs, the body's major defense cell and possibly the systemic blood circulation (WHO 2012). The health benefits derived from measures that focus on black carbon are mainly achieved by the overall reduction in fine particulate matter (UNEP, 2011).

Apart from direct health effects, BC causes warming of the atmosphere by a number of different processes. When deposited on ice and snow, BC reduces the albedo of these surfaces, increasing both atmospheric warming and the melting rate caused by increased absorption of heat by the darker snow and ice (UNEP, 2011). Black carbon aerosols have a large impact on regional circulation and rainfall patterns (e.g., monsoon) as they cause significant asymmetry in heating patterns over a region; the impact of black carbon on regional weather patterns and regional warming is more certain than its impact on global warming (UNEP, 2011).

The health effects of air pollution in Bangladesh have been documented in a few field studies. A recent DoE sponsored study found that the school children in Dhaka have increased respiratory difficulties during periods of elevated PM in the ambient air (Ahmad et al. 2008). The study used a random sample of 180 asthmatic and non-asthmatic students from 1,681 registered participants in the three participating schools and measured their peak expiratory flow meter readings (PEFR) during the morning and the afternoon. The study found that PEFR decreases by about 30% to 34% when the $PM_{2.5}$ concentration is increased from its lowest to the highest (the range on $PM_{2.5}$ during the study period was 18 $\mu g/m^3$ to 233 $\mu g/m^3$). Another study at BUET found an elevated occurrence of respiratory troubles among traffic police in Dhaka, who are exposed to a high dose of air pollution (Rahman et al. 2010). Out of 27 traffic personnel who have worked in the field for at least 5 years, everyone had a lower PEFR, indicating respiratory problems, of which 14 would require immediate medical attention.

There is only one study in Bangladesh that attempts to 'quantify' the changes in a specific health effect due to changes in ambient pollutant concentration, also known as the concentration response function (CRF). Aktar and Shimada (2005) utilized the daily variation of PM_{10} data from the CAMS monitors of Dhaka and patients' mortality records at the Dhaka Medical College Hospital to determine that every 10 $\mu g/m^3$ increase in the exposure to PM_{10} increases the mortality rate by 0.65%. Although the number is comparable with CRFs in other international literature, two significant advances in epidemiological studies make these results less useful: firstly, $PM_{2.5}$ is now thought to be more potent than PM_{10} and increasingly most health studies use the CRFs of $PM_{2.5}$, and secondly, the time series studies (such as above) can underestimate the premature mortality by a factor of ten.[5] Therefore the actual impact of fine particles on premature mortality is possibly larger than those in this study.

Studies on lead (Pb) levels in human bodies identified the presence of high blood Pb concentrations in Dhaka as early as in 1980. Subsequent studies clearly indicated the presence of Pb in human bodies, which came from Pb in ambient air. Although the major source of Pb in ambient air, Pb additives in petrol, has been banned since 1999, blood Pb level is still high at industrial locations in Dhaka, as evident from various studies carried out in Bangladesh (Table 4.2). No studies on the final health effect of Pb (e.g. elevated blood pressure, loss of IQ in children) were undertaken in Bangladesh, although such effects have been confirmed in the developed countries.

[5] e.g. various high-profile studies found that the relative risk for mortality increases by 6% to 17% for every 10 $\mu g/m^3$ increase in $PM_{2.5}$ in the ambient air (Pope and Dockery, 2006).

Fig. 4.1 Masking faces to avoid inhaling harmful airborne particles (source: internet)

The health impact of O_3 has not been studied in Bangladesh, but the impacts of O_3 on crops were observed in a study at Bangladesh Agricultural University through field experiments (Islam and Sattar 2008). Fig. 4.2 shows the conditions of an O_3 resistant and a non-resistant variety of spinach in the field. The stress due to exposure to O_3 on the non-resistant variety is clearly visible in the second panel. Fig. 4.3 demonstrates the effect of air pollution on visibility, where visibility is much better during the monsoon (despite a cloudy sky!) than in the winter, when pollution is high. These non-health impacts also have significant welfare costs to the society.

Table 4.2 Blood Pb concentration in Bangladesh

Study year	Location	Blood Pb (µg/dL)	Sample size	Reference
1980	Dhaka	55±18	100 adults	Khan et al. 1980
2000	Dhaka	15 (90% of sample > 10)	779 children (4-12 yr)	Kaiser et al. 2001
2007-2008	Dhaka- residential	2.5±3.3 (5% > 10)	57 children (6-12 yr)	Mitra et al. 2009
2007-2008	Dhaka-industrial	24.6±10.3 (99% > 10)	105 children (6-12 yr)	Mitra et al. 2009
2007-2008	Dinajpur	7.2±6.3 (14% > 10)	183 children (6-12 yr)	Mitra et al. 2009

(a) (b)

Fig. 4.2 Effect of O_3 on plant: (a) O_3 resistant variety, (b) regular variety (Source: Islam and Sattar 2008)

(a) (b)

Fig. 4.3 Visibility during a) winter and b) monsoon (source: DoE)

4.2 Social Costs of Air Pollution in Bangladesh

In addition to the direct evidences of health, crop or visibility impacts mentioned above, there have been various attempts to model the total or regional impacts of air pollution or benefits of air pollution reduction in Bangladesh. Table 4.3 summarizes these studies. Apart from Wadud and Khan (2011), all the studies use CRF from time series epidemiological studies, and possibly underestimate the air pollution impacts or benefits due to reduced air pollution. Also, it appears that the avoided non-mortality health costs are generally valued relatively highly in comparison to avoided premature mortality health costs. Regulatory Impact Assessments (RIA) of the USEPA show that mortality benefits consistently contribute to more than 80% of all health benefits due to air pollution reduction measures, which is not the case in most of the studies in Bangladesh and require a thorough understanding.

Table 4.3 Health impacts and associated monetary impact of air pollution or air pollution reduction

Study	Region	Yearly Health Impacts/Benefits	Monetary value-M$	Comments
AQ BENEFITS				
Carter 1997	4 cities	Reduction to WHO standard avoids 14,850 premature deaths (Dhaka 10,800) 6.54 mil hospital admissions or medical treatments (Dhaka 4.74 mil)	185~810	Fairly old estimate
Khaliquzzaman 2004	Urban	20% - 80% reduction avoids 1,200 – 3,500 premature deaths 80 - 235 mil sickness cases		
	Country-wide (indoor)	20% - 80% reduction avoids 7,600 – 30,400 premature deaths 0.3 – 1.2 mil DALYs (disability adjusted life years)		For indoor air pollution
Aktar and Shimada 2005	Dhaka	AQS attainment avoids 1,210 premature deaths	97.0	Mortality impact from time series data
ADB 2005	3 major	20% reduction avoids		Mortality costs appear to be

Study	Region	Yearly Health Impacts/Benefits	Monetary value-M$	Comments
	cities	1,070 premature deaths 18,300 chronic bronchitis 17 mil restricted activity days 54.8 mil respiratory symptom days Total AQS attainment avoids 3,340 premature deaths 57,100 chronic bronchitis 53.2 mil restricted activity days 171 mil respiratory symptom days Total	30.2 62.3 15.8 42.0 152.0 94.2 194.3 49.2 131.1 474.4	underestimated, or morbidity costs over-estimated. US studies show avoided premature death benefits govern the total benefits.
	18 minor cities	20% reduction avoids 190 premature deaths 1,780 chronic bronchitis 1.65 mil restricted activity days 5.31 mil respiratory symptom days Total AQS attainment avoids 200 premature deaths 1,830 chronic bronchitis 1.71 mil restricted activity days 5.47 mil respiratory symptom days Total	 5.3 6.0 1.5 4.1 17.2 5.5 6.2 1.6 4.2 17.7	Secondary cities
Khaliquzzaman 2008	Dhaka	30%~50% reduction from brick kilns avoids 200~332 premature deaths 1,870~3,110 chronic bronchitis 1.74~2.9 mil restricted activity days 5.59~9.3 mil respiratory symptom days Total	 7.3~12.1 8.2~13.6 2.1~3.5 5.5~9.2 23.3~38.8	
Wadud & Khan 2011	Dhaka	CNG conversion avoided 4,260 premature deaths	500	Impact-pathway approach with AQ models used, CRF for long term exposure
AP COSTS				
Daily star	Dhaka	6,000 premature deaths		Source unclear
	Dhaka	3,580 premature deaths 10 mil restricted activity days 87 mil respiratory symptom days	60~270	Source unclear

Note that the USD amounts are in nominal terms

Table 4.3 indicates that there are large social costs associated with air pollution in Bangladesh, or that there are large social benefits if the air pollution can be reduced. An important observation from these modeling exercises is that, in terms of health impacts, the ambient air pollution is the most important in a few major cities. In fact the air pollution impact in 3 large cities combined dwarfs the impact in 18 smaller cities by a ratio of ten to one. This is a result of not only larger pollution in large cities, but also a larger exposed population in those cities. This indicates that focusing on large urban areas will always be more beneficial than focusing on smaller cities in terms of cost savings. This finding does not mean that air pollution is not an issue in smaller regional cities and towns (there is little data), but highlights the importance of larger cities in mitigating air pollution. It should be noted that the ambient air quality standard applies for all cities irrespective of their sizes.

On the other hand, although the ambient air quality is not as bad in the rural areas, indoor air pollution is a significant cause of concern. According to WHO (2005), the ill effects of indoor air pollution, resulting primarily from burning biomass fuel, are more than five times those resulting from outdoor air pollution. Women (and young children), who typically spend a lot of time indoor

in kitchen environment, are particularly vulnerable to the adverse effects of indoor air pollution. Fine particulates from biomass burning could damage the respiratory tract, making people vulnerable to viral and bacterial infections (Gurley et al., 2008). A number of studies have demonstrated that both children and adults exposed to indoor air pollution are more likely to suffer from respiratory infections. The World Health Organization (WHO, 2005) estimates that globally acute respiratory infections from indoor air pollution are responsible for an estimated 900,000 deaths in children under 5 every year. Indoor air pollution has also been linked to tuberculosis, pre-term birth, low birth-weight, and asthma (World Bank, 2010). In addition, a study in urban slums of Dhaka (Khaliquzzaman et al., 2007) has found significant association between exposure to indoor air pollution and respiratory symptoms, e.g., redness of eyes, itching of skin, nasal discharge, cough, shortness of breath, chest tightness, wheezing, and whistling chest. The WHO (2007) estimates that as much as 3.6 percent of the total burden of disease in Bangladesh is attributable to exposure to indoor air pollution; 32,000 children below 5 years of age die annually due to acute lower respiratory infections, and 14,000 adults die due to chronic obstructive pulmonary disease. It is therefore important to address both in a comprehensive air pollution control strategy. An interesting point to note is that, in both indoor and outdoor air pollution, fine particulates are the most hazardous pollutant.

4.3 Key Pollutants and Their Sources

The discussion in the preceding sections indicates that fine particulates (including black carbon from diesel combustion) and other $PM_{2.5}$ precursors such as SO_2 (from high sulphur diesel) are the most harmful outdoor pollutants of concern while developing an air quality strategy, since other pollutants are well within the national AQS, although some hot spot violations cannot be ruled out (e.g. NO_2 which is also a $PM_{2.5}$ precursor). Coarse particulates are also an important source with its large impact on minor health incidences. The most important sources for ambient air pollution currently are and in future will be motor vehicles, brick kilns, cement factories, open burning, metal smelters, glass factories, power plants and re-suspended soil or dust.

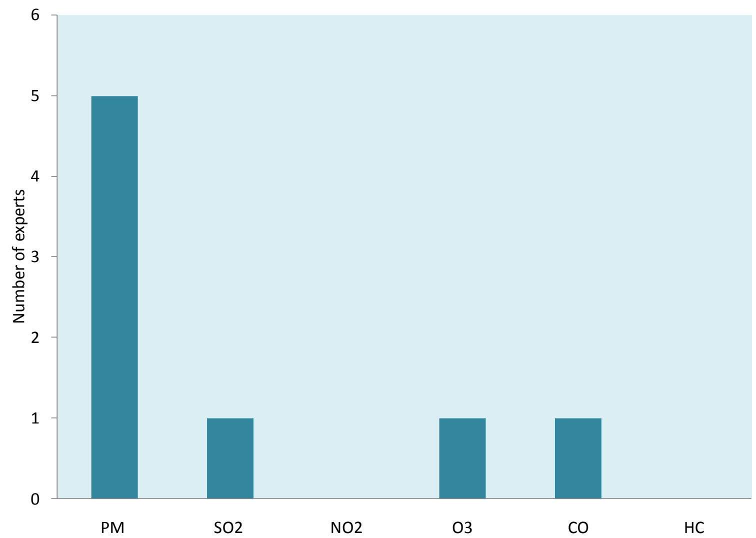


Fig. 4.4 Stakeholders' view of important air pollutants in Bangladesh (Source: Peters and and Kuylenstierna 2008)

For indoor pollution, the most harmful pollutants are the fine and ultrafine particulates (including black carbon) from cooking stoves using kerosene or other forms of solid fuels, although CO can be fatal especially in the winter when doors and windows are shut. A recent survey of 6 air quality experts in Bangladesh also indicates that PM is considered the most important pollutant in Bangladesh (Fig. 4.4). In the absence of emissions inventories, and any authentic projection of emissions into the future, the choice of key sources and pollutants were made by expert judgment, taking into consideration the feedback from key stakeholders.

Chapter 5
PAST AIR QUALITY STRATEGIES IN BANGLADESH

Bangladesh has set an ambient air quality standard, as described in Chapter 2. A number of specific strategies were undertaken in the past addressing specific emissions sources in order to reduce the concentration of the criteria air pollutants to the ambient AQ standards. Some of these strategies were successful, while others were not so. This chapter describes these specific strategies undertaken by the Government, discusses the successes and failures and attempts to understand and generalize the lessons from those successes and failures.

5.1 Lead Phase Out from Petrol

Phasing out of lead (Pb) from petrol in 1999 is one of the major success stories in air pollution regulation in Bangladesh. The scientific findings of high Pb concentration in blood and ambient air and the identification of petrol in motor vehicles as the major source of Pb emissions in the 1980s and 1990s received much attention from national and international media. This resulted in the government decision to phase out Pb from petrol in the mid 1990s. By 1998, Pb content in petrol was down to 0.4 g/L from a high of 0.8 g/L in 1980. Regular petrol was Pb free by 1998, while the remaining Pb from premium petrol (locally known as Octane) was made Pb free on July 1, 1999.

There was strong media coverage about lead pollution in Dhaka in the mid 1990s, which made the Government take action. One major reason for the success of the policy was the single, government-run point of control. Bangladesh Petroleum Corporation (BPC) is the only agency for production and marketing of petroleum products in Bangladesh and it only has one refinery plant to process petroleum products. Since BPC is a subsidiary of the Government of Bangladesh, it was easy to implement the policy quickly, without any significant hindrance. As Fig. 5.1 below shows, there was a marked reduction in Pb content in ambient air after the phasing out Pb from petrol, making the program the first success story in combating air pollution in Bangladesh. Although Pb was successfully phased out from motor vehicles, there are still some sources which have not been addressed and elevated blood Pb levels are still observed in people living near the industrial areas (see Table 4.2).

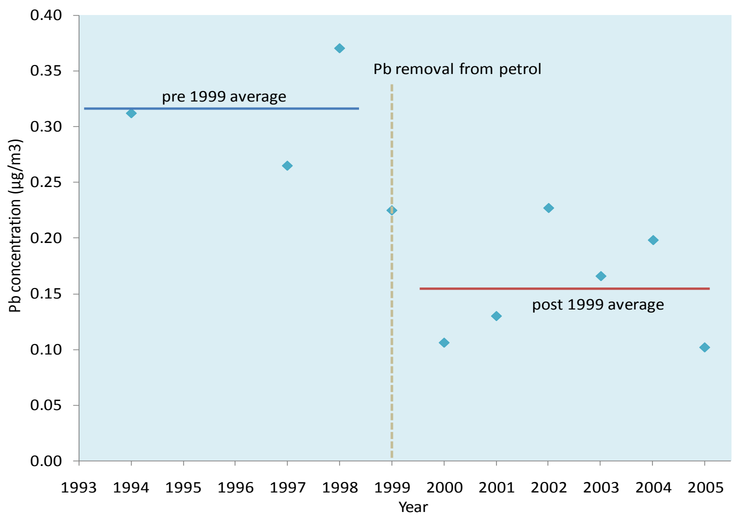


Fig. 5.1 Ambient concentration of Pb in Dhaka (source: Table 2.2)

5.2 Ban on Two-Stroke Three-Wheelers in Dhaka

Two-stroke three-wheeled baby taxis (also known as scooters) were identified as a major source of PM emissions in Dhaka city due to their incomplete and inefficient combustion mechanism. Since PM has large health impacts, running of these two-stroke three-wheelers imparted large social costs on the economy. In order to improve the air quality, the Government of Bangladesh banned the use of two-stroke three-wheelers in Dhaka from January 1, 2003. Around 12,000 existing two-stroke baby taxis were replaced by 9,000 new four-stroke CNG baby taxis, imported from India (Fig. 5.2). The benefits were visible immediately – air quality at various locations in Dhaka improved significantly as measured by ambient PM concentrations (Fig. 5.3). Although the AQ improvements were *not* picked up at all by the DoE's CAMS monitors, it is widely accepted the policy resulted in significant AQ improvements.

Fig. 5.2 CNG fueled four stroke three-wheelers replaced two stroke petrol three wheelers in Dhaka and Chittagong

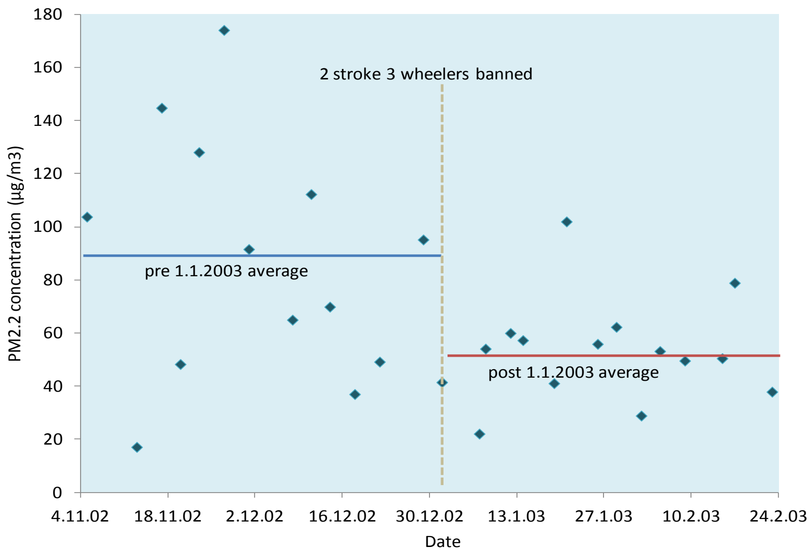


Fig. 5.3 PM before and after CNG baby taxis (Source: BAEC)

There were multiple additional benefits to the economy that encouraged the government to take such a bold step of banning the two-stroke three-wheelers. These included reduction in petroleum import bills and energy security (since natural gas is an indigenous resource). Public support was one of the major reasons behind the success of the policy. Although the number of replacement CNG three-wheelers was smaller than the banned vehicles, making travel difficult initially, people were willing to accept the extra discomforts. The installation of mandatory meters to control travel fare (though not widely followed) in the new CNG three-wheelers (and newly introduced taxis around the same period) was also well received by the travelers. Also, the banned baby taxis were allowed to ply in other regions of Bangladesh, thus the loss of income and protest from the businesses were not significant.

Since the pre-existing baby taxis moved to other regions in Bangladesh with potentially adverse air quality impacts, there is some concern about the distributional impacts of the policy. However, the net beneficial impacts were still clearly positive since the concentration of both population and the relocated two-stroke baby taxis were much less in the new operating locations. Some of the benefits were possibly eroded by the increased emissions from diesel powered public transport to fill the void left by the reduced number of para-transit available. One major flaw of the policy was the lack of competition in importing CNG three-wheelers from abroad. Only two companies were initially given permission to import such vehicles, of which only one could import finally. This led to a monopoly resulting in higher prices of the new CNG three-wheelers, making the program more expensive to the society than it needed to be.

5.3 Promoting CNG Conversion of Vehicles

CNG as a vehicle fuel has multiple environmental and fiscal benefits: reduction in criteria air pollutant emissions and improvement of local air quality, reduction in GHG emissions, improvement in foreign currency reserves, and improving energy security. All of these benefits encouraged the Government of Bangladesh (GoB) to actively promote conversion of petroleum vehicles to run on CNG. However, instead of the command and control (CAC) approaches, typical of the GoB, the policy was designed to utilize the market forces.

The decision to replace two-stroke three-wheelers with CNG baby taxis in early 2003 and to introduce 9,000 new CNG run taxis in Dhaka city ensured a minimum level of demand for CNG fuel. This helped overcome the chicken and egg problem (build CNG supply infrastructure first and wait for vehicles to convert later or convert the vehicles first and wait for CNG filling stations to respond to demand later) and created a thriving CNG industry fairly quickly. The particular market friendly policy decisions that contributed to the success of CNG conversion included:

- Restructuring CNG and petroleum prices in order to make CNG more lucrative as a transportation fuel and removing or reducing subsidies on petroleum fuels;
- Allowing the private sector to participate in CNG conversion of vehicles and in setting up CNG filling stations, curbing the previous monopoly;
- Encouraging the private sector to enter the industry by making available government land to them only for setting up CNG filling stations;
- Dropping import duties on CNG conversion kits, storage tanks and filling station related equipments, bringing down the conversion costs;

- Dropping import duties on dedicated CNG buses reducing duties on CNG baby taxis;
- Asking all government vehicles to convert to CNG;
- Running safety campaigns to ensure the use of proper CNG storage tanks.

All these policy initiatives successfully led to a large scale CNG conversion (Fig. 5.4) of different types of vehicles – including private cars, SUV's, minibuses, and buses (Fig. 5.5). The direct air quality improvements of the conversion policy are not readily evident through monitoring data, which remained stable (Figs. 2.1 and 2.2). However, vehicle ownership and congestion has increased significantly over the last decade (thus increasing potential emissions) and the CNG conversion policy successfully kept the potential increases in PM concentration in check. Most of the vehicles converted used to run on petrol originally, and diesel to CNG conversion is slowly catching up. However, since diesel PM emissions are high, conversion of the remaining diesel vehicles to CNG can still have large air quality benefits.

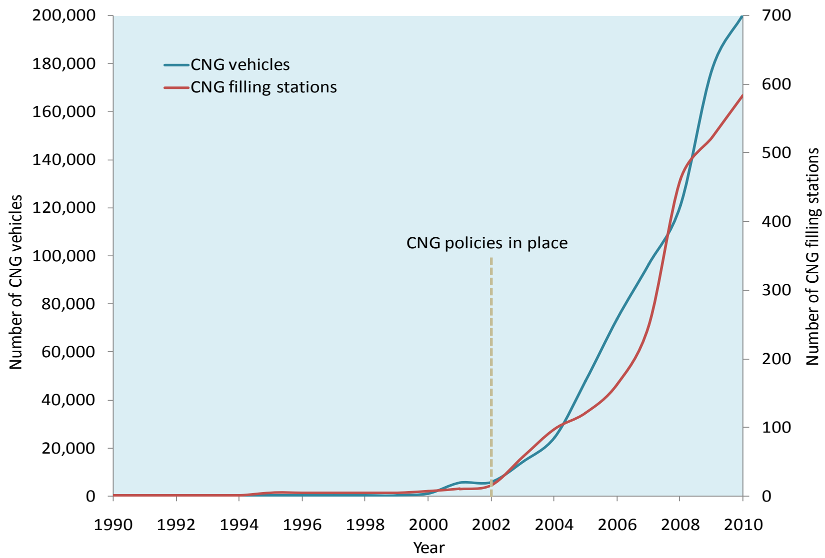


Fig. 5.4 Evolution of CNG vehicles and CNG filling stations in Bangladesh

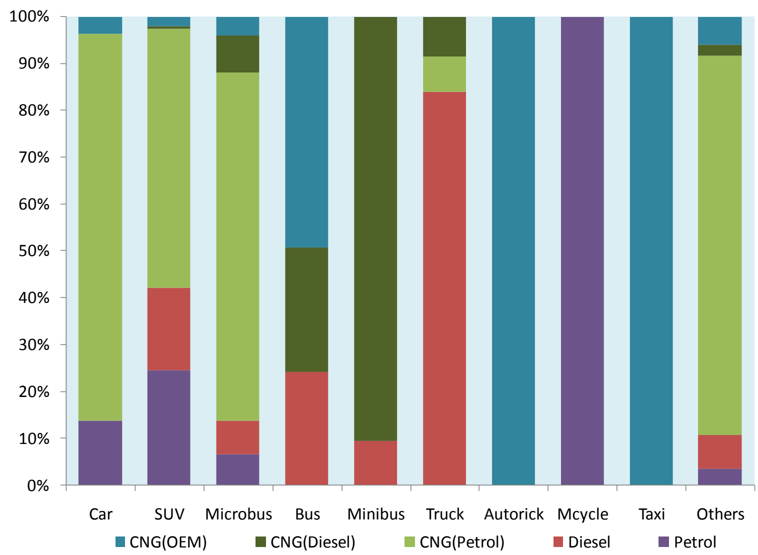


Fig. 5.5 Share of different vehicles running of different fuels in Dhaka in 2010 (Source: Wadud and Khan 2011)

The ambient PM concentration remained stable for the past few years despite a significant growth in vehicle numbers in Dhaka, indicating the success of CNG conversion in mitigating air pollution. However, one unintended effect of the availability of CNG at relatively lower prices is the increased congestion in the streets of Dhaka. There has been suggestion that vehicle ownership has increased due to the cheap availability of CNG as a transport fuel. This does not appear to be the sole reason since income over the last 10 years have also significantly increased, which in turn increases vehicles ownership; in adequate public transport is another important factor. However, CNG run vehicles indeed have a lower operating cost per km, and therefore it is possible that the converted CNG vehicles run more than the original petrol vehicles. No specific study looked into the increased congestion and emission impacts of CNG, but studies at BUET do show that CNG cars run, on average, 30% more than the petrol ones (Wadud and Khan 2011). There is also a large risk of fugitive methane emissions through poor conversion, which is a powerful GHG and precursor of tropospheric ozone. This is an important consideration for emergent short-lived climate pollutant (SLCP) policy in Bangladesh.

5.4 Ban on Older Vehicles

It is well known in urban air pollution management that a small number of highly emitting vehicles are responsible for a disproportionately larger amount of emissions from motor vehicles. Often these high emitting vehicles are the oldest vehicles on the street, which were not subject to any emissions regulations. In 2002, rules were proposed to ban buses older than 20 years or trucks older than 25 years from Dhaka city. Unfortunately despite repeated attempts, successive governments failed to enforce the ban on older buses and trucks. Strong bus and truck unions, with backing from the owners, threatened to stop providing transport services and got the upper hand during each previous attempt to enforce the ban. While a blanket ban on vehicles depending on their age may not be appropriate theoretically (it penalizes the owners who have maintained their vehicles properly), the number of well maintained older buses and trucks is very small in Bangladesh. The older buses and trucks run primarily on diesel with no emissions mitigation technologies and banning them could have significant air quality benefits.

It is interesting to note that during the Cricket World Cup in February 2011, the polluting buses and trucks were successfully kept off the road, which indicates that governments can enforce the ban, even if temporarily, if they are serious about it. However, the governments do not appear strong enough to enforce a permanent ban as yet. Since it is the truck and bus owners who oppose the move, discussion with them and providing some financial incentives to retire the old buses completely can be a good way forward (a program similar to the 'cash for clunkers' in the USA).

5.5 Policies on Import of Personal Vehicles

Almost all of the personal vehicles plying in the streets in Bangladesh are reconditioned vehicles, imported from Japan, although new vehicles are slowly appearing. GoB has banned the import of vehicles older than 5 years, and also reduced import duties on newer vehicles. Still, older, reconditioned vehicles (primarily 'Toyota' make) are more popular and command a premium price over new vehicles because of their higher resale value. These vehicles generally have better emissions performance too.

Import duties are linked to vehicle cylinder size, which is intended to be beneficial for air quality, but the incentives are not ideal since they are *not* based on emission performance of the vehicles – e.g. a large new vehicle can still emit less than a small car of poorer quality but still be subjected to a larger import duty. Still, considering the costs associated with emissions measurement and enforcement of a perfect emissions based system, the differentiated vehicle import tariffs are a step in the right direction.

The only proper MBI in this area that aims to reduce air pollution is the removal of any import duty on hybrid vehicles. So far, however, no hybrid vehicles have been imported in Bangladesh.

5.6 Vehicle Emissions Standards

Bangladesh has had a vehicle emissions standard since 1977, which was tightened in 2005 (see Appendix), to correspond to Euro 2. Although the standards are legally binding and any vehicle which fails to meet the emissions standard is theoretically barred to ply on the roads, the enforcement of the emissions standard is very lax. Bangladesh Road Transport Authority (BRTA), the organization responsible for issuing vehicle 'fitness' certificate, does not even have the necessary equipments to test emissions - even of grossly polluting vehicles. There is widespread allegation of corruption at the BRTA offices, making enforcement further difficult.[6]

It should also be mentioned that the drive cycle used in emissions compliance in the developed countries mimic their own driving style, which is very significantly different from those in Bangladesh. Thus a vehicle meeting the emissions standard using a European Drive Cycle or US Drive Cycle would still emit more pollutants per km than the specified standard while operating in Dhaka/Bangladesh.

Emissions standards are possibly the least cost approach to reducing pollutant emissions in Bangladesh. Since Bangladesh imports vehicles from other countries, it does not have to calculate the costs to the manufacturers in controlling emissions through technological improvements. Also, since most of the vehicles are imported from Japan, it is easy to adopt Japanese standards (or Euro) and lag it by 3 to 5 years, reflecting that most of the vehicles are reconditioned.

5.7 Policies to Reduce Emissions from Brick Kilns

Brick kilns around large cities of Bangladesh are one of the largest sources of ambient air pollution (see Section 3.2.2). They are also an important source of outdoor air pollution in smaller, regional towns, where vehicular and other industrial sources of emissions are small. Their contribution to air pollution is especially important, since the kilns operate during the dry season when ambient air quality is already at its worst. There have been several initiatives to control emissions from brick kilns and their impacts.

The Brick Burning (Regulation) Act of Bangladesh was first legislated in 1989. The law banned the use of wood as a fuel in the brick kilns, and made it compulsory to obtain licenses from the regulatory bodies to set up a brick kiln. The primary concern for banning the use of wood was

[6] It has been alleged that it is possible to get a fitness certificate even without sending the vehicle to the BRTA office!

deforestation, although it did help reduce emissions per unit of brick production because of the inefficient combustion process of fire wood.

The Brick Burning Law was amended a number of times since 1989. An amendment in 2001 banned the setting up of any brick field within a 3 km radius of residential areas, forests and fruit orchards – in an attempt to reduce the exposure of people to emissions. In 2004, moving chimney Bulls Trench Kilns (BTK) were banned, since they were the most polluting of different types of brick kilns. In 2002, at least 120 ft tall smoke stacks were made compulsory for Fixed Chimney Kilns (FCK). In the most recent amendment in 2010, FCKs are also banned (from 2012) and are to be replaced by Zigzag Kilns (ZK), Hybrid Hoffman Kilns (HHK), Vertical Shaft Brick Kilns (VSBK) or by other modern technologies.

Use of wood decreased drastically after the enactment of the law, although a significant amount of wood was still being used in violation of the law in 2003, as is evident from Gomes and Hossain (2003) and (IIDFCL 2009). One major reason for the switch from wood to coal (in addition to the law) is that the economics of the two fuels have changed in favour of coal because of the improved transport infrastructure. Even today, some remote kilns use wood or mix wood with coal where local economics are favourable (see Fig. 3.3).

Banning the BTK was, again, was a qualified success. While 90% of the brick kilns in 2001 were BTKs, by 2006, 75% were FCKs (see Fig. 5.6). Worrying cause, however, was that still a good 16% of the kilns were BTKs, despite the ban on using such kilns, indicating a lack of enforcement. Switching to FCKs was possible fairly quickly, especially when it became clear that the quality of bricks were better, the wastage was smaller although the payback period was longer than the BTKs. The longer payback period was an impediment for the short sighted entrepreneurs (FCKs are more profitable in the long run than in the short run since they are more energy efficient). The air quality benefits of the ban on BTK have not been quantified through any study.

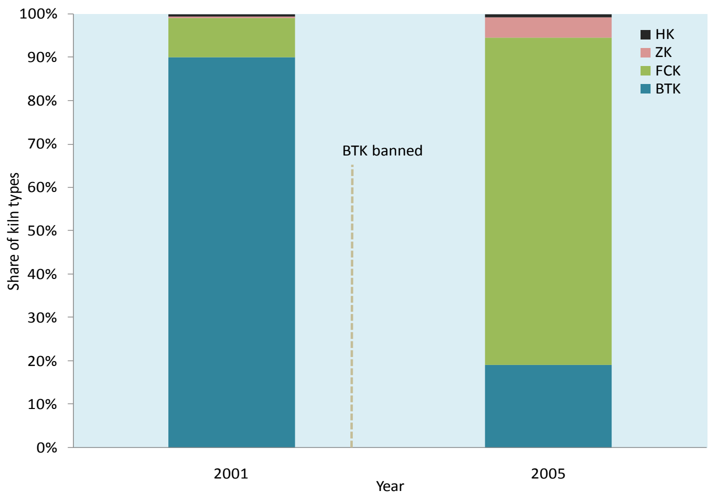
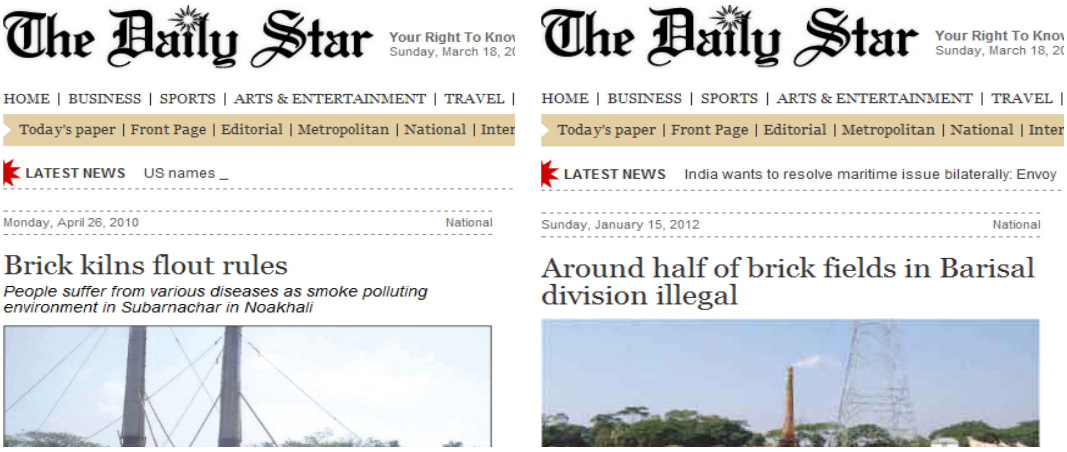


Fig. 5.6 Share of different brick kilns before and few years after BTK are banned (Source: Gomes and Hossain 2003 and IKEBMI 2006)

Compulsory erection of 120 ft smoke stacks has interesting implications. Higher stacks allow the settling of coarser particles within the stack and efficient burning through better air flow, thus reducing the coarse emissions, but distribute the finer particles over a wider area (note that the finer particles have larger health impacts). The policy can actually counteract the positive effects

of the other GoB order which bans brick kilns within 3 km of human settlements (although rarely enforced). Since a higher stack allows emissions to reach a larger area (though at reduced concentration due to increased dilution/dispersion), it can aggravate the total health impacts, whereas a shorter stack could keep the emissions (albeit larger emissions) concentrated within a smaller area and can result in lower total impacts if the nearby area is unpopulated (which however is not the case for most kilns). A trade off study on emissions reduction and larger reach of emissions should be carried out to understand the net effect of the policy.

All the initiatives to reduce the impacts of brick kiln emissions are governed by CAC approaches. Lax enforcement did undermine the effectiveness somewhat (16% BTKs working), still, the policies can be declared a qualified success. However, the economic burden of the policies was and is significant.[7] Outright banning of FCKs in future and forcing the kiln owners to adopt a specific, more expensive technology can force out the numerous small entrepreneurs with significant distributional impacts. It also does not allow innovations within the industry which would have occurred if an emission based tax were imposed, or even emissions standards were enacted (e.g. adding scrubbers to existing FCKs could be cheaper than constructing a new type of kiln). Also, among the technologies allowed in future, ZKs are the cheapest, and it is expected that such kilns will largely replace the FCKs in future. MBIs (emission tax or tradable permits) could have increased the penetration of even better technologies (HHK, VSBK) since the benefits of the reduced emissions could be enjoyed by the brick kiln owners. While MBIs are strongly recommended from a theoretical efficiency perspective (reducing the emissions at the least cost to the economy), the lack of enforcement and capacity, can significantly hinder the effectiveness of the MBIs in Bangladesh in the near term.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Around half of brick fields in Barisal division illegal

Fig. 5.7 News headlines about lack of enforcement (Source: Daily Star)

5.8 Ban on High Sulphur Coal

Larger sulphur content and impurities in coal increases harmful particulate emissions further. Following this, there was a ban on the import of high sulphur coal in Bangladesh (check) through the Import Policy of Bangladesh, enforced by the Ministry of Commerce. Although the Import Policy does not allow the import of coal with a sulphur content of more than 1%, the Government

[7] Note that, this does not mean that the costs to the entrepreneurs were more than the social benefits, but the same benefits could be attained with lower costs to the entrepreneurs through other MBIs.

allowed the import of such coal from the Meghalaya region of India. Although the coal from that region has a sulphur content of around 3-5%, the government possibly bowed to the pressure of the entrepreneurs (especially brick kiln owners) who sought cheap energy sources. It is quoted that the coal from the Meghalay region costs almost half that of better quality coal from Indonesia or China. The Ministry of Commerce mentioned that the Department of Environment should charge the brick manufacturers for poor emissions performance, yet, an import ban or an import tariff on high sulphur coal would have been a much cheaper option to reduce emissions because of lower monitoring and enforcement costs. The u-turn on ban is another example of poor governance and weakness in policy implementation (Fig. 5.8).


Latest : Arbitration on Dhaka-Delhi sea row on: Dipu Moni

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Govt permits harmful coal import

Tue, Jul 6th, 2010 11:38 pm BdST

Dhaka, July 6 (bdnews24.com) – The government has again allowed coal import containing over 1 percent sulphur from next year, raising concern among environmentalists who fear that the move would harm the environment.

The commerce ministry, in a press release, said on Tuesday that the high-sulphur coal could be imported considering its demand for the sake of the country's economic development and conserving environmental balance as far as possible until June 30, 2011.

'Over one percent sulphur-mixed coal' is banned in the current Import Policy-2009-12 and Import Policy-2006-9.

Fig. 5.8 News on lifting of the ban on import of high sulphur coal (Source: Bdnews24.com)

5.9 Improved Cooking Stoves (ICS)

Introduction of improved cooking stove (ICS) is a very important and essential step in the management of indoor air pollution (IAP) that also results in improved fuel efficiency and reduced cooking time. A good number of ICS programs have been implemented by government organizations (e.g., LGED/BCSIR), non-government organizations, and donor agencies. Although quality data are scarce, there is sufficient indirect evidence to suggest that introduction of ICS significantly reduces indoor air pollution in the kitchen environment and thus protect women and children from being exposed to adverse health effect of IAP. The recent World Bank report (World Bank 2010) on lessons learned from household energy and sanitation programs provides a review of six energy programs in Bangladesh, including three ICS programs. The report concludes that ICS has the potential to alleviate many household energy problems in Bangladesh. However, there is a significant lack of awareness concerning IAP in Bangladesh (World Bank 2010). There is also the potential to reduce black carbon emissions and obtain regional climate benefits as well as health benefits.

5.10 Emissions Standards

There exists a number of emissions standards regulation pollutant emissions to ambient air from various sources discussed in this document. In addition to motor vehicles (mentioned above) these emissions standards cover the following types of industries: brick, cement, fertilizer, power plant and sugar. While cement industries report their emissions to the DoE, it is not clear about

the enforcement status of the other industries. The authenticity of submitted reports is also questionable. In addition, the emissions standards are not stringent enough and there is significant scope to review these standards and ensure enforcement. An excellent, yet slightly dated, source of the existing emissions standards is Huq 2002.

5.11 Summary of Air Quality Strategies in Bangladesh

Table 5.1 summarizes the lessons learnt from the previous policy experiments in Bangladesh.

Table 5.1 Summary of AQM experiences in Bangladesh

Policy/Strategy	Policy	Year	Result	Lessons learnt
Lead phase out from Petrol	CAC	1999	Success	Media and public support allow easy implementation, implementation quick and easy if few, government run bodies are targeted
Vehicle emissions Standard	CAC	1997, Update 2005	Failure	There is no testing facilities for monitoring vehicle emissions during certification, poor institutional capacity and enforcement hinder implementation
Brick kiln stack height	CAC		Success	Benefit to the owners (more efficient burning, better quality bricks) is good for policy implementation, ease of monitoring is also important
Ban on older vehicle import	CAC		Success	Small number of vehicle importers, no significant losses to businesses (increased cost of vehicles passed on to buyers) allow easier implementation, somewhat covers vehicle emissions standard initially
Differentiated vehicle import tariff	MBI		Success	Although not a perfect MBI, strong public support, smaller points of regulation means easier implementation
Ban on driving older vehicles in Dhaka	CAC	2010	Repeated failure	CAC did not work when many polluters are financially affected, especially when they have a strong lobby. MBI instruments with active stakeholder engagement during policymaking can be useful
Ban two stroke three wheelers	CAC	2002	Success	Extensive public support allows easy implementation, unforeseen practices (smaller diesel vehicles) can erase the benefits, monopoly in new CNG three wheeler supply can make a good policy costlier than necessary, multiple benefits
Promotion of CNG vehicles	MBI	2002	Success	Extensive public support, good pricing policy, good incentive to private sector, multiple benefits – all are important for a functioning MBI
Compulsory use of catalytic converter	CAC	Not enacted	--	Proper technical evaluation of a proposed strategy is needed, before implementation
Ban on use of wood in brick kilns	CAC		Success – qualified	Fuel choice primarily governed by economics – high sulphur coal is generally cheaper than wood currently (unless in remote areas), monitoring and enforcement lax in rural areas
Lane based traffic	CAC	2010	Failure	Trying to impose a policy very quickly, without education and advertisement campaigns does not work, not enforced
Carpooling	CAC	2010	Failure	Unrealistic proposals certainly do not work!
Colored kerosene	CAC		Unclear	Price is an important issue, monitoring difficult
Ban on import of high Sulphur coal	CAC		Failure	CAC did not work when many polluters are financially affected (fuel choice governed by economics), especially when they have a strong lobby to overturn the ban
ICS Programs	--	--	Success - qualified	There is lack of awareness regarding IAP. Involvement of community, especially women, and innovative financing (e.g., microcredit) are important for success of program.

Table 5.1 indicates that an air quality strategy requires the following components in order to be successful in practice:

1. Widespread understanding among the public and stakeholders of the extent of problem and its impact
2. Information campaign and involvement of media in disseminating information
3. Government will and capacity to enforce
4. Private co-benefits (e.g. cost reductions)
5. Small number of regulation points

5.12 International Environmental Treaties and Bangladesh

Participation of major international environmental treaties and conventions can often lead to policy changes in developing countries. Bangladesh is a signatory to most of the international environmental conservation protocols or treaties, some of which directly or indirectly seek to improve the quality of air. The major ones are listed in Table 5.2. Among these, the Montreal Protocol, the Vienna Convention, the Kyoto Protocol, the UNFCCC and the Malé Declaration directly address the air pollution issue. The Montreal and Vienna protocol address the emissions of Chloro-Fluoro Carbons (CFCs) that are known to deplete the Ozone layer (i.e. high level stratospheric ozone and not low level tropospheric ozone that causes health, crop and climate effects). The Kyoto Protocol and UNFCC address GHG emissions causing global climate change – and can be seen as a global scale air pollution issue. The Male Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia is a regional cooperation program between the South Asian countries, including Iran, rather than a binding treaty. Unlike the other treaties and conventions, the Malé Declaration covers all types of air pollution, though major emphasis is on local air pollution and its regional, transboundary effects.

Table 5.2. Bangladesh and international conventions on environment and air pollution (source: UNDP and DoE)

Name of Convention	Convention Year	Bangladesh Sign Year
Convention of the Law of the Sea	1982	2001
Vienna Convention for the Protection of the Ozone Layer	1988	1990
Montreal Protocol on Substances that deplete the Ozone Layer	1989	1990
Convention on Biological Diversity	1992	1994
Framework Convention on Climate Change	1992	1994
Rio Declaration on Environment and Development	1992	1992
Convention to Combat Desertification	1994	1996
Kyoto Protocol to the Framework Convention on Climate Change	1997	2001
Male Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia	1998	1998
Cartagena Protocol on Biosafety	2000	2004
Stockholm Convention on Persistent Organic Pollutants	2001	2007
Johannesburg Declaration on Sustainable Development	2002	2002
Rio+20 Declaration on 'the Future We Want'	2012	2012

Chapter 6
POLLUTION CONTROL APPROACHES

This chapter briefly describes the various approaches to pollution control in general with some theoretical economics background, their advantages and disadvantages. The chapter then briefly describes some international experiences in air pollution control strategies and comments on their applicability in Bangladesh.

6.1 Approaches to Pollution Control

All of the potential strategies or policies to reduce air pollution can be broadly classified into two distinct sets of instruments: command and control (CAC) and market based instruments (MBI) (Stavins 1998). Command and control sets a uniform maximum emission limit – often known as standards – for the emitting units (*e.g.* firms, vehicles, households, individuals) and then monitors and enforces the set standards. This is by far the most widespread method for controlling harmful emissions in both developed and developing countries. The emissions standards can be performance or technology based. Examples of performance based emissions standards include vehicle emissions standards that have been successfully implemented to control the pollution of local air pollutants (*e.g.* CO, NO_x, HC, PM) in many countries.[8] Bangladesh has also enacted such vehicle emissions standards (see Appendix). Technology based regulations can include the imposition of a specific technology – e.g. compulsory use of catalytic converters in every vehicle or, as in Bangladesh, regulations increasing the height of brick kiln stacks to 120 ft or banning a specific type of brick kiln.

The cost of controlling emissions can vary greatly among the emitters, and therefore setting the same target of emission reduction for all units as in the CAC approach, can be unfairly expensive for some and expensive as a whole. This concern for economic inefficiency of standards and regulations paved the way for market based instruments. Air pollution is an *externality* to the polluters, since the cost of air pollution is not borne by them directly (Varian 2006, Stern 2007). The efficient policy solution is thus to force the polluters to internalize the external costs *i.e.* to ensure that the cost of pollution is directly borne by the polluters (Jaffe et al. 2005). Thus, an appropriate price signal – reflecting the cost of pollution – from the policy makers can help the production sector (i.e. the polluters) adjust its structure to abate emissions at the least cost to the economy. Although such policies were first mentioned in the academic literature as early as the 1920s, in practice the applications started to appear in the 1980's. Two of the most commonly used MBIs are:

1. Emission taxes (or charges, fees, subsidies), in principle, the Pigouvian tax (Pigou 1932) – e.g. SO_2 and NO_x emissions charges in several European countries, noise based landing charges in airports, carbon taxes in Sweden and Norway.

[8] CO: Carbon Monoxide, NOx: Oxides of Nitrogen, HC: Hydrocarbons, PM: Particulate Matters

2. Emissions trading (also known as Cap and Trade, Tradable permits), based on the Coase theorem (Coase 1960)[9] – e.g. lead phase out from gasoline in the USA, NO_x emissions trading in the Netherlands, etc.

The emission taxes discourage emission of a pollutant by imposing a financial payment for it. The emitting units will reduce their emissions until the cost of reducing per unit of emission is lower than or equal to the tax rate. If the cost of abatement is higher, then all of the units will prefer to pay the tax. In the cap and trade program, an upper limit (cap) is placed on the *total* emissions of the pollutant, which are then allocated to the emitting units (in the form of permits or quotas or allowances), that can be traded amongst the units. Emitters will reduce emissions when permit prices are larger than the abatement costs, and buy permits from the market otherwise. Thus, both the policies basically increase the opportunity cost of pollution and ensures that the marginal cost of reducing the emissions will be equal (to the tax rate or market price of permits) for all polluters, ensuring least cost for abatement.

Box 1. Command and Control (CAC) vs. Market Based Instruments (MBI)

The Government of Bangladesh recently banned the use of FCKs in order to reduce emissions from brick kilns. This is a perfect example of a CAC approach. However, such a policy forces all brick manufacturers to switch to ZK, HHK or VSBK, which are all more expensive, thus imparting a cost burden on every manufacturer. It is possible that some FCKs currently use a high quality coal or have installed some emissions control technology (e.g. Gravity Settling Chamber/Scrubber) which emits much less particulates and fulfills the emissions standards. Despite investing capital in innovative practices, these FCK owners have to invest again, and the previous capital investments are wasted. Thus, the economic investments are wasted, and, rather unfairly, environment friendly producers are penalized.

Instead, if each kiln is taxed according to its emissions, the good FCKs will not need to make further investments, reducing the overall costs, and giving them a competitive advantage over their polluting rivals. Similarly, the CAC approach of banning FCK will force most kilns to switch to ZK, the least-cost approach currently. Once all the switch is completed, and further reduction becomes necessary in 5 to 10 years, there will again be a need for capital investment. On the other hand, if there were long term signal from the policymakers in the form of an emissions tax (calibrated properly), existing FCK owners may have switched directly to even more advanced technologies (HHK, VSBK, Tunnel) which reduces emissions further, since that would give them a competitive advantage in running production costs (lower pollution = lower tax = lower operating costs).

It is well established in economics that the same amount of reduction can be brought about by emissions taxes or emissions trading at a lower economic cost than a blanket ban on a specific technology. However, administrative and monitoring costs can be large (including potential for corruption), especially in a country like Bangladesh, where no previous example of a pollution market exists. In such cases, CAC approaches may be more effective and cost-efficient. Still, as capacity for monitoring and enforcement will hopefully grow in future, MBIs will be easier to implement and thus the long term policy goal should be using MBIs for air pollution control.

Table 6.1 briefly compares the MBI and CAC approaches of air pollution control with special reference to some of these criteria and applicability in Bangladesh. It is clear that, although theoretically MBI is preferred to CAC – especially in terms of cost efficiency and incentives for further emissions reduction – it can have some severe administrative concerns in terms of policy design, monitoring and enforcement, which could all adversely affect its effectiveness in a

[9] The theorem states that any allocations of property right (permits) are equally efficient since interested parties will bargain privately to correct an externality.

country like Bangladesh. Because there is a lack of information on even the distribution of technologies or even the number of different types of industries with their emissions loads, devising a successful MBI can be very difficult in Bangladesh. Weak institutions and potential for collusion among polluters and between polluters, monitors and enforcers can also make MBI less effective than CAC approaches. CAC approaches therefore prominently appear in the strategies and policies discussed, although MBI have also been considered for a few cases where they are deemed feasible. Note that almost all of the existing air quality improvement policies in Bangladesh as discussed in the previous section follow the CAC approach.

Table 6.1 Comparison of command and control and market based instruments in air pollution control

	Command and Control	Market Based Instruments	Comment
Effectiveness	Can achieve goals quickly, with greater certainty	May take longer to achieve the goals, may not always be effective	MBI may not be effective in a weak institutional framework
Efficiency	Total cost of abatement is high	Theoretically, abatement is done at the least cost to economy	MBI preferred, but if the number of trading entities is low, information is unavailable, enforcement and administration is costly, then costs could be high in MBI too
Equity	Can put excessive burden to some firms or users	Marginal burden is equal across firms or users	MBI preferred
Ease of policy	Widely understood by regulators and polluters	Relatively new concept, policy design is difficult	Lack of capacity in Bangladesh – MBI could be difficult to design and implement
Administration, monitoring and enforcement	Relatively easier	Requires more administrative efforts	Administration, monitoring and enforcement is weak in Bangladesh – MBI may be ineffective
Market requirement	Does not require a competitive market	Requires a properly functioning competitive market	Potential collusion among polluters, a real possibility in Bangladesh, can render MBI ineffective
Further emission reduction and innovation	No such incentives	Large incentive for further reduction and innovation	MBI preferred as every unit of reduction has a financial benefit
Evolution with time	Less flexible as changes are expensive, requires update as standards may become too strict or too lax	More flexible – but also requires updating to account for the changes in economy	Regulation is often slow to catch up with technology

Besides these two approaches there can be other soft approaches, e.g. voluntary emissions reductions schemes, reduction of emissions through planning of transportation and land use, etc. In a recent work, Peters and Kuylenstierna (2008) interviewed stakeholders in three South Asian countries including Bangladesh and made the following observations regarding air pollution reduction policy approaches:

- Command and control regulation has been successfully applied in South Asian countries

- Command and control regulation is enhanced through economic incentives and disincentives
- Strong judiciary role in society is a government partner for policy development
- Education of society bolsters community support for air pollution control programs, and creates political pressure
- Role of economic instruments in air pollution control remains limited
- Cities are leading beacons for air pollution policy development

Except for the role of judiciary, all other points are valid for air pollution policy making in Bangladesh. Peters and Kuylenstierna (2008) also reviewed a few international good practices and summarized six stakeholders' views about those policies. Table 11 present those strategies and their applicability in Bangladesh as per the stakeholders.

Table 6.2 Application of applicability of some good practice measures in Bangladesh (Source: Peters and Kuylenstierna 2008)

Programme	Country	Applied in Bangladesh?	Applicability in Bangladesh
Two control zone for SO_2 emissions	China	No	Not applicable
Acid rain cap and trade	USA	No	Not applicable
CNG conversion of vehicles	India/Bangladesh	Yes	Applicable
Ultra low sulphur diesel	US, EU, Hong Kong	No	Applicable
Electric vehicles	EU	Yes	Applicable
EU vehicle emissions standards	Europe	Yes	Inconclusive
Hybrid vehicles	UK, USA, Japan	No	Not applicable
NO_x/SO_x emissions taxes	Sweden	No	Not applicable
High vehicle registration fees	Singapore	No	Applicable
Toll road/area road pricing	UK, Singapore	Yes	Applicable
Hydropower	Nepal	Yes	Not applicable
Brick kiln manufacturing	India, Vietnam	Yes	Applicable
Air quality index	Singapore	Yes	Applicable
Toxic release inventory	Indonesia	No	Inconclusive

6.2 International Case Studies

6.2.1 Mexico City Car Rationing

In order to tackle congestion and air pollution, Mexico City imposed a regulation in 1989 that every car will be off the streets one day of the working week (e.g. cars with license plate no ending with 0 and 1 will not run on Monday, with 2 and 3 will not run on Tuesday, etc.). Such a CAC policy obviously has its criticism due to larger welfare losses than the MBIs, but this specific policy had another adverse unintended effect. Research has shown that in order to circumvent the restriction, many households bought additional cars: Mexico City had exported 74,000 used vehicles annually to the rest of the country before 1989, but it imported 85,000 vehicles annually during the first four years of the regulation (Eskeland and Feyzioglu 1997). A petrol demand model also clearly showed that vehicle petrol use (and therefore travel) had increased significantly after the regulation, which is primarily the result of owning a second car. The ban also encouraged owners of older, more polluting vehicles to delay the sale of their vehicle,

aggravating the air pollution further. This is an example of a policy where unforeseen effects of a policy totally negate the primary objective of the policy.

Car rationing is fairly common in other Latin American cities, e.g. Bogota, Santiago, Sao Paulo, La Paz, Quito etc. It is not clear how the schemes in these cities worked out (i.e. if there were unintended effects like in Mexico). China also has recently introduced a car rationing scheme in Beijing, following its successful temporary implementation during the Olympics in 2008.

One of the largest impediments of such a program in the context of Bangladesh is enforcement. The possibility of owning a second car is much smaller than in Mexico, considering the income difference – however there will be large incentives to beat the system by owning an alternate license plate (which is very easy). This would vastly increase the workload of traffic police, who are already overworked.

6.2.2 Vehicle Inspection and Maintenance

Vehicle inspection and maintenance (I&M) is a major strategy for reducing air pollution from the transport sector in many countries and cities. There are also good and bad examples of such programs. It is generally regarded that Mexico City's I&M was a good example of a switch from a corrupt inefficient system to an example-setter. In 1991, Mexico City allowed private sector participation in vehicle I&M, and there were 24 private test-only and 500 test-and-repair centre within 2 years. There was no effective oversight from the government, and these centres were competing against each other by lowering price of inspections and allowing false passes. In response, the government took a variety of steps which helped theI&M system to work effectively. These included:

- Elimination of repair-and test centres (the major sources for corruption) and optimize the number of test-only centres (too many centres increase competition and increase the chances for corruption, too few is bad for public service)
- A good quality assurance program with video surveillance, computerized and central data logging, blind testing (operator does not know test results), etc.
- Private test centre relays data automatically to a central authority allowing monitoring of individual centre and individual employees.
- A high penalty for non-compliance (which increased the 'going' bribe rate for corrupt police) made I&M more acceptable.

While I&M can be useful for Dhaka and Bangladesh, the major issue with vehicle emissions now (after the large CNG conversion) is identifying the high-emitters. Mmost obviously, they would be diesel trucks and buses (and some jeeps). Thus an extensive I&M for diesel trucks and buses should get more emphasis and should be more cost-effective in the near term. The experience could also help towards an all-encompassing I&M program later.

6.2.3 Shift to Electric Vehicles in Nepal

The unique valley topography of Nepalese cities makes them especially susceptible to air pollution. Diesel run three wheeler vehicles were identified as a significant polluter as early as the 1990s and new diesel three wheelers were banned in 1991. This was followed by a removal of

around 600 in-use diesel three wheelers from the streets of Kathmandu by 1999. The dearth of transportation vehicles were immediately filled by the locally produced electric vehicles (EVs), known as Safa tempos. The local manufacturing of these tempos began in 1996. The innovative entrepreneurs saw an opportunity and, supported by conducive government policies, moved in to convert the banned three-wheelers to run on batteries charged using grid electricity. The Nepalese government aided in the conversion through friendly policies such as reduced import tax for vehicle parts, batteries, charging equipments, no annual registration fees, lower electricity tariff rates etc. Since hydropower is a significant source of energy in Nepal, the conversion to EVs had large air quality and greenhouse gas benefits. Currently there are around 600 Safa tempos in Nepal, but their growth has been stalled due to conflicting government policies (Clean Energy Nepal 2003). Still, the introduction of EVs in Nepal is an example of innovative application of CAC and MBI to encourage cleaner vehicles on the streets.

Fig. 6.1 Safa Tempo in Kathmandu (source: internet)

Electric vehicles, while clean and especially useful in large cities like Dhaka and Chittagong, present a challenge for Bangladesh because of its lack of and unreliability in electricity supply. Only 40% of the population has access to electricity, and that supply too is not reliable, and there is a severe power shortage during most of the year. Under this circumstance, electricity use for vehicles will aggravate the power situation further and can cause public uproar. However, there has been a reasonable proliferation of electric baby taxis (primarily imported from China) in smaller towns and in some pockets within Dhaka city as well. The running costs of these vehicles are much cheaper than those of CNG baby taxis.

6.2.4 Vertical Shaft Brick Kilns in India, Nepal and Vietnam

Vertical Shaft Brick Kilns (VSBKs) were developed as an energy efficient brick manufacturing technology in China. It is also generally less polluting than BTK, FCK or ZK. There were various attempts to introduce VSBK in other Asian countries, especially by the various development agencies, because the large contribution of the brick sector to air pollution in those countries. In India, there were around 100 VSBKs in 2007. The installations were expedited due to a ban on BTKs in 2002 and an earlier imposition of an emissions standard in 1996. This led to the large brick kilns to switch to FCKs, but the small to medium capacity ones had to opt for other technologies, VSBK among them. Swiss Agency for Development and Cooperation (SDC) assisted

in introduction, demonstration and modification of the technology to suit local needs along with conducting training and awareness seminars. There were 100 VSBKs operational at various places in India in 2007.

In Nepal and Vietnam, the programs were implemented by UNDP with Global Environment Fund and SDC support, respectively. In Nepal also, BTKs were banned and VSBK won a very slow market share: as of 2007, there were 10 VSBK operational in Kathmandu valley. Vietnam, on the other hand, saw a rapid proliferation of VSBKs, with more than 300 in operation in 2007, which was also expedited by the planned phasing out of old technologies by the government.

Fig. 6.2 VSBK in India (source: internet)

Although the VSBKs run profitably after installation, there still appear to be some barriers, which is their higher capital costs, round the clock labour requirements and longer pay back period (although longer term profitability is possibly better). Despite the emissions standards in 1996 and BTK bans in 2002, only 100 operational VSBKs in India indicate a relatively slow penetration. On the other hand, rapid penetration in Vietnam was followed by financial losses of some VSBKs due to management problems and lack of information.

VSBK and other advanced brick kiln technologies appear to be gaining momentum in Bangladesh, especially helped by the government policy (of banning further FCK), although the barriers mentioned above are relevant to Bangladesh as well. Carbon financing are currently being used to develop a few HHK in Bangladesh. Such innovative financing schemes may be necessary in the beginning in order to overcome the market barriers. One potential drawback is the increased transport emissions since VSBK and HHK each will replace a number of existing kilns in low density rural areas.

6.2.5 Diesel Vehicle Retrofit in Hong Kong

On-road diesel commercial vehicles were a major source of air pollution in Hong Kong in the 1990s accounting for almost all particulate emissions. In order to control emissions from those vehicles, there was an extensive vehicle retrofit program targeting the commercial diesel vehicles from 2001. At the first stage, around 24,000 pre-Euro light commercial diesel vehicles were retrofit with diesel oxidation catalysts (DOC), which can reduce PM emissions by 30% (Ha 2006).

By December 2003, all pre-Euro light diesel vehicles were to install DOCs. Between December 2002 and December 2004 around 34,000 pre-Euro medium and heavy-duty diesel vehicles were retrofitted. A further 2,500 long-idling pre-Euro trucks were retrofitted by December 2005. Retrofit DOCs reduced PM emissions from these vehicles by about 25% to 35%. Regulations also dictated all pre-Euro heavy vehicles to be retrofit with DOCs from April 2006 (Ha 2006).

The diesel bus fleet was also brought under the umbrella of the retrofit program. 2000 pre-Euro and Euro-I compliant buses were to fit DOCs, while Euro II and Euro III buses were retrofitted with Diesel Particulate Filters. The retrofit programs were ably assisted by Hong Kong's incentives to introduce ultra low sulphur diesel. By 2005 all diesel in Hong Kong had to meet a sulphur content standard of 50 ppm, but proper financial incentives reduced the content to 10 ppm in all highway diesel now (UNEP 2009). Although road side particulate emissions has been reduced by 34% from 1999 level, the retrofit program may have increased NO_2 emissions, as a recent study suggested (China Daily 2011).

While diesel vehicle retrofit is an effective way of reducing emissions, experts at the stakeholders meetings in Dhaka opined against it since most of the ambient air in Dhaka and Chittagong is carbonaceous PM, not sulphurous and the strategy would require simultaneous introduction of low sulphur fuel. Also diesel filters would require frequent cleaning/regeneration in Bangladesh due to high emissions load, monitoring of which is difficult.

Chapter 7
EVALUATION OF AIR QUALITY STRATEGIES

In light of the previous discussions on current status of air pollution in Bangladesh, key pollutants for the most harmful impacts, major sources of pollution, approaches to pollution control and international examples, the consultants have shortlisted a number of potential strategies to address emissions from the different sectors. These strategies were evaluated by the consultants and then presented to stakeholders. The initial set of strategies was then reduced to half on the basis of various evaluation criteria and discussion in the stakeholder meeting. This chapter describes the evaluation criteria, the initial set of strategies and the final recommendations.

7.1 Evaluation Criteria

Nearly all policies for emissions control consist of two distinct components: identification of the goal and the means to achieve the goal; and these two components are often linked within the political process (Stavins 1998). For air quality improvement, the goal is to achieve the Ambient Air Quality Standard for different pollutants in every region of Bangladesh. In determining the means to achieving this goal, it is important to emphasize at least five distinct components of the policy effects: effectiveness, efficiency, equity, monitoring and enforcement (Nordhaus and Danish 2003). Formulating a policy that excels in all five criteria is not always feasible: emphasizing one may undermine another. Therefore, compromises among the criteria often become necessary during the selection of the appropriate policies.

The evaluation criteria that are qualitatively considered in this document to evaluate the various strategies are briefly described below. It is emphasized that the criteria are evaluated only qualitatively, since there is not enough information in the country to carry out a quantitative evaluation at the moment. It is highly recommended to revisit the options when more quantitative information becomes available.

7.1.1 Impact

Impact describes the 'potential' of the strategy to reduce total impact on human health. While the criterion is primarily concerned about the reduction in population exposure to the pollutants, the reduction in exposure depends on two parameters: reduction in emissions and population distribution of the areas where the reduction is taking place. Thus, a small reduction in emissions can have a large impact in Dhaka city, yet a large reduction in emissions can have a smaller impact if the reduction takes place in a rural village. Therefore the emphasis on total impact can result in less importance in local scale acute air pollution problems (e.g. slash and burn practices in the hilly regions). Thus strategies that focus on cities, especially large cities, get priority over other measures. The focus on total impact can also lead to important distributional issues, e.g. a strategy of relocating existing industries out of Dhaka city can reduce total impact without reducing emissions (since Dhaka is densely populated), yet inhabitants of the newly industrial area will now face higher air pollution. However, these tradeoffs in air pollution control are often necessary.

7.1.2 Time to Introduction

This criterion summarizes the potential time required to implement the strategy considering, especially the technical aspect of the strategy. Short term means within 3 years, medium term means between 4 to 8 years, while long term means more than 8 years. Since no strict technical evaluation was undertaken, the timeline is based on judgment rather than on specific calculations, and has uncertainties associated with it. Therefore each strategy may require somewhat longer/shorter time than mentioned below.

7.1.3 Time to Benefits

This criterion refers to the timeline to realize the benefits *after* the policy has been successfully implemented. This is different than the time to introduce, because a strategy, after successful implementation can still take time to realize benefits. For example, strict emissions standard for new vehicles may be introduced fairly quickly making the time to introduction short, yet the realization of the benefits of the new standards is slow since fleet turnover is very slow in Bangladesh. On the other hand, banning the FCKs from brick kilns will have immediate health quality benefits from the moment the ban is implemented in practice.

7.1.4 Technical Effectiveness

This criterion describes the effectiveness or certainty of the strategy in reducing emissions. A technically effective strategy implies that if the strategy can be properly implemented, the reduction in air pollutant emissions is almost certain. Strategies such as emissions standards, fuel switch, fuel quality can all be technically effective to reduce air pollution. On the other hand, strategies such as discouraging driving, encouraging walking etc. may not always be effective in reducing emissions, since it is uncertain as to how much of the population will voluntarily follow these strategies.

7.1.5 Implementation Effectiveness

This criterion refers to the effectiveness of the policy as implemented. A strategy can be technically perfect to reduce emissions, yet it may have many barriers during implementation. These barriers can include political unwillingness, possibilities of collusion, corruption among regulatory officials, lack of resources in monitoring and enforcement, etc. Since all of these barriers are largely present in Bangladesh, implementation effectiveness is of utmost importance. There is no point in suggesting an excellent policy which cannot be properly implemented, say, due to corruption. Although this document does not specifically look into governance (corruption) issues, some strategies can be more prone to corruption than others (e.g. in-use vehicle emissions testing can be more prone than import of emissions certified vehicles).

7.1.6 Costs

This item reflects roughly the total costs to the economy, and includes costs to the users, businesses and the government. No specific cost calculations were undertaken, and the item refers to qualitative judgment only. A more detailed costs and benefits analysis should be undertaken for each of the measures before the policy can be considered for implementation.

7.1.7 Co-benefits and GHG Mitigation

Most of the strategies discussed can have significant co-benefits (or, in a few cases, possible harmful impacts). While, primarily GHG benefits are considered, references have been made to other benefits as well, e.g., reduced congestion, reduced noise, land development, etc. Co-benefits are an important criterion because of the cost efficiency of the strategy can be enhanced manifold once the co-benefits are significant and considered. A prime example is mass rapid transit. An MRT is a very expensive undertaking to improve air quality, but it generates large economic benefits through enhancing productivity.

Integrating air quality strategy and GHG mitigation policies in order to combat climate change has become increasingly important in the environmental policy arena. There are many strategies that have beneficial impacts on both local air quality and climate change (Mazzi and Dowlatabadi 2007, Bollen et al. 2010, Hammingh et al. 2010) and it is important to have the holistic view as much as possible. Such a holistic approach is beyond the scope of current work. Quantification of GHG benefits of the AQ strategies was not possible due to lack of information, however, it is also important to note that most of the air pollution control strategies discussed here generate GHG benefits (exceptions clearly mentioned).

7.2 Candidate Strategies

A multi-criteria assessment table has been created with the candidate strategies to control air pollution in Bangladesh, which is presented in Table 7.1. Based on the above mentioned criteria and a stakeholders' discussion, these strategies are further prioritized in section 7.3.

Table 7.1 Summary of emissions control strategies considered

Control options	Applicable area	Likely impact	Time to: Introduce / benefits	Effective: technical/ implement	Cost	Co-benefits	Requirements for success (other than regulations)	Comments (including comments from stakeholders, abbreviated SH)
MOTOR VEHICLES								
Stringent emissions standards	All new and in use imported vehicles	High	Short/ Long	Good/ Good	Low	Some GHG benefits	Emissions testing and monitoring capacity	Emissions certificate prior to import- can overcome the lack of capacity here Since Bangladesh only imports vehicles, emissions standard can simply lag by only 3 to 5 years of Japan/EU standard, with negligible cost to the economy.
Differentiated emissions standards	All in use vehicles	High	Medium/ Short	Good/ Low	Medium		Emissions testing and monitoring capacity Good governance	Differential taxes based on emissions performance As lack of emissions testing capacity, age based vehicle tax can be a good substitute
Diesel switch to CNG	All diesel vehicles in cities	High	Short to medium/ Short	Good/ Moderate	Low	Possibly GHG benefits	Further price difference with CNG	Uninterrupted CNG supply can be challenging Poor conversion poses safety risk & more GHG May raise corrupt practices of registering vehicles in smaller cities
Discourage diesel as motor fuel	Fuel distributors	Medium	Short/ Short to Medium	Good/ Moderate	Low	GHG benefits	Increasing the price of diesel to reflect its health costs Good governance	Diesel for agricultural use needs to be subsidized Differentiation of agriculture and motor diesel could be difficult
Biofuel/ethanol blend	All vehicles	Low	Long/ Long	Not clear/ Not clear	High	Long term impact not clear		Not practical for Bangladesh due to unavailability of agricultural land Government is against biofuel due to its perceived impact on food prices and food security
Retrofit diesel engines with oxidizing catalytic converters	All diesel vehicles	Low	Short/ Short	Low/ Moderate to Low	Low	NO2 increases, black carbon decreases	Good governance for inspection and maintenance	Not very effective in removing particulates, filters are better
Retrofit diesel engines with particulate filters	All Euro III or higher diesel vehicles in cities	High	Short/ Short	Moderate/ Moderate to Low	Low	Some GHG benefits	Certification of the filters Good governance for inspection and maintenance Low sulphur fuel	One time installation may not be useful, if not maintained, Needs low sulphur fuel May not work in Bangladesh (SH)

Control options	Applicable area	Likely impact	Time to: Introduce / benefits	Effective: technical/ implement	Cost	Co-benefits	Requirements for success (other than regulations)	Comments (including comments from stakeholders, abbreviated SH)
Cleaner fuel	Refineries, import entities	Small to Medium	Short/ Short	Medium/ Good	Medium	SO_2 reduction Black carbon reduction	Government mandate, transport and storage system	Works best with better technology Most particulates are carbonaceous, not sulphurous, so impact will not be large (SH)
Inspection and maintenance of existing vehicles	All vehicles, Diesel truck, bus priority	Large	Medium/ Medium	High/ Low to Moderate	Low	Some GHG benefits	Strong governance Capacity	Effectiveness can vary depending on governance. Most cost efficient (SH) Especially target highly polluting ones
Emissions based registration fees	All vehicles	Medium	Medium/ Long	High/ Low	Medium	GHG benefits	Strong testing and monitoring capability Good governance	Effectiveness can vary depend on governance, at the moment looks like effectiveness will be low Age based registration fee can be an option
Enforcement of ban on 20 year old commercial vehicles	Large cities	Large	Short/ Short	High/ Low	Low	GHG benefits, Noise reduction	Strong government will Good enforcement	Possibly the most cost effective solution
Ban on commercial vehicles older than 15 years	Large cities	Medium to large	Medium/ Short	High/ Low	Low	GHG benefits, noise reduction	Strong government will Good enforcement	Can be implemented only after 5-10 years after the 20 year ban has been implemented
Electric vehicles	All vehicles in large cities	Very high	Medium/ Long	Good/ Good	High	Unclear GHG impacts	Infrastructure, power supply, Appropriate incentives	Will put pressure on the already critical electricity supply situation Coal-based electricity supply can have adverse impacts Battery disposal is an issue Some battery electric vehicles already in use Not recommended in short term (SH)
Electric motor cycles	All new motor cycles	Medium	Short/ Long	Good/ Good	High	Unclear GHG benefits	Infrastructure, power supply Appropriate incentives Technical capacity in repair and maintenance	Will put pressure on the already critical electricity supply situation Coal-based electricity supply can have adverse impacts Battery disposal is an issue Not recommended (SH)
Hybrid vehicles	All vehicles in large cities	High	Short/ Long	Good/ Good	High, but lower than EV	GHG benefits,	Appropriate incentives Technical capacity in repair and maintenance	Import tariffs for hybrids are low already, but no hybrid vehicles in use Not recommended (SH)

Control options	Applicable area	Likely impact	Time to: Introduce / benefits	Effective: technical/ implement	Cost	Co-benefits	Requirements for success (other than regulations)	Comments (including comments from stakeholders, abbreviated SH)
Traffic flow management	Urban	Small to Medium	Long/ Short	Low to Medium/ Moderate	Medium	GHG benefits Travel time benefits	Technical capacity in flow management	Current super-saturated flow situation is nearly impossible to manage with traditional approaches, without substantial investment in infrastructure oppotunities are limited
Odd/even vehicle days	Large cities	Small to Medium	Medium/ Short	Medium to High/ Moderate	Large costs of foregone trips	GHG, travel time benefits	Good governance Good public transport system	Buses are generally exempt, which are among the most polluting Easy to beat the system Not recommended (SH)
Improve public transport	Large cities	Large, especially in long term	Long/ Short	High/ Moderate	Low, because of other benefits	GHG, travel time, economic benefits	Mass rapid transit, Bus rapid transit, walking facilities, etc. Large capital investment	Switch from personal cars to public transport is unclear High priority (SH)
Discourage vehicle use	Large cities	Small to Medium	Short/ Medium	Low/ Moderate	Low	Some GHG benefits	Increase costs of vehicle use, e.g. parking restrictions, parking fees, large fuel prices	If alternatives not available, it will not work
Encourage walking	Large cities	Small	Medium/ Medium	Low/ Low	Very low	GHG, health benefits	Good infrastructure, safety	Could increase exposure to those walking and adverse health impacts!
BRICK KILNS								
Ban on upwind location	Whole country, esp. large cities	Very Large	Short/ Short	High/ Moderate to High	Low		Development of wind maps near cities and towns	Since there already is a ban on FCKs, new kilns will be installed anyway – enforce locations Monitoring easy Some equity of exposure issues
Cleaner technology	Whole country	Very Large	Medium/ Medium	High/ High	Medium		Training on construction and operation of new kiln types	Already ban on FCKs (high cost) Provision of incentives for cleaner kilns, would be more suitable in the long run Monitoring relatively easy
Ban on clusters	Whole country	Very Large	Medium/ Short	Medium/ Moderate	Medium		Good governance Monitoring	Monitoring is easy, especially with satellite based pictures Outright ban is always expensive to the economy
Clusters based on technology or emissions	Whole country	Large	Medium/ Short	Medium/ Moderate	Medium		Regulations Good governance	Management and monitoring could be complicated Similar to air shed management (SH)

Control options	Applicable area	Likely impact	Time to: Introduce / benefits	Effective: technical/ implement	Cost	Co-benefits	Requirements for success (other than regulations)	Comments (including comments from stakeholders, abbreviated SH)
Retrofitting new technology	Whole country	Very Large	Short	Medium to High/ Low	Low		Emissions testing and monitoring facilities Good governance	Current ban on FCK makes it redundant
Cleaner coal	Import authority	Medium	Short/ Short	High/ Moderate	Medium	Some GHG benefits	Strong government will Quick testing facilities Good governance	Larger import tariff for larger impurities in coal Government could not uphold a previous ban on high sulphur coal Also useful for power plants
Alternate construction material	Whole country	Small to Large (depends on what material)	Long/ Short	Low to Medium/ Moderate	Medium	GHG benefits	Research and commercialization of some alternates	Good examples include pressed brick, sun dried brick with treatment, etc., requires R&D Concrete blocks require R&D as cement used in these blocks has adverse AQ impacts and large scale deployment can backfire
POWER SECTOR								
Adequate power supply	Whole country	Small to Medium	Medium to Long/ Short	High/ High		Large economic benefits	Government will Large capital & operating cost	Will reduce diesel use for agriculture use and allow increasing the price of diesel, with further benefit
Emissions standards for diesel generators	New generators	Small to Medium	Short/ Medium to Long	High/ Moderate	Low	GHG benefits	Emissions testing and monitoring facilities	Indian reports mention large benefits Diesel generators emit closer to people
Inspection & maintenance of diesel generators	In-use generators	Small to Medium	Short to Medium/ Short	High/ Moderate to Low	Low		Annual certification for fitness Emissions testing and monitoring facilities Good governance	Indian reports mention large benefits Diesel generators emit closer to people
Emissions based feed in tariff	All power plants	Small to medium	Medium/ Medium	Moderate/ Moderate to Low	Low		Emissions testing and monitoring capacity	Due to the lack of capacity, during a transition period, the tariff can be based on technology and fuel (type and quality), rather than on direct measurement.
Emissions standards	All new power plants, phase in for older plants too	Medium	Medium/ Short	High/ Moderate to High	Low		Emissions testing and monitoring capacity Good governance	Effective reduction of any subsidies based on emissions performance can be used as an incentives If compliance is ensured, better than technology mandates, below

Control options	Applicable area	Likely impact	Time to: Introduce / benefits	Effective: technical/ implement	Cost	Co-benefits	Requirements for success (other than regulations)	Comments (including comments from stakeholders, abbreviated SH)
Technology specification	All new coal & oil based plants	Small to Medium	Short/ Short	High/ High	Low		Good governance to ensure proper maintenance	Technologies include dry or wet scrubbers, electrostatic precipitators, fabric filters, cyclone separators, preprocessing, flue gas desulphurization, catalytic or non-catalytic reduction etc.
Ban on upstream location	All new coal & oil based plants	Small	Short/ Short	High/ High	Low		Development of wind maps near cities	Since all new plants, easy to implement Monitoring easy
OTHER INDUSTRIES								
Particulate control technology	Especially steel & cement	Small to medium	Medium/ Short	Moderate	Medium		Good governance	After treatment devices, such as bag filter, especially for steel mills, cement and glass factories
Physical shifting of industries	Large cities	Medium	Long/ Short	High/ Low	Low to Medium	Land develop. Benefits	Alternative locations Good infrastructure Strong government will	Equity is an issue, since pollution exposure will be transferred to others Comprehensive land use plan for current locations will recover the costs
Banning new industries with emissions in degraded air sheds	Large city limits	Medium	Medium/ Long	High/ Moderate	Low		Strong government will Alternative locations Good infrastructure	Equity is an issue
Enforcement of emissions standards	Large cities	Small	Medium/ Short	High/ Low	Low		Emissions testing and monitoring Good governance	Some of the standards are failry dated, require modification
Industrial emissions standards	Large cities	Medium	Medium/ Short	High/ Low	Low		Emissions testing and monitoring capacity Good governance	Standards need to be defined and updated where not defined
DUST SOURCES								
Better construction practices	Constructio n sector-sites + transport	Medium	Medium/ Short	Low to Medium/ Low	Low		Good governance Awareness building	REHAB can take some responsibility of monitoring Construction safety still could not be established, highly unlikely construction practices for air pollution can be implemented
Construction ambient standards	Constructio n sites	Medium	Medium/ Short	Medium to High/ Low	Low to medium		Ambient monitoring	Links well with DoE's airshed management for brick kilns

Control options	Applicable area	Likely impact	Time to: Introduce / benefits	Effective: technical/ implement	Cost	Co-benefits	Requirements for success (other than regulations)	Comments (including comments from stakeholders, abbreviated SH)
Paving unpaved roads	All urban roads	Small	Short/ Short	High/ Moderate	Low to medium			No data on roads In large cities, large roads are already fully paved
Timely road maintenance	All urban paved roads	Medium	Short/ Short	Medium/ Moderate	Low	Travel convenience	Good MIS	Quick repair of potholes just after monsoon can
Regular sweeping and watering	All urban paved roads	Small to Medium	Short/ Short	Medium/ Low	Low			Water flashing through pressurized prays of water is more effective than manual brushing, as now.
Landscaping and gardening	Large cities	Small	Short/ Short	Medium/ Moderate	Low	Pleasant	Adequate maintenance	
INDOOR SOURCES								
Domestic fuel switch - Gas	Urban slums	Large	Short/ Short	High/ High	Low		Moderate subsidies Utilize co-operatives	Does not add to costs significantly. Large benefits.
Domestic fuel switch	Rural areas	Medium	Medium/ Short	Medium/ Moderate	Medium		Possible subsidies	
Improved cooking stoves (ICS)	Rural areas	Large	Medium/ Short	High/ Moderate to Low	Medium		Social mobilization, supply chain development	Lack of awareness regarding IAP. Involvement of community, especially women is important for success.
OPEN BURNING								
Ban open burning of refuse	City areas, winter only	Small to medium	Medium/ Short	High/ Low	Medium	GHG benefits	Good enforcement	Too many small sources. Implementation of the ban very difficult.
Awareness on open burning	Whole country	Small to medium	Medium/ Medium to Long	Medium/ Moderate	Low	Awareness in general	Good, savvy campaigns	Should be cheaper than implementation of a ban.
Ban slash and burn practices	Primarily hilly areas	Small, locally large	Medium/ Short	High/ Low	Low	GHG benefits	Good enforcement	There already is a ban on deforestation and slash and burn practices, enforcement is important. Local impact only.
Ban open asphalt processing	Large cities	Small, local	Medium/ Short	High/ High	Low			Local impacts only

7.3 Recommended Strategies

Clearly, there are various tradeoffs involved among the various criteria for strategy choice in the previous section. In evaluating the tradeoffs between these criteria in reducing the emissions of a *particular* pollutant, 'technical effectiveness' and 'total impact' have been identified as the key criterion in this policy document. Although 'implementation effectiveness' is an equally, if not more, important criterion in order to ensure certainty in reduction, it includes issues such as good governance, which cannot be ensured through this policy documents and requires a much broader *system wide* changes. However, strategies deemed too prone to corrupt practices have been given lower priority. Table 7.1 and a description of the evaluation criteria have been presented in the stakeholders meeting held at the Department of Environment in January 2012 for initial comments. The chosen strategies applicable for Bangladesh reflect both the consultants and the stakeholders opinion, and are presented in Table 7.2 in detail.

In conjuntion with Table 7.1, the recommended control strategies of Table 7.2 are summarised in Fig. 7.1 in terms of their potential impact, time to impact and potential costs. Note that all these items are qualitative and have large uncertainties associated. Accordingly, the sizes of the bubbles, time to benefits and cost are all in ordinal (ranked) scale, rather than quantitative scale. The uncertainties in the cost dimension are particulary large in Fig. 7.1. In addition, cost-effectivness, i.e. cost per unit reduction of impact should be used whenever possible. However, determination of cost-effectiveness cannot be carried out unless extensive modelling is undertaken, which currently offers limited benefits due to the lack of input information. Thus Fig. 7.1 is for illustrative purposes only, although a similar version was initially used by the consultants to reduce the initially considered 50 strageies of Table 7.1 down to these 26 strategies. An updated, quantiative model-driven evaluation of strategies may change the relative location of some of these strategies, once more data become available.

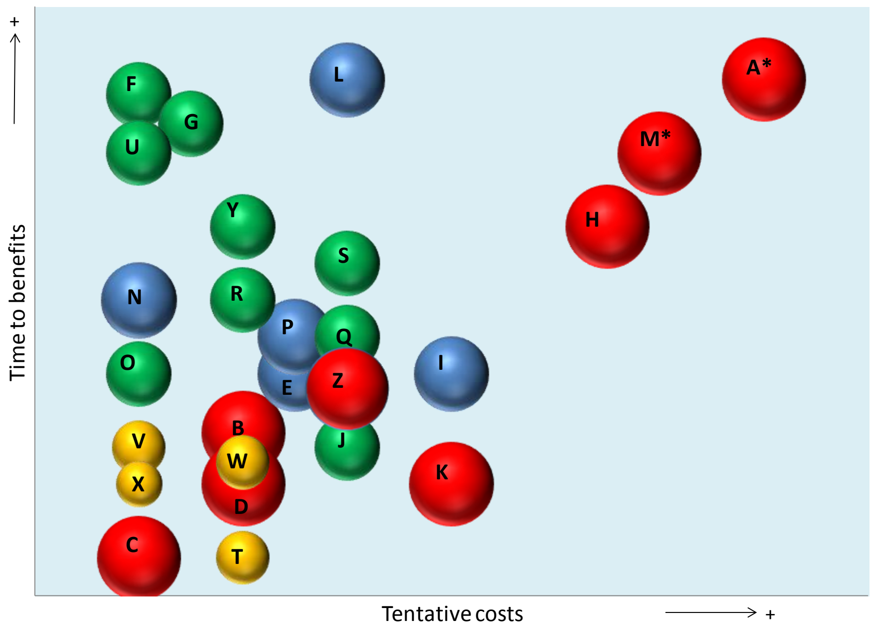

Fig. 7.1 Qualitative comparison of different strategies with respect to tentative costs, time to benefits realization and potential benefits. Bubble size reflects benefits – qualitatively; benefit code: Red ++++, Blue +++, Green ++, Yellow +. *very large co-benefits. A, B, C . . . in Table 7.2

Table 7.2 Proposed strategies to reduce air pollution from different sectors

Control Sectors		Strategy	Area of application	Priority	Detail about the strategy
A. TRANSPORT					
Vehicle use	A	Improve public transport	Large cities	High	Very large benefits in economic productivity through reduced travel time and reduced fuel bill. AQ may deteriorate during construction phases of mass rapid transits (same is true for expressways as well). Ideally, AQ improvements are co-benefits of transportation projects. Such benefits must be considered in appraisal of large transportation projects. Expressways alleviate the congestion and AQ in the short run, for longer term improvements in congestion and AQ, mass transits preferred.
Existing vehicles	B	Strengthen vehicle inspection and maintenance	All, especially large cities	High	Car fleet is mostly CNG driven now, so high emitters in the vehicle fleet are very important. I&M framework is already there (annual fitness certificates), only capacity building and enforcement are important now. I&M to be phased in, and initially target buses and trucks as they are the largest emitters currently. Centralized (but a few centres) test-only facilities running under the private sector with the government oversight is possibly the best way forward. Road site emissions testing is useful enforcement tool as well.
	C	Ban vehicles older than 20 years	Commercial vehicles, large cities	High	A ban is legally in place, but not enforced. Strict enforcement of the ban will be the most cost effective method to improve air quality immediately. It was shown during the World Cup Cricket in 2010 that strong Government will can enforce the ban when necessary. However, there are often conflict of interest between policy makers and transport workers lobby.
	D	Encourage Diesel to CNG switch through incentives	All diesel vehicles, especially commercial in large cities	High	There are pricing incentives already (but diesel to CNG price difference is not as large as petrol to CNG). Increasing diesel price is difficult since almost half of diesel is used in the agriculture sector. However, subsidizing CNG conversion equipments for diesel vehicles can be useful to reflect the lower price differential with diesel.
	E	Emissions based annual registration fees	All vehicles	Medium	Replace existing fixed annual registration fee by a variable registration fee directly linked to emissions. Since there is an immediate lack of capacity in emissions measurement from vehicles for regulatory purposes, vehicle age, engine size, fuel and manufacturer/ manufacturing country based registration fees are recommended for a transition period. Manufacturing country is important, since it has been argued that vehicles imported from certain countries deteriorate in their emissions performance much quicker than the Japanese ones. This strategy should be applied to all vehicles to encourage turnover of existing fleet. The fee structure must be designed to encourage vehicle substitution as they get older and should be directly linked to GDP growth rate.
New vehicles	F	Stringent emissions standards	All new vehicles	High	Current vehicle emissions standards are outdated. Emissions standards should be directly linked to EU/Japan standards but lagged by 3/5 years to reflect the import of reconditioned vehicles. Since Bangladesh does not produce any vehicles, the cost impact of the policy is negligible.

Control Sectors		Strategy	Area of application	Priority	Detail about the strategy
					Existing 'in-use' emissions standards should be replaced by existing 'new vehicles' standard while updating. Motorcycle emissions should be given special consideration, considering large volume.
	G	Emissions based import tariff	All new vehicles	Medium	It is already in place in a different form - based on engine size, instead the tariff should be restructured to be based on both engine size and emissions certification. Since the origin of vehicles also have a long run impact on emissions performance, tariff differentiation should include the country of origin as well (with lower tariffs for imports from the developed countries).
B. INDUSTRIES					
All industries	H	Comprehensive land use plan for industry locations	All industries, especially new ones	High	Highly polluting industries (e.g. Brick kilns, steel mills etc.) must not be located in an upstream location from large human habitats (cities and towns). Develop an exclusion zone for large cities based on wind rose, ban any new sources in that zone immediately, and relocate existing ones away from the zone in the long run. There is a ban in place (not enforced strongly) about not constructing brick kilns within 3 km of some human habitats, but the upstream ban will be more effective in reducing impacts. Especially apply to brick kilns since the FCK ban will force brick manufacturers to seek new locations for their new kilns. Also apply to all new power, cement and steel plants. A ban for any new highly polluting (brick, steel, glass, cement) industries within large city limits (irrespective of exclusion zones). Relocation of some of the highly polluting industries from city centers to downstream locations can have large land development benefits in the inner cities.
	I	Cluster management using air shed approach	Cluster of highly polluting industries	High	Clusters of highly polluting industries to be removed or properly managed. The cluster problems are most acute for brick kilns & steel mills near Dhaka & Chittagong, with brick most polluting. Any new set up in the clusters must be banned altogether. For existing clusters, ambient concentration standard must be set and monitored allowing owners within the cluster to work toward a common goal. A separate technology, fuel quality and emissions standards, more stringent than nationwide standards, should be set for clusters (e.g. FCK and ZK both can be banned in clusters). Regular inspection must take place in clusters. Impact of reducing emissions from clusters is larger than reducing emissions from one factory.
Brick kilns	J	Emissions based license fee	All kilns	High	Ban on FCKs is burdensome where air pollution is not a big issue, or where production volume is not large (so a ZK or HHK will never be profitable). Such a blanket ban can largely increase transport emissions. Even with the ban in place, emissions based fees should be introduced, but during a transition period, technology and production based licensing fee can be implemented. Technology based fees are easy to monitor as well. The fee structure should encourage substitution to cleaner kilns.
	K	Technology standards	All kilns	Medium	Already in place, FCKs now banned. Ideally, the ban should be replaced by approach 1 above.

Control Sectors		Strategy	Area of application	Priority	Detail about the strategy
	L	Alternate construction material	All country, especially large cites	Medium	Encourage R&D for sun dried and pressed brick, involve entrepreneurs in R&D. There can be foreign exchange savings. Concrete block making requires further R&D since cement is a polluting industry and large scale deployment to replace bricks can have an adverse impact, especially if brick kiln emissions can be reduced significantly through above strategies, concrete blocks could be more harmful.
Power industries	M	Ensure adequate power supply	-	High	Ensuring adequate, uninterrupted power supply for everyone would reduce the need for diesel generators in residential, industrial and commercial use and diesel irrigation pumps for agricultural use, eliminating the need for monitoring the numerous dispersed diesel generators. Adequate power supply also has a large economic benefit through increased productivity.
	N	Emissions standards	All new plants	High	Regardless of fuel types, all power plants should be subject to the same (strict) emissions standards, this creates a level playing field for environment friendly fuels.
	O	Emissions standard for diesel generators	All new generators	High	No standards in place now.
	P	Inspection & maintenance of diesel generators	All existing generators	High	Although it requires technical capacity in implementation, diesel generators emit close to people and often emissions get trapped in urban canyons with large health impacts.
Other industries	Q	Technology specification	Existing steel mills, cement and glass factories	High	Compulsory use of after treatment devices.
	R	Inspection and maintenance	Existing steel mills, cement and glass factories	High	Develop an efficient inspection and maintenance system.
	S	Emissions standards	All new and existing plants	High	Standard exists, but dated. Possibly new standards and enforcement.
C. FUEL					
Coal	T	Import control for quality of coal	Whole country, primarily brick and power industries	High	There has been a ban on high sulphur coal, which, in effect, has been overturned. Introducing the ban will reduce emissions from brick kilns and proposed new coal-based power plants. An impurity/sulphur content based tariff structure can be introduced to overcome the objections against an outright ban. Tariff structure must be high enough so that import and use of low-impurities coal is encouraged. Once the additional tariff is included, strict enforcement against deforestation is required as well. For brick industries, the tariff will also help development of alternates to brick. Ideally, high sulphur coal in remote areas should be allowed on cost effectiveness grounds, but enforcement of the use of low sulphur coal near dense areas (e.g. Dhaka) is very difficult.
D. DUST					
Construction	U	Better construction practices on site and during transportation	All construction sites	High	Develop a guideline for dust control in construction sites. Compulsory covering of trucks carrying sand, cement, soil and other bulk material. Involve REHAB and its members in self-enforcement.

Control Sectors		Strategy	Area of application	Priority	Detail about the strategy
	V	Air pollution mitigation plan and its enforcement	Large construction projects	Medium	Large construction projects such as new roads, elevated expressways and metro rail in large cities will be responsible for large dust (and other) emissions in near future, which must be addressed on a case by case basis through proper monitoring and enforcement by the regulator.
Road	W	Timely road maintenance and cleaning	All roads	High	Potholes are a major source of local dust and, if untreated, gets larger aggravating the dust problem and increasing the repair costs. Implementation of an asset management information system for quicker response to maintenance needs have dual benefits of reducing repair costs and dust emissions. Co-ordination between various government bodies regarding road excavation and repair required. Water flashing during winter months (can include private sector participation).
Land use	X	Landscaping and gardening	All exposed soil in urban areas	Medium	Can involve private sector participation.
E. INDOOR					
Fuel	Y	Encourage fuel switch	Urban slums and rural areas	High	Encourage switch to natural gas in urban slums and ensuring a continuous supply. Encourage high density pellets in rural areas through fiscal incentives.
Technology	Z	Improved cooking stoves (ICS)	Peri-urban and ural areas	High	Involve participation from NGOs who has better experience at community level. Potential for CDM to offset the initial high costs.

It is important to note that some of these strategies are complimentary to each other, while others are reasonable substitutes. For example, improving public transport and any vehicle based strategy are complimentary to each other. On the other hand, if a large scale conversion of diesel to CNG is carried out, the immediate benefits of vehicle I&M will be much less. Similarly, if adequate, reliable electricity supply can be ensured diesel generators will lose their significance, and an I&M strategy for diesel generators would be redundant. These inter-relationships among the policies must be considered during the final choice and implementation of the strategies by the policymakers.

The 26 options selected here have the largest total impact as described earlier in this chapter. There can however be significant local impacts of some of the local policies, e.g. enforcing ban on slash and burn can be beneficial in the hilly districts, but that has not been shortlisted since the impact on population is small because of the low population density in those areas.

Chapter 8
OTHER POLICY ISSUES

A successful air quality management regime requires various other tools to implement the strategies mentioned above. Although the purpose of this report is not to develop action plans of the strategies or to develop an air quality management system in the country, it is important to identify the other policy and implementation relevant aspects. This chapter describes these *necessary* parameters briefly.

8.1 Regulatory and Fiscal Reform

One of the major approaches in pollution control is to ensure the 'polluter pays' principle, which can be enforced efficiently through MBIs (economic incentives and disincentives). Although currently most of the policy approaches in Bangladesh is CAC, the success of CNG conversion is an excellent example of the success of MBIs. In the long run, the government should move away from CAC where it is feasible, toward restructuring the taxation framework to price pollution in all sectors of the economy (known as the green tax reform).

MBIs or green tax reform require excellent monitoring, enforcement capacity and good governance, which may be in short supply in Bangladesh (see later). During a transition period there can be some variants of the 'perfect MBIs' with lower capacity requirements in monitoring and enforcement which can still be implemented with reasonable success. These should be implemented as soon as possible, as these would also act as pilot programs and increase the capacity of the regulating and monitoring authority and also the polluters.

Another large problem in the fiscal and regulatory approaches to pollution control in the current system is the relatively low penalties for violation of an environmental rule or regulations. These low penalties are not enough of a deterrent to switch to an environmentally friendly behavior or technology. A larger penalty structure will be more visible and more effective (see Mexico I&M example). The penalties (or other fiscal incentives) should also be directly linked to real GDP growth rate, and reviewed every 5 years. In summary, the key points in regulatory and fiscal reforms are:

- Prioritization of strategies linked directly to impact (not emissions)
- Employment of a combination of CAC and MBI approaches, depending on suitability for specific sources
- In general, a gradual shift from CAC approaches to MBIs in the long run, with 'middle of the road' MBIs as pilot cases
- Tariffs/emission taxes/penalties for violation of a regulation set using economic principles to encourage behavior or technology changes and review regularly
- Regulatory capacity building and updating of laws, rules, regulations

8.2 Awareness and Motivation

Success in environmental policy implementation often critically depends on the awareness of the public of the adverse impacts of pollution and the participation of the media in building

awareness, as was evident from the lead removal and CNG conversion in Bangladesh. Participating firms and businesses should also be made aware of the adverse impacts of their pollution activities in addition to the fiscal incentives and penalties mentioned above.

Keys areas for awareness raising are:

- Raising awareness about adverse impacts of air pollution (including indoor air pollution), especially on public health.
- Raising awareness, both at individual and community levels, regarding regulations/options for control/reduction of air pollution (e.g., on locations of polluting industrial units, vehicular emission, smoking restrictions, benefits of improved cook stoves).
- Ensuring easy access to air quality monitoring data and disseminating data and other relevant awareness information.
- Especial emphasis on awareness among children in the school and teachers in order to build long term impact.

8.3 Research and Development

There are still large gaps in knowledge regarding air pollution in Bangladesh. However, in order for policy makers to make informed decisions to optimize the various strategy packages the importance of research and development cannot be underestimated. It is however, important, to focus on the priority impact areas and not to 'reinvent the wheel' (e.g. research demonstrating the health impacts of particulates is well documented everywhere in the world and does not need repetition; rather important is quantitative modeling of health impacts).

It is also important to have a central information repository system within the framework of DoE and/or MoEF, which would contain all research and policy reports (DoE/non DoE) and their background data (where available) as relevant to air quality. Especially, there have been a number of studies abroad, conducted by Bangladeshi researchers on air quality in Bangladesh. These can be a large source of important information. Important points with regard to research and development include:

- Identification of priority areas of research involving all stakeholders;
- Encouraging and supporting research initiatives for better understanding of emission sources, spatial and temporal variation of pollution, population exposure and health effects in major urban centers and other pollution hot-spots (e.g., industrial areas);
- Promoting research on development of options for control/ reduction of air pollution from major sources along with their health benefits and costs;
- Promoting research on indoor air pollution, including improved cookstove and alternative/ less polluting fuel for domestic use;
- Disseminating research findings and background research data widely in order to enhance co-operation among researchers.

8.4 Co-operation and coordination

Co-operation, coordination and collaboration among various government agencies other than DoE/MoEF, businesses, academia and stakeholders are all vital in improving the air quality and

quality of life. In particular it is important to interest the Ministry of Finance as that is where many of the big decisions affecting air pollution issues in the long run are made. Since there are different regulators and actors directly responsible for decisions that affect the air quality, proper co-operation in information sharing, coordination of the activities and collaboration toward achieving the same goal is necessary. It is also important that all government bodies take into consideration the impact on air pollution of their policies (e.g. an expressway) before a final decision is taken. The major points for attention are:

- Cooperation and coordination among research/ educational institutes, professional groups, international/ regional organizations involved in various activities related to air pollution.
- Cooperation among relevant Government, Non-Government Organizations, research/ educational institutes, donor agencies and international/ regional organizations.
- Cooperation among neighboring governments to tackle trans-boundary air pollution.
- Especially, coordination and co-operation among stakeholders on strategies which have multiple benefits across different sectors
- Development of a platform for information sharing among research institutes, professional bodies, governments and other stakeholders

8.5 Capacity Building and Knowledge Retention

While the research and development section above describes some capacity building, the previous section primarily deals with knowledge creation, while capacity building and knowledge retention refers to the capacity to utilize the knowledge. In addition to lack of information, a major limitation of introducing cost effective strategies (most MBIs) to control air pollution is the lack of capacity, both in qualitative and quantitative terms. Air pollution control is more technical than other regulatory and fiscal controls, and therefore capacity in all relevant sectors (regulators, policy makers, firms, media) is vital. Equally important to capacity building is the retention of capacity or knowledge. The following capacities are relevant in controlling air pollution in Bangladesh:

- Capacity in monitoring ambient air pollution in major cities and pollution hot-spots (e.g., industrial areas);
- Capacity of laboratories (e.g., in relevant educational institutions) in measurement/ monitoring of air quality;
- Capacity of relevant organizations/ professionals in developing/ updating emission inventory, air quality models;
- Capacity of relevant organizations/ professionals in assessing health impacts, costs of air pollution and policy design;
- Capacity to assess/ certify/ qualify cook stoves in an effort to reduce indoor air pollution;
- Capacity to retain knowledge and people among policy makers and firms.

8.6 Institutional Set up & Governance

Good governance and effective enforcement are of paramount importance in any regulatory environment, including pollution control. Almost all of the strategies can be susceptible to corrupt practices and lack of governance and enforcement can make even the best of the

strategies ineffective. Air pollution control is more technical than other regulatory and fiscal controls, and therefore capacity in all sectors is vital. The DoE should develop capacity in monitoring and enforcement, while firms and businesses should also develop capacity of monitoring and testing facilities.

- Coordination among relevant Government organizations on matters related to air pollution (MOEF/DoE, Ministry of Industries, Ministry of Communication, Ministry of Health).
- Effective collaboration (through a proper institutional arrangement) between DoE, BRTA, and Traffic Police with regard to vehicular inspection.
- Inclusion of air quality (as well as other environmental) and related public health issues in the planning and development of specialized industrial zones (e.g., EPZ), urban centers (e.g., new townships), and other major infrastructure (e.g., highways); coordination among relevant experts in this regard, e.g., urban/ industrial planners, environmental experts, social scientists.

Chapter 9
CONCLUSIONS

9.1 Revisiting the Tasks

Table 9.1 revisits the work breakdown structure for this project and describes the status in a structured form. As can be seen, the recommendations were generated following the stated tasks.

Table 9.1 Status of work breakdown structure

	Work breakdown	Status	Reference
1	Determine the current status of air pollution in Bangladesh, with emphasis on highly polluted cities	Extensive review completed	Chapter 2
2	Review of the emissions inventory by the DoE and make corrections, if necessary	Initial review revealed the inventory of year 2000 will not be relevant now. Year 2005 inventory not available. Consultants and stakeholders views incorporated.	Chapter 3
3	Based on 1 and 2, identify the key air pollutants that require action	Literature review, consultants and stakeholders view guided the choice	4.3
4	Review of international literature on air pollution control strategies (technologies) and their effectiveness from environmental and engineering perspective	Completed, with focus on vehicles and brick kilns as current technology landscape of other industries not known	7.2
5	Collect existing relevant air pollution strategies, policies, laws, standards and regulations in Bangladesh	Completed	Chapter 5
6	Review the evidence (based on published literature) of the impact of previous policies, strategies on air quality in Bangladesh and of potential co-benefits of strategies with respect to GHG emissions	Completed	Chapter 5
7	Collect government plans and projections on industrial and transport developments over the next few years, especially on coal based power plants, highways, public transportation and brick industries	Use of coal in power plants in future was the most important plan with respect to air quality	3.2.6
8	Review of international literature on policies and strategies to reduce air pollution and their effectiveness and economic efficiency	Completed, some case studies presented	6.2
9	Based on 5 to 8, identify the key control strategies for Bangladesh and potential policies to help implement the strategies	Completed	7.3
10	Incorporate feedback from stakeholders (responsibility of DoE) and update the report	Completed in January. Oral and written feedbacks incorporated within this document.	Various places
11	Preparation of the draft report	Completed	

9.2 Selected Strategies

Approximately 50 strategies were initially selected, of which 26 are finally recommended after evaluation of the strategies. The criteria for evaluation were likely impact, time to introduce, time to benefits, technical and implementation effectiveness, cost effectiveness and co-benefits. The recommended strategies are presented in detail in Table 7.2, which are reiterated briefly below in Table 9.2 (*not* in order of priority, for detail on the priority of the strategies, see Tables 7.1 and 7.2 and Fig. 7.1). Note that the choices were based on a qualitative evaluation of the criteria because of lack of information to perform a quantitative benefit-cost modeling, and every effort should be made by the government and the DoE to develop capacity on quantitative evaluation of the strategies. It is also strongly recommended that before final implementation of each of the strategies, it is quantitatively evaluated as much as possible by the existing data and capacity. It is also recommended to implement the strategies according to their impact and priority order.

Table 9.2 Recommended strategies for air pollution reduction in Bangladesh

	Strategy	Area of application
A	Improve public transport	Large cities
B	Strengthen vehicle inspection and maintenance	All, especially large cities
C	Ban vehicles older than 20 years	Commercial vehicles, large cities
D	Encourage Diesel to CNG switch through incentives	All diesel vehicles, esp. truck & buses in large cities
E	Emissions (age) based annual registration fees	All vehicles
F	Stringent emissions standards	All new vehicles
G	Emissions based import tariff	All new vehicles
H	Comprehensive land use plan for industry locations	All industries, especially new ones
I	Cluster management	Cluster of highly polluting industries
J	Emissions (technology and fuel) based license fee	All kilns
K	Technology standards	All kilns
L	Alternate construction material	All country, especially large cites
M	Ensure adequate power supply	All country
N	Emissions standards	All new plants
O	Emissions standard for diesel generators	All new generators
P	Inspection & maintenance of diesel generators	All existing generators
Q	Technology specification	Existing steel mills, cement and glass factories
R	Inspection and maintenance	Existing steel mills, cement and glass factories
S	Emissions standards	All new and existing plants
T	Import control for quality of coal	Whole country, primarily brick and power industries
U	Better construction practices on site & during transport	All construction sites
V	Air pollution mitigation plan and its enforcement	Large construction projects
W	Timely road maintenance	All roads
X	Landscaping and gardening	All exposed soil in urban areas
Y	Encourage fuel switch	Urban slums and rural areas
Z	Improved cooking stoves	Peri-urban and Rural areas

9.3 Other Issues

In order to facilitate the implementation of the strategies mentioned above, there are other necessary components which must be addressed. A description of these points is presented earlier in Chapter 8, but a selection of the headline points are presented below:

1. Regulatory and fiscal reform to enable effective implementation of the strategies;
2. Awareness and motivation about air pollution across sectors;
3. Research and development to address the knowledge and information gaps so that future strategies can be based on quantitative modeling and assessments;
4. Co-operation and coordination among various stakeholders, from regulators to businesses to the general public;
5. Capacity building and knowledge retention;
6. Institutional reform to ensure coordination and governance.

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Bangladesh Air Quality and Emission Standards

রেজিস্টার্ড নং ডি এ-১

বাংলাদেশ গেজেট

অতিরিক্ত সংখ্যা

কর্তৃপক্ষ কর্তৃক প্রকাশিত

মঙ্গলবার, জুলাই ১৯, ২০০৫

গণপ্রজাতন্ত্রী বাংলাদেশ সরকার

পরিবেশ ও বন মন্ত্রণালয়

পরিকল্পনা শাখা-৫

প্রজ্ঞাপন

তারিখ, ১ শ্রাবণ ১৪১২/১৬ জুলাই ২০০৫

এস, আর, ও নং ২২০-আইন/২০০৫—বাংলাদেশ পরিবেশ সংরক্ষণ আইন, ১৯৯৫ (১৯৯৫ সনের ১ নং আইন) এর ধারা ২০ এ প্রদত্ত ক্ষমতাবলে সরকার পরিবেশ সংরক্ষণ বিধিমালা, ১৯৯৭ এর নিম্নরূপ সংশোধন করিল, যথা ঃ—

উপরি-উক্ত বিধিমালার—

(ক) তফসিল ২ এর পরিবর্তে নিম্নরূপ তফসিল ২ প্রতিস্থাপিত হইবে, যথা ঃ—

"তফসিল-২

বায়ুর মানমাত্রা (Air Quality Standards)*

[বিধি ১২ দ্রষ্টব্য]

বায়ু দুষণ	মানমাত্রা	গড় সময়
১	২	৩
কার্বন মনোঅক্সাইড	১০ মিলিগ্রাম/ঘনমিটার (৯ পিপিএম) [ক]	৮ ঘন্টা
	৪০ মিলিগ্রাম/ঘনমিটার (৩৫ পিপিএম) [ক]	১ ঘন্টা
লেড	০.৫ মাইক্রোগ্রাম/ঘনমিটার	বার্ষিক

মূল্য ঃ টাকা ৪.০০

১	২	৩
নাইট্রোজেনের অক্সাইড	১০০ মাইক্রোগ্রাম/ঘনমিটার (০.০৫৩ পিপিএম)	বার্ষিক
প্রলম্বিত বস্তুকণা (এস পি এম)	২০০ মাইক্রোগ্রাম/ঘনমিটার	৮ ঘন্টা
বস্তুকণা ১০	৫০ মাইক্রোগ্রাম/ ঘনমিটার [খ]	বার্ষিক
	১৫০ মাইক্রোগ্রাম/ ঘনমিটার [গ]	২৪ ঘন্টা
বস্তুকণা ২.৫	১৫ মাইক্রোগ্রাম/ ঘনমিটার	বার্ষিক
	৬৫ মাইক্রোগ্রাম/ ঘনমিটার	২৪ ঘন্টা
ওজোন	২৩৫ মাইক্রোগ্রাম/ঘনমিটার (০.১২ পিপিএম) [ঘ]	১ ঘন্টা
	১৫৭ মাইক্রোগ্রাম/ঘনমিটার (০.০৮ পিপিএম)	৮ ঘন্টা
সালফার ডাইঅক্সাইড	৮০ মাইক্রোগ্রাম/ঘনমিটার (০.০৩ পিপিএম)	বার্ষিক
	৩৬৫ মাইক্রোগ্রাম/ঘনমিটার (০.১৪ পিপিএম) [ক]	২৪ ঘন্টা

শব্দ সংক্ষেপ ঃ

পিপিএম ঃ পার্টস পার মিলিয়ন।

নোট ঃ * এই তফসিলে বায়ুর মানমাত্রা বলিতে পরিবেষ্টক বায়ুর মানমাত্রা (Ambient Air Quality Standards) কে বুঝাইবে।

(ক) প্রতি বৎসরে একবারের বেশী অতিক্রম করিবে না।

(খ) বার্ষিক গড় মান ৫০ মাইক্রোগ্রাম/মি^{৩} হইতে কম বা উহার সমান হইতে পারিবে।

(গ) ২৪ ঘন্টার গড় মান বৎসরে ১ (এক) দিন ১৫০ মাইক্রোগ্রাম/ মি^{৩} হইতে কম বা উহার সমান হইতে পারিবে।

(ঘ) প্রতি ঘন্টার সর্বোচ্চ গড় মান বৎসরে ১ (এক) দিন ০.১২ পিপিএম হইতে কম বা উহার সমান হইতে পারিবে।

(খ) তফসিল ৬ এর পরিবর্তে নিম্নরূপ তফসিল ৬ প্রতিস্থাপিত হইবে, যথা ঃ—

"তফসিল-৬

[বিধি ৪ এবং ১২ দ্রষ্টব্য]

অংশ-ক

(রেজিস্ট্রেশনের জন্য আবেদনের সময় ডিজেল ইঞ্জিনচালিত মোটরযানের নিঃসরণ মানমাত্রা)

বাংলাদেশ-১ (টেবিল-১)

মোটরযানের ধরণ	নিঃসরণ মানমাত্রা (গ্রাম/কি.মি.)			পরীক্ষণ পদ্ধতি
	কার্বন মনো অক্সাইড	হাইড্রোকার্বন + নাইট্রোজেনের অক্সাইডসমূহ	বস্তুকণা	
১	২	৩	৪	৫
হালকা (চালক ব্যতীত ৮ আসনের বেশী নয় এবং সর্বোচ্চ ওজন ২.৫ টন পর্যন্ত)				
নতুন টাইপ এপ্রোভাল (টি এ)	২.৭২	০.৯৭	০.১৪	৯১/৪৪১/ইইসি
কনফরমিটি অফ প্রোডাকশন (সিওপি)	৩.১৬	১.১৩	০.১৮	
আমদানীতব্য ব্যবহৃত	৩.১৬	১.১৩	০.১৮	
মাঝারী (চালক ব্যতীত ৮ আসনের বেশী কিন্তু ১৫ আসনের বেশী নয় এবং সর্বোচ্চ ওজন ২.৫ টনের অধিক কিন্তু ৩.৫ টন পর্যন্ত)				
নতুন টিএ	৬.৯	১.৭	০.২৫	৯৩/৫৯/ইসি
সিওপি	৮.০	২.০	০.২৯	
আমদানীতব্য ব্যবহৃত	৮.০	২.০	০.২৯	

বাংলাদেশ-১ (টেবিল-২)

মোটরযানের ধরণ	নিঃসরণ মানমাত্রা (গ্রাম/কিলোওয়াট-ঘন্টা)				পরীক্ষণ পদ্ধতি
	কার্বন মনো অক্সাইড	হাইড্রোকার্বন	নাইট্রোজেনের অক্সাইডসমূহ	বস্তুকণা*	
ভারী (চালক ব্যতীত ১৫ আসনের বেশী এবং ওজন ৩.৫ টনের অধিক)					
নতুন টিএ	৪.৫	১.১	৮.০	০.৩৬	৯১/৫৪২/ইইসি এবং ইসিই আর ৪৯.০২
নতুন সিওপি	৪.৯	১.২৩	৯.০	০.৪	
আমদানীতব্য ব্যবহৃত	৪.৯	১.২৩	৯.০	০.৪	

* ৮৫ কিলোওয়াট অথবা উহা হইতে কম শক্তির ডিজেলচালিত ইঞ্জিনের ক্ষেত্রে এই মাত্রা ১.৭ গুন হারে বৃদ্ধি পাইবে।

শব্দ সংক্ষেপঃ

কি মিঃ কিলোমিটার
ইসি ঃ ইউরোপিয়ান কাউন্সিল
টিএ ঃ টাইপ এপ্রোভাল
সিওপিঃ কনফরমিটি অফ প্রোডাকশন
ইইসিঃ ইউরোপিয়ান ইকোনমিক কমুনিটি
ইসিইঃ ইকোনমিক কমিশন ফর ইউরোপ

অংশ-খ

(রেজিস্ট্রেশনের জন্য আবেদনের সময় পেট্রোল ও গ্যাস ইঞ্জিনচালিত মোটরযানের নিঃসরণ মানমাত্রা)

বাংলাদেশ-২ (টেবিল-১)

মোটরযানের ধরণ	নিঃসরণ মানমাত্রা (গ্রাম/কি.মি.)		বাষ্পজনিত নিঃসরণ (গ্রাম/টেস্ট)	পরীক্ষণ পদ্ধতি
	কার্বন মনো অক্সাইড	হাইড্রোকার্বন+ নাইট্রোজেনের অক্সাইডসমূহ		
১	২	৩	৪	৫
(দুই ও তিন চাকাবিশিস্ট) চার স্টোক	৪.৫	৩.০	-	ইসিই-৪০
হালকা (চালক ব্যতীত ৮ আসনের বেশী নয় এবং সর্বোচ্চ ওজন ২.৫ টন পর্যন্ত)	২.২	০.৫	২.০	৯৪/১২/ইসি
মাঝারী (চালক ব্যতীত ৮ আসনের বেশী কিন্তু ১৫ আসনের বেশী নয় এবং সর্বোচ্চ ওজন ২.৫ টনের অধিক কিন্তু ৩.৫ টন পর্যন্ত)	৫.০	০.৭	২.০	৯৬/৬৯/ইসি

বাংলাদেশ-২ (টেবিল-২)

মোটরযানের ধরণ	নিঃসরণ মানমাত্রা (গ্রাম/কিলোওয়াট-ঘন্টা)			বাষ্পজনিত নিঃসরণ (গ্রাম/টেস্ট)	পরীক্ষণ পদ্ধতি
	কার্বন মনোঅক্সাইড	হাইড্রোকার্বন/ নন-মিথেন হাইড্রোকার্বন*	নাইট্রোজেনের অক্সাইডসমূহ		
ভারী (চালক ব্যতীত ১৫ আসনের বেশী এবং ওজন ৩.৫ টনের অধিক)					৯১/৫৪২ ইইসি এবং ইসিই আর ৪৯.০২ এবং *১৩-মুড টেস্ট সাইকেল
নতুন টিএ (পেট্রোল/ সিএনজি)	৪.৫	১.১	৮.০	২.০	
নতুন সিওপি(পেট্রোল/ সিএনজি)	৪.৯	১.২৩	৯.০	২.০	
আমদানীতব্য ব্যবহৃত (পেট্রোল/ সিএনজি)	৪.৯	১.২৩	৯.০	২.০	

* সিএনজিচালিত মোটরযানের ক্ষেত্রে প্রযোজ্য হইবে।

শব্দ সংক্ষেপ ঃ

কি মি ঃ কিলোমিটার
ইসি ঃ ইউরোপিয়ান কাউন্সিল
টিএ ঃ টাইপ এপ্রোভাল
সিওপি ঃ কনফরমিটি অফ প্রোডাকশন
ইইসি ঃ ইউরোপিয়ান ইকোনমিক কমুনিটি
ইসিই ঃ ইকোনমিক কমিশন ফর ইউরোপ
সিএনজি ঃ কমপ্রেস্‌ড ন্যাচারাল গ্যাস

অংশ-গ

(রেজিস্ট্রেশনের প্রাক্কালে অংশ-ক এবং অংশ-খ তে উল্লিখিত মানমাত্রা পরিমাপের পরীক্ষণ পদ্ধতি)

মোটরযানের ধরণ	স্থিতি মাপ	নিঃসরণ মানমাত্রা
১	২	৩
অন্যূন তিন চাকাবিশিষ্ট পেট্রোল ও সিএনজিচালিত যান	আইডল (Idle) কার্বন মনোঅক্সাইড আইডল (Idle) হাইড্রোকার্বন	০.৫% আয়তন/আয়তন ১২০০ পিপিএম
	বোঝাবিহীন (No Load)— ২৫০০ থেকে ৩০০০ আরপিএম কার্বন মনোঅক্সাইড হাইড্রোকার্বন ল্যামডা	০.৩% আয়তন/আয়তন ৩০০ পিপিএম ১±০.০৩
	ভিজুয়াল পরীক্ষা	নির্গমন পথে যুক্ত থ্রি-ওয়ে-ক্যাটালাইটিক কনভার্টার
ডিজেল ন্যাচারালি অ্যাসপিরেটেড	ফ্রি অ্যাক্সিলারেশন স্মোক (Free acceleration smoke)	১.২ মি.$^{-১}$ ধোঁয়ার ঘনত্ব (৪০ এইচএসইউ)
ডিজেল টার্বোচার্জড	ফ্রি অ্যাক্সিলারেশন স্মোক (Free acceleration smoke)	২.২ মি.$^{-১}$ ধোঁয়ার ঘনত্ব (৬১ এইচএসইউ)

শব্দ সংক্ষেপ ঃ

পিপিএম ঃ পার্টস পার মিলিয়ন

আরপিএম ঃ রিভোলিউশন পার মিনিট

মি $^{-১}$ ঃ মিটার $^{-১}$

এইচএসইউ ঃ হার্টরিজ স্মোক ইউনিট

অংশ-ঘ

[১লা সেপ্টেম্বর ২০০৪ এর পূর্বে রেজিস্ট্রেশনকৃত ডিজেলচালিত মোটরযান (In-use diesel driven vehicles) এর নিঃসরণ মানমাত্রা]

মোটরযানের ধরণ	পরীক্ষা	স্মোক অপাসিটি (Smoke opacity)		
		কার্যকর ১ সেপ্টেম্বর ২০০৪ ৩১ ডিসেম্বর ২০০৬	কার্যকর ১ জানুয়ারী ২০০৭ ৩১ ডিসেম্বর ২০০৮	কার্যকর ১ জানুয়ারী ২০০৯
বাস	ফ্রি অ্যাক্সিলারেশন (Free acceleration)	৮০ এইচএসইউ অথবা ৩.৭ মি.$^{-১}$	৭০ এইচএসইউ অথবা ২.৮ মি.$^{-১}$	৬৫ এইচএসইউ অথবা ২.৪ মি.$^{-১}$
ট্রাক এবং অন্যান্য ডিজেলচালিত যান	ফ্রি অ্যাক্সিলারেশন (Free acceleration)	৯০ এইচএসইউ অথবা ৫.৩ মি.$^{-১}$	৮০ এইচএসইউ অথবা ৩.৭ মি.$^{-১}$	৬৫ এইচএসইউ অথবা ২.৪ মি.$^{-১}$

অংশ-ঙ

(১লা সেপ্টেম্বর ২০০৪ এর পূর্বে রেজিস্ট্রেশনকৃত পেট্রোল এবং সিএনজিচালিত মোটরযান এর নিঃসরণ মানমাত্রা)

মোটরযানের ধরণ	পরীক্ষা	কার্বন মনোঅক্সাইড (% আয়তন)	হাইড্রোকার্বন (পিপিএম)
১	২	৩	৪
চার চাকাবিশিষ্ট পেট্রোলচালিত যান	আইডল স্পীড (Idle speed)	৪.৫	১,২০০
সিএনজিচালিত সকল যান	আইডল স্পীড (Idle speed)	৩.০	-
পেট্রোলচালিত দুই স্ট্রোকবিশিষ্ট ২ এবং ৩ চাকার যান	আইডল স্পীড (Idle speed)	৭.০	১২,০০০
পেট্রোলচালিত দুই স্ট্রোকবিশিষ্ট ২ এবং ৩ চাকার যান	আইডল স্পীড (Idle speed)	৭.০	৩,০০০

নোট ঃ আইডল স্পিড (Idle speed) আরপিএম প্রস্তুতকারক কর্তৃক নির্ধারিত হইবে।

অংশ-চ

(১লা সেপ্টেম্বর ২০০৪ এর পর রেজিস্ট্রেশনকৃত মোটরযানের নিঃসরণ মানমাত্রা)

মোটরযানের ধরণ	পরীক্ষা	কার্বন মনোঅক্সাইড (%আয়তন)	হাইড্রোকার্বন (পিপিএম)	ল্যামডা (λ)	ধোঁয়া
১	২	৩	৪	৫	৬
চার চাকাবিশিষ্ট পেট্রোল ও সিএনজি চালিত যান	আইডল স্পীল (Idle speed)	১.০	১২০০	-	-
	বোঝাবিহীন (No-load)- ২৫০০ থেকে ৩০০০ আরপিএম	০.৫	৩০০	১.০± ০.০৩	-
দুই ও তিন চাকা বিশিষ্ট চার স্ট্রোক পেট্রোলচালিত যান	আইডল স্পীল (Idle speed)	৪.৫	১২০০	-	-
তিন চাকাবিশিষ্ট সিএনজিচালিত যান	আইডল স্পীল (Idle speed)	৩.০	-	-	-

১	২	৩	৪	৫	৬
ন্যাচারলি অ্যাসপিরেটেড ডিজেল চালিত যান	ফ্রি অ্যাক্সিলারেশন (Free acceleration)	-		-	৬৫এইচ এসইউ বা ২.৪ মি.$^{-১}$
টার্বোচার্জযুক্ত ডিজেল চালিত যান	ফ্রি অ্যাক্সিলারেশন (Free acceleration)	-	-	-	৭২এইচ এসইউ বা ৩.০ মি.$^{-১}$

নোট ঃ আইডল স্পিড (Idle speed) আরপিএম প্রস্তুতকারক কর্তৃক নির্ধারিত হইবে"।

রাষ্ট্রপতির আদেশক্রমে

জাফর আহমেদ চৌধুরী
সচিব।

মোঃ নূর-নবী (উপ-সচিব), উপ-নিয়ন্ত্রক, বাংলাদেশ সরকারী মুদ্রণালয়, ঢাকা কর্তৃক মুদ্রিত।
মোঃ আমিন জুবেরী আলম, উপ-নিয়ন্ত্রক, বাংলাদেশ ফরম ও প্রকাশনা অফিস, তেজগাঁও, ঢাকা কর্তৃক প্রকাশিত।