Scoping Study for South Asia Air Pollution

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Creating Innovative Solutions For A Sustainable Future

ENERGY AGRICULTURE ENVIRONMENT HABITAT RESOURCE SECURITY CLIMATE HEALTH & NUTRITION

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Executive Summary

Urban air pollution is one of the major problems affecting public health and the environment, responsible for more than five million deaths in South Asia in 2012. Air pollution exposure is the second most important risk factor for ill health in South Asia, contributing up to 22% of all deaths. 51% of 1.4 billion people of South Asia are exposed to $PM_{2.5}$ concentrations exceeding the World Health Organization's Interim Target.

Apart from its effect on human health, air pollution has a range of effects on economic growth and prosperity. These include loss in agricultural productivity, climate effects, adverse effects on tourism. Air pollution disproportionately affects the poor and women in low and middle-income countries. Several of the sources and impacts of air pollution transcend political boundaries, adding to the complexity of managing the problem.

DFID has commissioned a scoping study to address key knowledge and policy gaps around air pollution issues in South Asia. TERI was selected to undertake this study in four South Asian countries, namely, India, Nepal, Pakistan, and Bangladesh. The main aim of the scoping study is to assess the current state of evidence of air pollution in these countries and identify the research gaps and priority areas at country level and regional-scale.

State of Evidence: Causes of air pollution

The levels of air pollutants in the atmosphere result from emissions from a wide range of sources, combined with long-range transport of pollutants from further afield, and complex atmospheric processes. Air quality modelling studies are used to understand these issues. A particular problem affecting South Asia is an atmospheric brown haze, consisting of sulfates, nitrates, organics, black carbon, fly ash and other pollutants. Biomass burning, rapid industrialization and urbanization are primarily responsible for this haze. Biomass burning is particularly widespread for cooking in rural areas of Bangladesh. It is also common practice to burn refuse in the open.

Dust from construction and vehicle movements is a major problem in urban areas during the dry seasons (winter, spring, late autumn). Air quality is also adversely affected by transportation of pollutants from other countries. This issue is particularly acute in relation to agricultural stubble burning, as this takes place in the adjacent provinces of Punjab in Pakistan and Punjab in India. Consequently, stubble burning in India affects air quality in Pakistan, and vice versa. Other sources of air pollution also contribute to trans-boundary air pollution issues.

Source apportionment studies show that the contribution from fossil fuel combustion to urban pollution in India was between 22% and 70%. Biomass combustion was responsible for 9% to 31% of urban air pollution. In residential areas, re-suspension of dust was responsible for up to half of fine particulate matter (PM_{10}). A similar pattern was observed for Bangladesh and Pakistan, with a higher contribution from biomass in some areas. Ambient concentrations of fine particulate matter in Lahore were found to be among the highest recorded anywhere in the world. Measured levels of PM_{10} and $PM_{2.5}$ in Bangladesh are well above the national standard. Levels of PM_{10} in India are higher still, but marginally lower in Nepal. In contrast, levels of sulfur dioxide appear to be higher in Bangladesh.

The public perception survey carried out in this project suggest that there is not much difference in top five major sources of pollutants in different south Asian countries. Road dust was identified as an important source of ambient air pollution in all four countries.

State of Evidence: Development Impacts

Air pollution is a major threat to public health; scientific research has established an association between airborne particulate matter (PM_{10} and $PM_{2.5}$), VOCs, oxides of sulphur (SO_x), oxides of nitrogen (NO_x), ozone, and carbon monoxide (CO) and their adverse health effects, especially on respiratory and cardiovascular diseases. The most vulnerable people are persons with pre-existing respiratory conditions, pregnant women, outdoor workers, children and the elderly, and people exercising outdoors.

Deaths due to outdoor air pollution are increasing. Deaths attributable to household air pollution in South Asia have remained high and relatively stable with only a modest increase from 1.1 million to 1.2 million between 1990 and 2015. The shortening of life due to air pollution has a disproportionate effect in South Asia because of the high levels of $PM_{2.5}$ in the region. Alongside mortalities, air pollution increases the incidence of ill health, with associated treatment costs, and reduces the productivity of healthy workers, as well as affecting economic growth and tourism. Air pollution is affecting tourist inflow in South Asian cities and figures among the top concerns that tourists face while traveling to this part of the world. Travel agencies and tour operators say that Delhi's foreign tourist inflow has gone down by 25-30% in recent years due to air pollution. Agricultural production on the one side contributes to the air pollution, while on the other it is also affected from air pollution. Agriculture is the largest contributor of atmospheric ammonia. Emissions of nitrogen oxides and volatile organic compounds react to form ground-level ozone in the atmosphere which, together with other pollutants, has direct and indirect effects on agriculture and natural vegetation. At the global level, ozone was estimated to result in up to 16% loss of soy, wheat and maize. Wheat yields in India in 2010 were found to be to 36% lower than they otherwise would have been due to climate change and pollutant emissions.

The total cost of air pollution in India is estimated to be 4.5% to 7.7% of GDP, with costs expected to more than double by 2060. In Pakistan, the direct cost of health damage linked with outdoor air pollution is estimated to be 6% of GDP.

State of Evidence: Solutions

Bangladesh: The primary legislation instituted to mitigate air pollution is the 1995 Bangladesh Environmental Conservation Act (ECA) and the 1997 Environmental

Conservation Rules. There are specific policies and rules applying to key sources in Bangladesh. A project to use Compressed Natural Gas (CNG) in vehicles instead of gasoline is under way. One possible constraint on adequate enforcement is the low level of maximum fine specified in the 1995 ECA (10 lac taka).

The sale of leaded fuel in Bangladesh came to an end in 1999. The use of two-stroke three-wheelers in Dhaka was banned in 2003, along with restrictions on older buses and trucks in order to improve air quality in the city. A strategy to take two-stroke engine vehicles and old vehicles off the roads is in progress. Other initiatives relate to public engagement and improving urban transportation. Bangladesh is a signatory to the Malé Declaration on Control and Prevention of Air Pollution, and to a range of other international treaties. The "polluter pays" principle is being progressively enforced, but the use of fiscal measures requires excellent monitoring, enforcement capacity and good governance. The Air Pollution Reduction Strategy highlights a number of capacity constraints for controlling air pollution, including insufficient monitoring, laboratory, inventory compilation, health impact assessment, and stove certification resources. Pollution reduction strategies in Bangladesh are based on qualitative multi-criteria evaluation because of lack of information for quantitative benefit-cost modelling.

India: The government of India has taken several initiatives for control of pollution in India, focusing on transportation, domestic, energy production, industrial and agriculture sources. The first air quality remediation plan was formulated in 2006-07, covering 17 cities. The aim of the action plan was to identify and implement a least- cost package of measures to improve air quality, such that the marginal costs equal the marginal benefits. After formulation of remediation plan, a comprehensive environmental pollution index was launched by CPCB in 2009. This enabled almost 50% of industrial areas to be identified as "critically polluted".

Nepal: The government has introduced a range of policies, legislation and standards related to air pollution. However, these have not been followed up with comprehensive plans and programmes, and updates to the ambient air quality standards are required. Prevention and control of pollution are reflected in the Environment Protection Act and Environment Protection Regulations (1997). Climate Change Policy 2011 was aimed at moving to a low carbon development path, which would provide co-benefits for reducing the air pollution. The National Sustainable Transport Strategy NSTS emphasizes the development of a transport system that includes environmental objectives. The Industrial Policy 2011 aims to promote the use of modern technology and environment friendly and sustainable production processes, but requires financial and technical support to enable industries to adopt environment friendly and energy saving technologies. The Industrial Enterprises Act 2013 sets a framework for industry licensing. Finally, the Rural Energy Policy 2006 and Re Energy Subsidy Policy 2016 are designed to provide access to clean, reliable and appropriate energy in rural areas.

Pakistan: Pakistan's performance in achieving or even moving towards effective air quality management is minimal and lags behind other regional countries. The Pakistan Environmental Protection Act (PEPA) requires all effluents to comply with the standards set in the NEQS, with sanctions depending on the nature and extent of any violation. As described above, the Pollution Charges Rule was not effective in using economic instruments to mitigate air pollution emissions, because of a lack of support from Government and unwillingness to publish information on emissions. Province level agencies now responsible for air quality management require capacity improvement to enable plans and policies to be developed.

Legal and institutional context

All four countries of the South Asia have their indigenous ambient air quality standards and governmental policies in place to control the ambient air pollution of the country.
Bangladesh: National Ambient Air Quality Standards were first specified in 1995, and laid down in the Environment Conservation Rules of 1997. The standards for [articulate Matter (PM_{10}, $PM_{2.5}$), nitrogen dioxide, sulfur dioxide, carbon monoxide and ozone are almost the same as the ambient air quality standards set by US EPA and by WHO.

Industrial emissions standards have been set out by Department of Environment, with specific controls on brick kilns. Vehicle emission standards were implemented from the Year 2005, and are in line with Euro 2 limits for light duty vehicles and Euro 1 for heavy duty vehicles. Emissions limits for motorcycles are common to other South and South-East Asian countries. Limited testing is specified.

India: The guidelines for air quality monitoring were developed under the Air (Prevention and Control of Pollution) Act 1982, Environment (Protection) Act 1986, and the Environment (Protection) Rules 1986. In 2009, the Revised National Ambient Air Quality Standards were published setting uniform air quality standards for all locations and widening the range of air pollutants.

The legal basis for emission standards is the Air (Prevention and Control of Pollution) Act, 1981, and the Environment (Protection) Act, 1986. Industries are monitored for adherence to emissions standards, and are also required to monitor ambient air quality within their premises. industries are prioritized into four categories for identifying the extent of emissions monitoring. Vehicle emissions are tested to a limited extent under the Pollution Under Control Program. Vehicles are required to be tested four times a year in Delhi, but twice a year in most other states. Emission standards for diesel generators have also been specified. A program of improving domestic cooking stoves has been implemented since 1985.

Nepal: National Ambient Air Quality Standards were introduced in 2003 and updated in 2012. These standards are generally less demanding than the WHO Guidelines. There are no annual standards for particulate matter TSP and PM_{10}.

Emission limits for brick kilns have been applied since 2008, with controls on cement and crusher industries, industrial boilers and diesel generators since 2012. A chimney height calculation for industrial stacks is also required. The Government applied vehicle emissions standards in 2000, and these standards require updating to match neighbouring countries. Standards for biomass stoves have been in place since 2016.

Pakistan: National Environmental Quality Standards (NEQS) for ambient air were specified in 2010. Following devolution of authority to province level, the environmental acts notified by the provinces state that emission of effluent, waste, air pollutants, or noise pollutants exceeding standards of the NEQS are offences of the Acts. Pakistan tightened its ambient air quality standards in 2010 and in 2013, but these remain relatively less stringent.

National Environmental Quality Standards for emissions have been applied since 1993. Since 1997, emissions controls have been applied under the Pakistan Environmental Protection Act (PEPA), which sets out sanctions for failure to comply with the standards. These standards are now set at a regional level. The Pollution Charges Rule was introduced in 2001 as a mechanism to ensure participatory approach from industries and other stakeholders. However, this initiative was not successful after devolution of environmental matters to provinces in 2010.

Organisational map

Bangladesh: The Ministry of Environment and Forest deals with environmental issues and concerns with national directors for air quality management, reporting to the Director-General. There are 21 district offices. The government of Bangladesh launched the Air Quality Management Project in 2000 with assistance of World Bank, and has continued under the name Clean Air and Sustainable Energy (CASE). From 2002, PM_{10}, $PM_{2.5}$, oxides of nitrogen, carbon monoxide, sulfur dioxide, ozone and hydrocarbons have been monitored at 11 locations in Bangladesh.

India has a federal governmental structure. The Ministry of Environment, Forests and Climate Change is responsible for India's environmental and forestry policies and programmes. This ministry, with the Central and State Pollution Control Boards, form the regulatory and administrative core, while other ministries and bodies are also involved in promoting air quality management. In addition, a network of government and nongovernmental institutions is involved in monitoring, reporting, and carrying out air quality studies. The present ambient monitoring programme in India was established in 1967, and later launched as the National Air Quality Monitoring Programme. The network was expanded from 28 monitoring stations in 1985 to 731 operating stations, including 131 continuous monitoring stations in 69 cities. Sulphur dioxide, oxides of nitrogen, PM_{10} and $PM_{2.5}$, together with meteorological parameters, are measured at all the locations. CPCB co-ordinates with other agencies to ensure the uniformity and consistency of air quality data, but measurements should nevertheless be considered as indicative rather than absolute. Other substances included in the network are carbon monoxide, ammonia, lead, hydrogen sulfide and polycyclic aromatic hydrocarbons.

Nepal has had a federal government structure since 2015 and hence the institutional framework is in transition. The Ministry of Forests and Environment promulgates policies and measures to control air quality, and the Department of Environment is responsible for the implementation of these policies. The Environmental Pollution Control and Monitoring Section monitor policy implementation and air quality status.

Routine air quality monitoring is only available from six permanent stations in the Kathmandu Valley area. These stations measure particulate matter (TSP, PM_{10} and $PM_{2.5}$), carbon monoxide, nitrogen dioxide, sulfur dioxide and benzene. In 2013, the Ministry resumed monitoring of PM_{10} at three of the stations, and measurements of $PM_{2.5}$ are being made at 14 stations around the country.

Pakistan: The Environmental Protection Agency is the principal environmental regulatory agency, managed by the Ministry of Environment. From 2010, Provincial Environmental Protection Departments became focal points for implementation of the environmental regulations within each of the four provinces, with responsibility for air quality monitoring. The first air monitoring project was launched in 2006 with fixed and mobile air monitoring stations in five major cities. The project ended in 2012; however, due to smog issues, air monitoring has recently restarted in Lahore.

The public perception survey carried out for this project suggests that the most important policies for improving air quality are improving public awareness, enhancing public transport, and implementing a clean air strategy. Respondents did not consider that improving in-use vehicular inspection systems and congestion pricing would be effective in improving air quality. More than 70% of survey respondents would be ready to pay extra, if this were required for specific policies.

Research gaps and priority areas

The key knowledge and policy gaps identified in this study are:

- Limited knowledge of sectorial and geographical (including trans-boundary) contribution to ambient air quality, resulting in actions based on perception rather than actual contributions. The air quality management plans developed in the cities of the four countries are generally not based on scientific source apportionment studies and hence do not result in optimal, cost effective reduction in pollutant concentrations.
- Lack of intra country and inter country knowledge exchange coordination and collaboration of different institutions to improve air quality. There are examples of successful strategies which have led to some reduction of air pollution in the region, however, there is no mechanism in place for knowledge transfer and exchange for faster learning and improvement.
- Lack of regional scale inter-governmental assessments and planning. There are some studies to understand urban sources , but regional sources have not yet been fully understood. City level studies have suggested background contributions due to trans-boundary movement of pollution and hence regional scale studies and controls are required for effective control.
- Limitations of capacities in the regulatory bodies: financial, manpower, skills. Capacities in the regulatory bodies like pollution control authorities are limited in comparison to the scale and extent of the problem. Strengthening of capacities is a pre-requisite for adequate enforcement of environmental standards and laws in the four countries.

- Lack of enforcement mainly due to insufficient technical or resource capacity. Due to limitations of capacities, the existing laws are not being adequately enforced which lead to unaccounted emissions and hence deterioration of air quality.
- Limited industrial emission standards (especially for gaseous pollutants). There are several categories of industries where PM is still being controlled, but there are no standards for gaseous pollutants, which remain unattended and react in atmosphere to form secondary pollutants (also particles).
- Absence of controls on fugitive sources of ammonia and organic compounds. There are presently very limited regulation on releases of ammonia and organic compounds. These pollutants are themselves toxic and also produce secondary pollutants and hence also need to be regulated.
- Lack of integrated assessment of policies, action plan and projects to develop regional action plan. Sectoral/city level policies are decided in silos and integrated assessments are lacking for effective control. Regional scale integrated assessment can lead to improved efficiencies and reduced pollution levels.
- Air pollution is the least priority issue of the political parties of the region, this leads to lesser allocation of budget towards addressing issues related to air pollution. Enhanced awareness , sensitisation and capacity building can lead to more demand for better air quality and in turn can lead to more action and controls.
- Limited public awareness on air pollution issues due to inadequate information dissemination and absence of air quality forecasting framework. Except in India to some extent, there is almost no framework for forecasting and dissemination of air quality information in the region. This is essential for emergency response planning and short term control.

Recommendations

Regional:

1. It is important to understand trans-boundary pollutant dispersion through monitoring and modelling. This kind of studies typically takes 2 to 3 years in collaboration with different country partners, as they require seasonal monitoring and repetition of monitoring for data validation.
2. Develop an intergovernmental regional collaborative committee to provide guidance, technical assistance and training to key stakeholders to prepare and implement national programs that can successfully address regional air pollution issue.

3. International co-operation to reduce transboundary pollution, under the auspices of an existing body such as UNESCAP or Malé Declaration

Country Specific:

Nepal

1. It is important to setup air quality monitoring stations across all provinces in Nepal as majority of monitoring stations are set up in and around Kathmandu only.
2. Prepare national or city-scale "bottom-up" emission inventories (i.e. inventories based on reports and estimates of activity and associated emissions). For example, such inventories would assemble data on sources including traffic movements, energy use, and industrial/agricultural production combined with appropriate emission factors to provide estimated emissions at a national or city level, and with geographical breakdown to the best available resolution.

Bangladesh

1. Undertake source apportionment studies using detailed air quality models, and develop to provide analyses of future trends and assessment of potential air quality improvement options, to support Air Quality Strategy and policy development at a national and city level.
2. Undertake studies on various intervention options along with cost-benefit analysis to assess the optimum solutions for air quality improvement.
3. Traffic is a major problem in Bangladesh, especially in major cities like Dhaka, hence, there is a need for improvement in public transportation by the use of mass rapid transport etc.

India

1. Modelling based studies on intervention and control options to assess the no-risk and low-risk control options for improving air quality
2. Pilot projects for improving air quality using newer technologies for reducing emissions from various sources like industries, biomass burning, power plants, etc.
3. Setting up of state-of-the-art laboratories for standardised protocols and calibrations of equipment to obtain comparable results as there are a number of studies conducted in India, however, there results are not comparable.

Pakistan

1. There is a clear priority to reinstate a working air quality monitoring network with robust QA/QC and data management. The province of Punjab will be the focus of a large investment in this area from the World Bank but the other provinces also require support. To focus further still, Karachi would be

recommended for investment with regard to air pollution monitoring followed by Peshawar and Hyderabad based on their population size.

2. The devolution of air quality responsibilities from national to state authorities in Pakistan has led to a weakening in air quality expertise and oversight. It is therefore recommended to review existing arrangements in detail and propose an improved institutional framework for Pakistan to include: strengthening of all provincial EPAs to improve their monitoring, enforcement, and planning capacities, and improve coordination mechanisms between provincial and national EPAs; identifying options for a central body with a clear mandate for AQM, and with responsibilities for intersectoral and intergovernmental coordination and collaboration; review and recommend improvements to existing clean air relevant policy and regulatory frameworks. It is possible that coordination with the World Bank Punjab project would provide valuable opportunity for cross province knowledge sharing and a template for other provinces to follows.

Chapter 1

Background

Urban air pollution is one of the major problems affecting public health and the environment around the globe. Owing to urbanisation and fast-paced development, the problem is complex and severe in both developing and developed countries, particularly in terms of health impacts. It has been reported that the majority of the air-pollution related health burden has been on low- and middle-income countries in the South-East Asia and Western Pacific Regions. In the year 2012, more than five million deaths were caused by indoor and outdoor air pollution in South Asian countries in a year. Of the top 30 cities in the world with the poorest air quality in 2016-17 are in South Asia. The causes and impacts of air pollution transcend boundaries. The "brown cloud" is a phenomenon captured in satellite images of atmospheric haze over land mass. Similarly, $PM_{2.5}$ particles and other air pollutants can travel long distances and generate impacts far away from the source areas. As evidence of this, the World Health Organisation (WHO) found that despite reductions in emissions levels of air pollutants across Europe, premature deaths from air pollution in Europe will fall only marginally over the next 15 years, in part due to transboundary pollution originating outside Europe (WHO, 2006).

The Indian Sub-continent, also known as South Asia, refers to the group of countries which lie on the Indian tectonic Plate. These include India, Pakistan, Bangladesh, Nepal, Bhutan, Sri Lanka and Maldives. These countries together cover an area of about 4.4 million km^2 (1.7 million mi^2), which is 10% of the Asian continent or 3.3% of the world's land surface area. The Indian sub-continent accounts for more than forty percent of Asia's population and one-fourth of the world's population. 51% of the Indian sub-continent's 1.4 billion people are exposed to $PM_{2.5}$ concentrations exceeding the Interim Target as given by WHO *i.e.* 35 $\mu g\ m^{-3}$. Further, the South Asian countries are among the top regions following the Northern and Southern China region in terms of average urban $PM_{2.5}$ concentrations (**Error! Reference source not found.**). They are developing at a fast pace, however; the air quality management in these South Asian countries has not developed at a similar pace to meet the evolving challenges of increasing air pollution, thus creating an imbalance.

Air pollution exposure is the second most important risk factor for ill health in South Asia, contributing to between 13% and 21.7% of all deaths and approximately 58 million disability adjusted life years (DALYs) through chronic and acute respiratory and cardiovascular illnesses (CAA, 2016). Estimates of the costs of the health effects from exposure to $PM_{2.5}$ in ambient and household environment in Asian and Pacific countries in 2016 is estimated at $1.76 trillion in 2016, equivalent to 10% of the region's GDP (GBD, 2016). The poor are more vulnerable to the health impacts of air pollution due to lack of access to medical care and ways to mitigate exposure such as masks and air purifiers. Women in low and middle-income countries are also more at risk due to exposure to household air pollution from polluting and unhealthy home energy sources. Studies show that increased ozone pollution is also destroying millions of tons of crops in North India, as ground-level ozone enters leaves and damages plant metabolism.

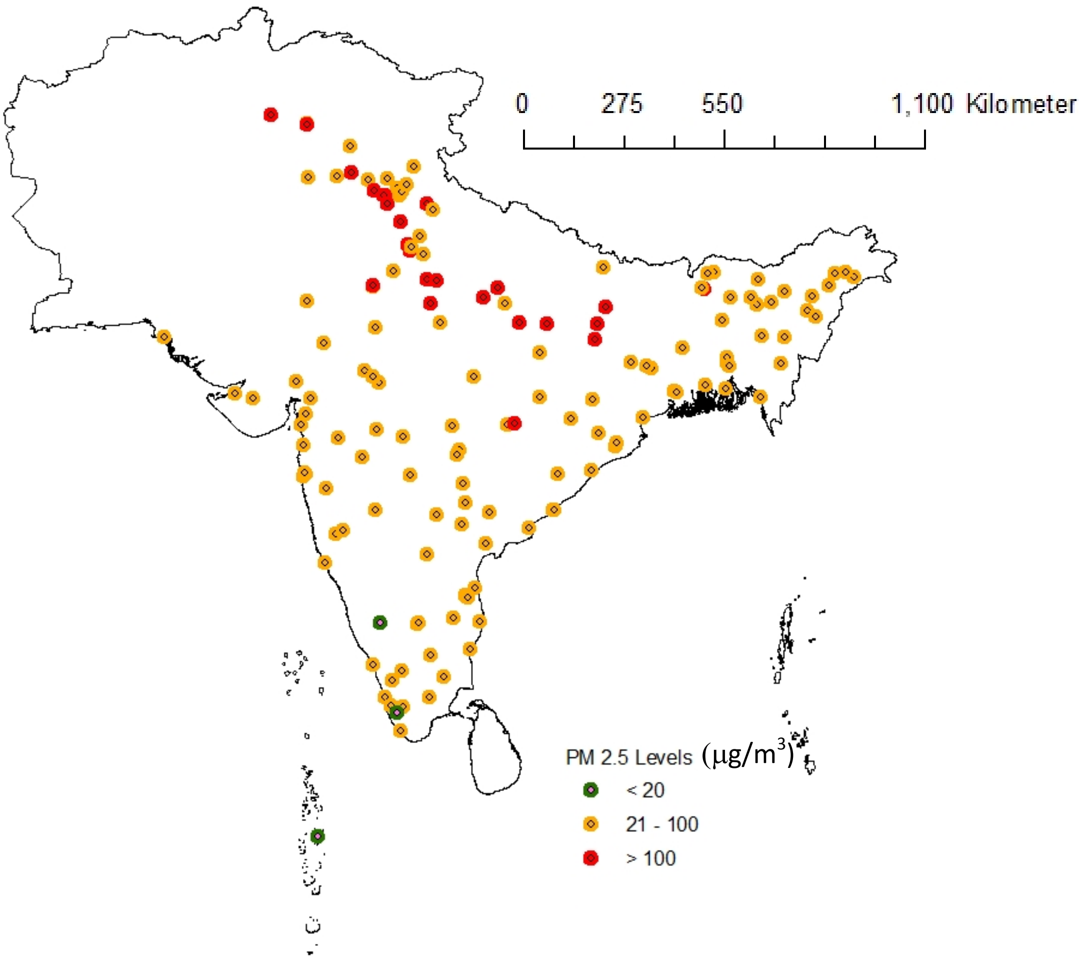


Figure 1 Annual average ambient $PM_{2.5}$ concentrations in different cities of South Asia (Source: WHO Global Ambient Air Quality Database, 2018)

South Asia has one of the highest concentrations of black carbon emissions from cars and trucks, cooking stoves, and industrial facilities. In addition to their effect on health, black carbon particles have short lived local climate effects with a possible impact on local precipitation patterns and on the Himalayan glacier system, which threatens water resources in the region. There is however significant heterogeneity within the region around sources of ambient air pollution. The split between localized and trans-boundary sources also varies by geography and socio-economic context. For example, in Bangladesh, relatively localized sources like brick kilns and motorized transport contribute to the base pollution load throughout the year while transboundary transport of particulate matter across the Indo-Gangetic Plain airshed contributes to higher levels of $PM_{2.5}$ in winter (Begum et al., 2007). In many parts of South Asia, air quality is impacted by conventional electricity generation and other causes (industries, brick-kilns, transportation, construction works etc.). Some of the solutions which may need to be considered include optimal dispatching of conventional power plants with emission control, compliant power generation technology, electric or hybrid electric vehicles, energy efficiency and use of zero-emissions renewable technologies where possible etc.

Tackling air pollution is dependent on economic development pathways and there are potential co-benefits. Industrialization, urbanisation and increased energy consumption are major drivers. Biomass burning and other intensified agricultural production practices are also major contributors in South Asia. Investments in air pollution abatement can potentially offer no-regrets options to boost economic development (through cost savings from energy efficient technologies, improved transportation systems, enhanced urban facilities, reduced health costs and improved overall productivity of workforce as a result of reduction in the number of DALYs) as well as mitigate climate change (several air pollutants such as ozone and hydrofluorocarbons also contribute to global warming).

Against the above context, DFID has commissioned a regional research piece to address key knowledge and policy gaps around air pollution issues in South Asia. TERI was selected to undertake a scoping study in four South Asian countries, namely, India, Nepal, Pakistan, and Bangladesh. The main aim of the scoping study is to assess the current state of evidence of air pollution in these countries and identify the research gaps and priority areas at country level and regional-scale.

Objectives

This scoping study has strived to achieve the following set of objectives;

- An analysis of the current state of the evidence of air pollution in four countries in South Asia, namely, India, Bangladesh, Nepal and Pakistan
- The implications for development at a country and regional level
- Mapping of the institutions and networks involved, including major programmes supported by bilateral/multilateral agencies
- Identification of research gaps and priority areas of research at country level.

TERI is leading the scoping study in the region. The UK partner, Ricardo Energy and Environment, is leading the study in Pakistan and Bangladesh. Three institutions from each of the countries have been involved as local partners for facilitating the research and stakeholder consultations with various policy makers and academic institutes within each of the countries. The lead and collaborating institutions for each of the countries are given below:

Country	Lead Institution	Collaborating Institutions
India	TERI	
Nepal	TERI	Tribhuvan University
Pakistan	Ricardo Energy & Environment	SDPI
Bangladesh	Ricardo Energy & Environment	NACOM, TERI

A systematic literature search has been carried out for each of the four countries which are the focus of this study. The publications relevant to South Asia on a regional basis have been investigated in detail. The research organisations, academic institutes, policy makers, and programmes funded through bilateral and multilateral agencies for air pollution in South Asia have been mapped to identify current research and policy interventions being implemented. Some of these organisations were prioritized for consultation to understand the regional and local-scale problems, knowledge gaps and potential solutions. The current state of data, systems and scientific understanding of air quality in South Asia has been discussed with the consultees. Consultees have been asked to identify knowledge gaps, and highlight what they see as priorities for future investment, to deliver additional information and resources which are needed to deliver the necessary air quality improvements across the region.

Chapter 2

State of Evidence

This report presents the findings of the scoping study of air pollution management in four South Asian countries: India, Pakistan, Bangladesh and Nepal. The study has analysed the causes responsible for the problem of air pollution at a country level and regional level through monitored data and published literature. Systematic literature search has been carried out for published literature for each of the four countries. Source apportionment studies have been referred for identification of different sources and their contribution to the ambient pollution. Air pollution has both direct and indirect effects on the economic growth and prosperity. Indirect effects on economic growth include health impacts on individuals due to exposure, loss in agricultural productivity, and climate change, whereas, direct effects include economic activities like tourism, etc. Evidence has been collected on impact of air pollution on both direct and indirect economic impacts by literature survey (where available), reports and data from governmental agencies.

Modelling Studies

Various studies have been conducted in all the four countries regarding the assessment of air quality, major sources contributing to the pollution loads and associated impacts on health, environment and economy. Pollutant formation in atmosphere is an outcome of complex processes involving characteristics of emissions sources, physical processes like diffusion, advection, deposition, etc. and chemical reactions. In order to derive correct emissions control strategies, it is important to accurately simulate pollutant concentrations in a region under different growth scenarios by using air quality models. Hence, air quality modelling is important not only for prediction of pollutant concentrations but also for apportionment of contributing sources, which leads to development of emissions control strategies. While some primary pollutants released from various sources are more or less inert and hence modelling of their ambient concentrations is simpler, the secondary pollutants formed in the atmosphere by reactions of different primary ones, are complex, considering their high reactivity with other pollutants, and meteorological conditions. The concentrations of these pollutants depend on pre-cursor specie emissions, chemical reactivity, and other meteorological influences like temperature, relative humidity (RH), wind speed and direction. Broadly, three approaches have been used employed to model pollutant concentrations - deterministic, statistical and physical. The selection of approach depends upon the objectives of the study. Deterministic air quality models are based on the science of physical and chemical processes, which are employed in the models in the forms of equations to predict ambient pollutant concentrations. These models use source emissions inventories and meteorological variables as inputs. The basic principle of these models is derived from the mass balance approach. The models are used for several purposes, ranging from source apportionment studies to impact assessments for regulatory purposes. Statistical models are very different from deterministic ones, as they are used for predicting future pollutant concentrations based on past data of ambient pollutant concentrations. These past data are used to develop appropriate empirical statistical relationships. The models learn from past data and are then used for generating short term real-time forecasts. These models are also used for providing early warnings. The third category of models is physical models which are used to simulate real world conditions within a laboratory. These models are mainly used for experimentation purposes on small-scale replicas of large structures and buildings. The models save costs which would have been incurred if experiments are carried out directly in real world conditions. The three modelling approaches are different and hence are used for different applications.

In India, air quality modeling is prescribed in the environmental impact assessment (EIA) process in India, to assess the possible impact of any upcoming project in a region on air quality. In 1994, Ministry of Environment and Forests (MoEF), Government of India issued the the Environmental Impact Assessment (EIA) notification which makes it mandatory to carry out an EIA study before actual establishment of certain projects in a specific region. The notification mandates the assessment of impact on air quality along with other environmental resources. This assessment is carried out using deterministic dispersion modelling. In India, Gaussian Plume Models are used for this purpose. CPCB (2003) stated that models have been used incorrectly, and the inputs data required for the models are many times adopted from other countries without assessing the applicability in Indian context. CPCB (2003) standardized the procedure and presented a guideline for conducting air quality modelling for EIA purposes. However, the efficacy of the process and reliability of modelling results is not ascertained. AERMOD is the prescribed model for carrying out EIA for air quality.

The Gaussian plume models like ISCST3, AERMOD are the most commonly used models in India mainly due to user friendliness and data availability (refs). However, some institutes like Indian Institute of Tropical Meteorology, The Energy and Resources Institute, CDAC, and some of the Indian Institutes of Technology are also using advanced chemical transport models (CTM) to take into account the chemistry and long-range transport of pollutants. Kumar et al. (2012) simulated the tropospheric GLO concentrations using the WRF-Chem CTM over South Asia for 2008 and evaluated the model performances. The modelled values when compared against the TES-retrieved observations showed satisfactory performance. The study found most of the region to be NOx-limited for ozone formation, which was later confirmed by a study by TERI (Sharma et al., 2016) also. There are other modelling-based studies which have studied the impact of particular parameters on ozone formation or the impacts of ozone on receptors in Asian region. A study conducted at IITM, Beig and Brasseur (2006), studied the influence of anthropogenic emissions on tropospheric ozone over the Indian tropical region during monsoon. The study estimated a maximum variation of 5–10 ppb in ozone concentration close to the surface. Sharma et al. (2016) assessed the sensitivity of ground level GLO in India towards various precursor contributing sources and species in 2010.

They applied the WRF-CMAQ models at a fine resolution of 36×36 km^2 and found that NOx sensitive conditions prevail in India at most locations, except in cities where the VOC-limited regime prevails. They also predicted that in future, a change in regime from NOx-sensitive to VOC-sensitive may take place mainly due to rise in NOx emissions. At urban centres, reduction in NOx emissions actually results in increase in GLO concentrations due to titration chemistry. It was also observed that all the source sensitivities do not add upto 100%, mainly due to non-linearity and boundary conditions (contributions from outside study domain covering India) and has a sensitivity of 32% in domain average ozone concentrations in India

The chemical transport models have been used to project the future scenarios of GLO in Asia. TERI participated in a study (Chatani et al.,2014) and used the WRF-CMAQ models to predict and project GLO concentrations in the Indian domain and project future scenarios. They showed that GLO is expected to increase considerably in the next two decades in a business-as-usual scenario. At urban scale, TERI (Sharma et al., 2013) applied the WRF-CMAQ model to predict GLO concentrations in heavily populated and polluted regions of New Delhi and concluded that the model performed better in middle ranges than for extreme concentrations. They also demonstrated the use of a hybrid model wherein the results of CMAQ are improved with the help of statistical distribution models. The index of agreement between modelled and observed ozone values increased from 0.77 to 0.91, when the CMAQ model outputs were improved using statistical distribution model. A modelling group at IIT Delhi is primarily concentrated on developing statistical, deterministic and numerical based AQMs and validating it with experimental data. The AQCRs for which these AQMs are developed and validated are mainly urban areas and their scale is mostly urban scale.

Recently, other than dispersion models, receptor models have been used to carry out source apportionment studies (discussed in the next section). These models take into account the ambient PM concentrations characterized into species and source profiles to generate source contributions using mass balance approach. The studies based on dispersion and statistical models in Indian context during last decade are summarized in Table 18. As seen from Table 18, most of studies carried out for Indian cities have used ISCST3, instead of AERMOD, which is a regulatory model. Moreover, these studies have mainly focused on assessing the source contributions to ambient pollutant concentrations. Therefore, there is a need to build capacity to carry out air quality modeling using state of art models like AERMOD, WRF-CHEM etc. Also, a greater number of studies focusing on air quality forecasting and design of air quality monitoring network are needed.

Bangladesh and Pakistan lack a systematic air pollution modelling study, although in-country sources are very important in both countries. Bangladesh is surrounded by the Indian border, and borders the Bay of Bengal to the south. North-western wind flows during the winter, and south western wind flows during the monsoon influence transboundary air pollution and dispersion within Bangladesh. Biomass is widely used in rural areas of Bangladesh, mostly for cooking. Biomass burning in traditional cooking stoves, contributes in significant air pollution. In rural Bangladesh, majority of people depend 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. 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. Dust is a major problem in most urban areas in Bangladesh during the dry seasons (winter, spring, late and autumn). Construction and vehicular activities give rise to dust in urban areas. 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 specific guidelines or rules on storage and transport of construction materials. In addition, most of the construction takes place during the winter, which is dry and further favorable to air pollution. Concreted 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 re-suspension of the settled dust on the road (DOE, 2012).

A review of these studies conducted in the countries is provided in Annexure I.

Trans-boundary pollution Studies

Trans-boundary pollution causes a lot of issue as atmospheric pollutants go beyond national borders and affects the health conditions of the population of other countries. Regional environmental problems are considered to be international public goods, which involve significant problems of collective action (Haas, 2016). As global public goods are concerned, it is normally very difficult to coordinate the policies of the countries involved. The complexities and uncertainties of recent environmental issues have made international policy coordination indispensable, but at the same time difficult to achieve or maintain. As access to scientific data and knowledge is becoming increasingly critical in understanding the mechanisms and process of environmental problems, the role of the epistemic community has been emphasized in facilitating international environmental cooperation.

Malé Declaration

In 1998, the United Nations Environment Programme (UNEP), together with the Stockholm Environment Institute (SEI) drew attention to the possibility of the impacts of transboundary air pollution in South Asia. This initiative led to the adoption of the Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia (Malé Declaration). The Malé Declaration's objective is to aid the process of providing a clean environment through clean air. The Declaration calls for regional cooperation to address the increasing threat of transboundary air pollution and its possible impacts. Its implementation has been carried out in phases. The eight member-countries of Malé Declaration include Bangladesh, Bhutan, India, Iran, Maldives, Nepal, Pakistan and Sri Lanka. Country governments nominated the National Focal Points (NFPs) and the National Implementing Agencies (NIAs) for its implementation. The Swedish International Development Cooperation Agency (Sida) provided funding to the Malé Declaration from 1999 to 2013. The Twelfth Session of the Intergovernmental Meeting of the Malé Declaration held in June 2011, agreed on sustainable financial mechanism, in accordance with the UN scale based-burden sharing. During the last 17 years of implementation, network of policy makers and stakeholders has been established, monitoring and impact assessment have been carried out, completed several impact assessment studies and communicated to policy makers and stakeholders, and initiated policy measures to control emissions of air pollutants. The Malé Declaration provides a framework to promote integrated approach for air pollution issues at national and regional level in South Asia. Some Malé Declaration countries have initiated an integrated approach by prioritising action on air pollution and short-lived climate pollutants (SLCPs) such as black carbon and methane (a precursor of ground-level ozone).

There have been some studies regarding the trans-boundary dispersion of air pollutants, however, the number of literature available is very limited. Based on model simulations representing different geographical domains encompassing Asia, India, North India and Delhi and their corresponding emissions, it was clearly reflected that contributions due to emissions of the megacity Delhi alone is 11%–41% and thus remaining (59%–89%) proportion is expected to be contributed from the sources outside of the Delhi region which is significant (Gupta and Mohan, 2013). Indian Ocean Experiment (INDOEX) scientists discovered the Atmospheric Brown Haze that infiltrates most of South Asia (Khwaja *et al.;* 2012). This haze consists of sulfates, nitrates, organics, black carbon, fly ash and other pollutants. Biomass burning, rapid industrialization and urbanization are primarily responsible for this haze over South Asia. This report stated that other sources of air pollution are increasing traffic trends, thermal power plants and incineration of solid waste.

Masud *et al.*, 2016 investigated probability of contribution of trans-boundary sources to PM pollution in Bangladesh. Ninety-six-hour backward trajectories at 3-hour intervals were computed and clustered into six groups based on angle distance matrix. The probabilities that individual clusters were associated with different ranges of coarse and fine particles were evaluated. Gazipur station near Dhaka city was found to have 68% probability of receiving PM_{10} concentration higher than 150 µg/m^3 when air masses followed the route of Middle East through the Himalayan valley to the station. This channel was identified as the main route of PM transport to Bangladesh during the dry season. Transboundary source-regions were identified by concentration weighted trajectory (CWT) method and also by the monthly average aerosol optical depths (AOD) over South Asia. North-western Indian regions, Nepal and its neighbouring areas, and Indian state of West Bengal were identified as the most probable zones contributing to PM pollution in Gazipur, Dhaka, particularly between November and January.

During the present study an effort was made to identify the probable trans-boundary sources of air pollution in different countries of the South Asia using the HYSPLIT trajectory model. Two locations were selected in each country of the South Asia included in this study and 5-days HYSPLIT air parcel back trajectory was simulated for each month of the year 2018 over these locations. The **Figure 2** shows the trajectories of air pollutants for the cites which clearly demonstrate the trans-boundary dispersion of pollutants. This analysis suggests that there are possibilities of trans-boundary air pollution in all four countries; however for countries like Pakistan and Nepal there are possibilities that other non- South Asian countries can also contribute to their ambient air pollution.

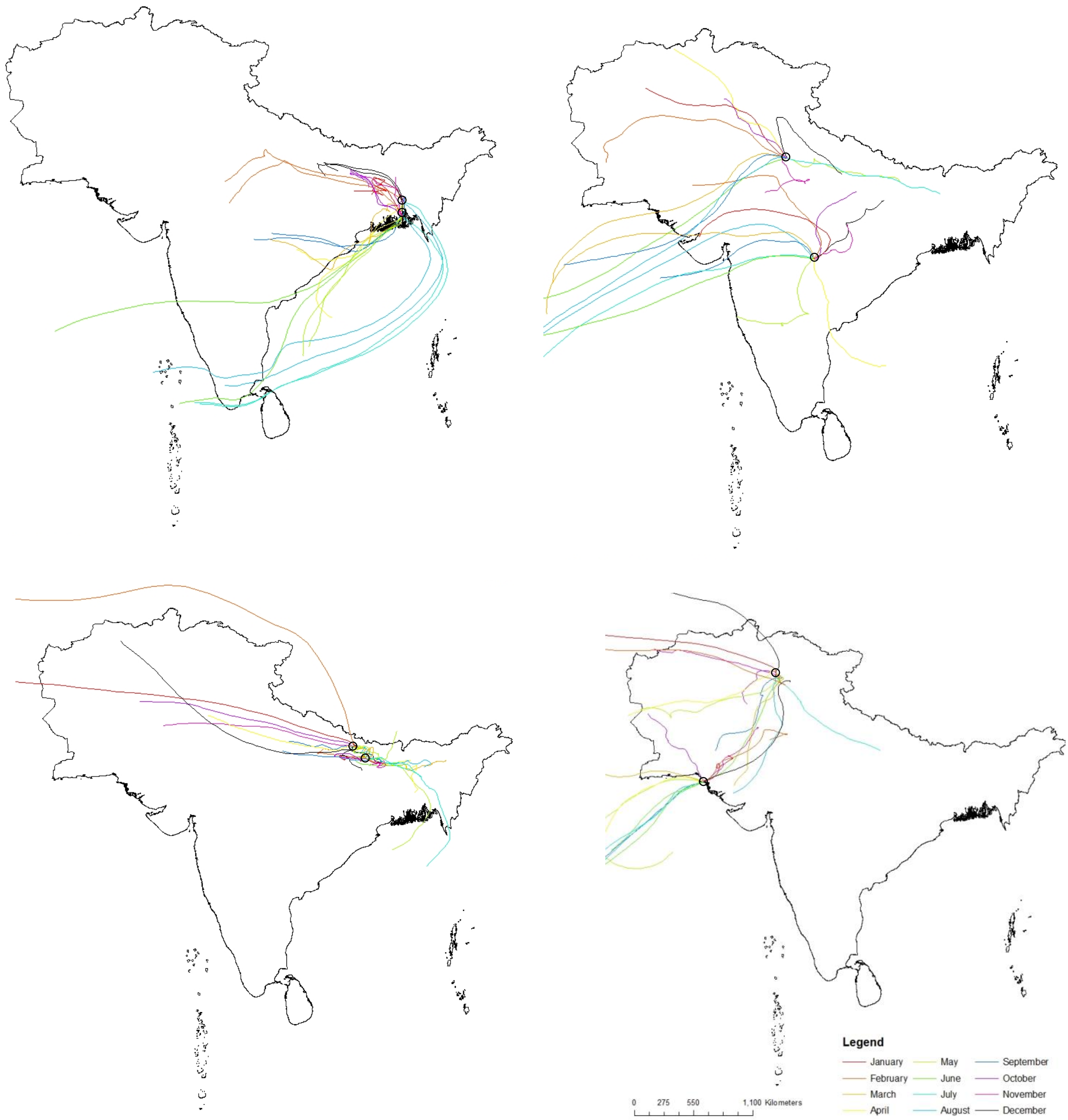


Figure 2 Air Parcel back trajectory at different cities of South Asia during different months of the year (2018). NOAA HYSPLIT model was used for this study.

Saadat *et al.,* 2013 studied trajectory trans-boundary atmospheric air pollution data in the Satkhira district of Bangladesh using the HYSPLIT Model from December 2005 to April 2007. Backward air mass trajectory showed that the levels of SOx and NOx increase when there is an air mass movement over India, and fall when the trajectories spend most of the preceding five days over Bay of Bengal. The study demonstrated that trans-boundary air movements have a significant effect on air quality in Bangladesh. Begum *et al.*, 2014 collected PM samples from four continuous air monitoring stations in Bangladesh. The highest $PM_{2.5}$ concentrations were detected when trans-boundary pollutant transport was expected to be high, indicating that trans-boundary transport of pollutants from agricultural burning in upwind regions of India may be the reason for the high levels of air pollution.

Air quality in Pakistan is also adversely affected by transportation of pollutants from other countries. This issue is particularly acute in relation to agricultural stubble burning, as this takes place in the adjacent provinces of Punjab in Pakistan and Punjab in India. Consequently, stubble burning in India affects air quality in Pakistan, and vice versa. Biomass burning has been found to make a significant contribution to air pollution in Lahore, the capital of Punjab province, and this is likely to include a significant trans-boundary component. Other sources of air pollution also contribute to trans-boundary air pollution issues. There is little information available at present to judge the significance of trans-boundary sources of air pollution in Pakistan, although air pollution, especially in smog season, is widely believed to originate in India and travel to Pakistan. However, an analysis conducted by the State of Punjab mentions pollution originating from India but emphasizes the internal contribution of air pollution, without providing quantitative details (State of Punjab, 2017).

Source Emission Inventory of Air Pollution

Detailed inventory of different sources of major air pollutants are important to undertake mitigation actions to reduce ambient air pollution. It is already evident from Figure 2 that trans-boundary sources are important in the ambient air pollution in different South Asian countries. Country specific high resolution source emission inventory is required to develop the required mitigation plan to combat air pollution over the region. However, development of the high resolution source emission inventory was beyond the scope of present study. However, top-down inventories have been produced for multiple countries, using the Greenhouse Gas –Air pollution Interaction and Synergies (GAINS) model and the Emission Database for Global Atmospheric Research (EDGAR). These calculated values are based on a range of assumptions, but in the absence of air quality modelling analysis, provide useful contextual information to guide assessments of emission of different countries. The GAINS ECLIPSE v5a database (using the TSAP Report #16A) was used to assess the source contribution of major air pollutants from different countries of the South Asia.

The GAINS source emission estimates indicates significantly higher emission of major pollutants from different sources in India compared to other South Asian countries included in the present study (

Power Industry Transport Residential Agriculture Others

Figure 3). The source emission of major pollutants from the four countries followed the order: India > Pakistan > Bangladesh > Nepal. Higher source emission contribution of India can largely be attributed to its significantly higher economic growth rate than others.

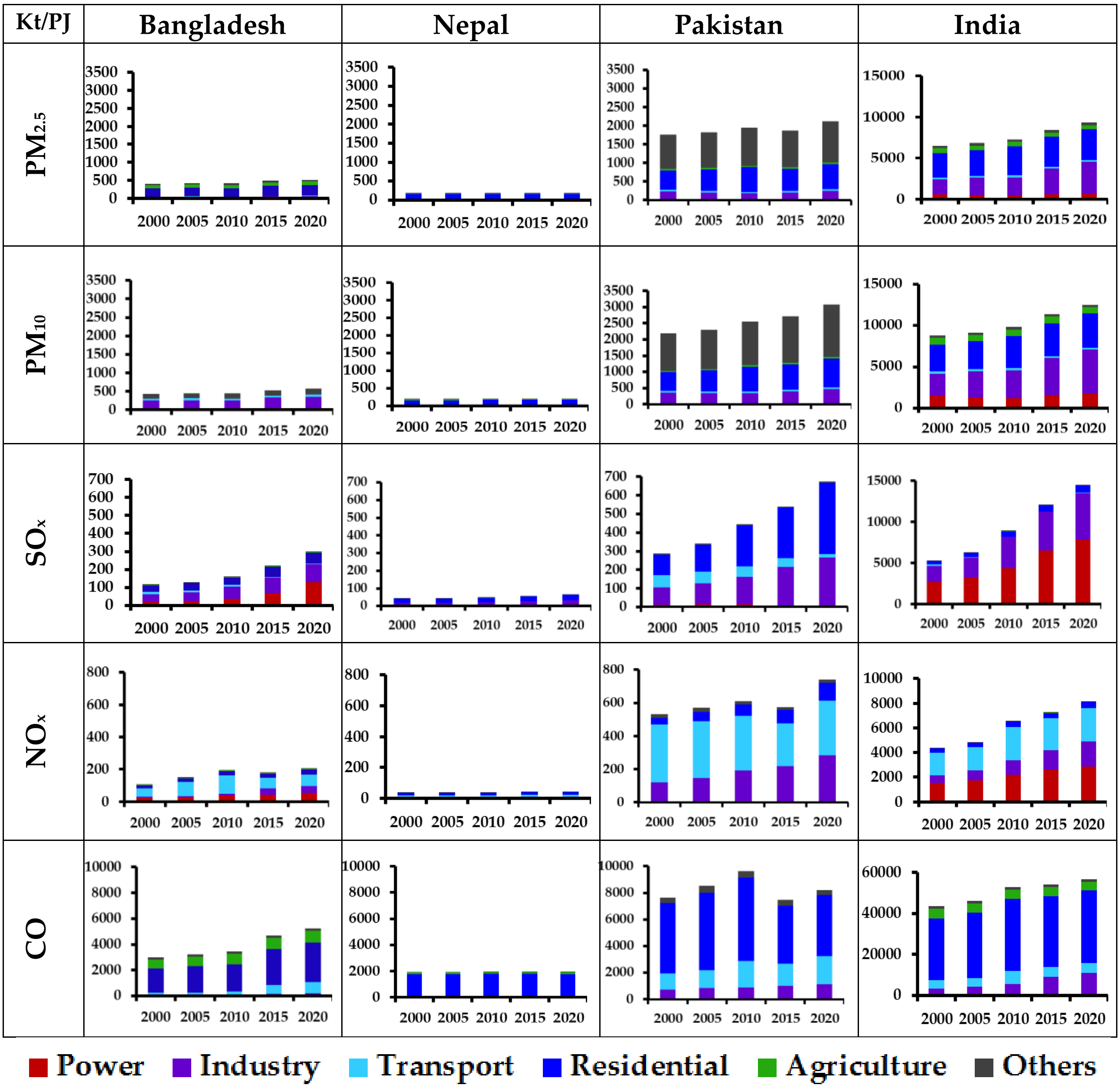


Figure 3 Source emission inventory of different pollutants in South Asia

Source Apportionment Studies

In order to design cost effective programs and strategies for reduction of pollutant concentration in the ambient air, it is necessary to have information about the sources and their respective contributions. The term, source apportionment describes techniques used to quantify the contribution of different sources to atmospheric pollutant concentrations. There are currently two basic approaches to carry out source apportionment (SA) studies: (1) top-down or receptor-based source apportionment methods, and (2) bottom-up or source-based methods. The top-down approach begins by taking air samples in a given area (i.e. via air sampling receptors) and comparing the chemical and physical properties of the sample to the properties of emissions sources. It helps in providing information on the types of emission sources and their relative contributions to measured air pollution. Bottom-up methods begin by identifying pollution sources, then estimating their emissions factors and collecting detailed meteorological data (i.e. humidity, temperature, wind speed and direction etc.). An atmospheric dispersion model estimates ambient pollution levels.

The first source apportionment study in India for $PM_{2.5}$ based on top-down model was conducted in four cities (i.e. Delhi, Kolkata, Mumbai and Chandigarh) by World Bank in the year 2001-02. The study found that primary emissions from fossil fuel combustion (coal, diesel, and gasoline) were 22-33% in Delhi, 23-29% in Mumbai, 37-70% in Kolkata, and 24% in Chandigarh. The contribution of biomass was 9-28% for Delhi, 12-21% for Mumbai, 15-31% for Kolkata, and 9% for Chandigarh (World Bank, 2011). Thereafter, CPCB took an initiative and conducted source apportionment study by using both top-down as well as bottom-up approach in six Indian cities i.e. Delhi, Mumbai, Pune, Kanpur, Bangalore and Chennai in the year 2011. Based on the top-down approach, they found that in residential locations, re-suspension of road dust and soil dust emerged as prominent sources of PM_{10} in the cities of Pune (57%), Bangalore (49%), Mumbai (47%) and Delhi (15%). Vehicular sources (15–48%) contributed significantly in Bangalore, Chennai, Delhi and Kanpur. At the kerbside locations in all the cities, except Kanpur, re-suspension of road/soil dust was found to be the major source (27-75%). At industrial locations, contribution of industries was reflected only in Bangalore (27%), Kanpur (19%) and Delhi (9%; CPCB, 2011). Based on the review, road dust re-suspension contributed the maximum (i.e. 46%) to PM_{10} concentrations in metro cities followed by transport (i.e. 27%) and industries (19%). In case of fine particulate matter i.e. $PM_{2.5}$, transport contributed the most (i.e.42%) followed by fossil fuel combustion (i.e. 17%), secondary aerosols (i.e. 16%), road dust re-suspension (i.e. 13%) and industries (i.e. 10%). CPCB (2007) also brought out conceptual guidelines and common methodology for air quality monitoring, emission inventory & source apportionment studies for Indian cities. Other than these, academic/research institutions in India like Indian Institutes of Technology, Indian Institute of Science, National Environmental Engineering Research Institute, Automotive Research Association of India, Indian Institute of Tropical Meteorology, CDAC, NPL, The Energy and Resources Institute are also involved in carrying out air quality modelling studies.

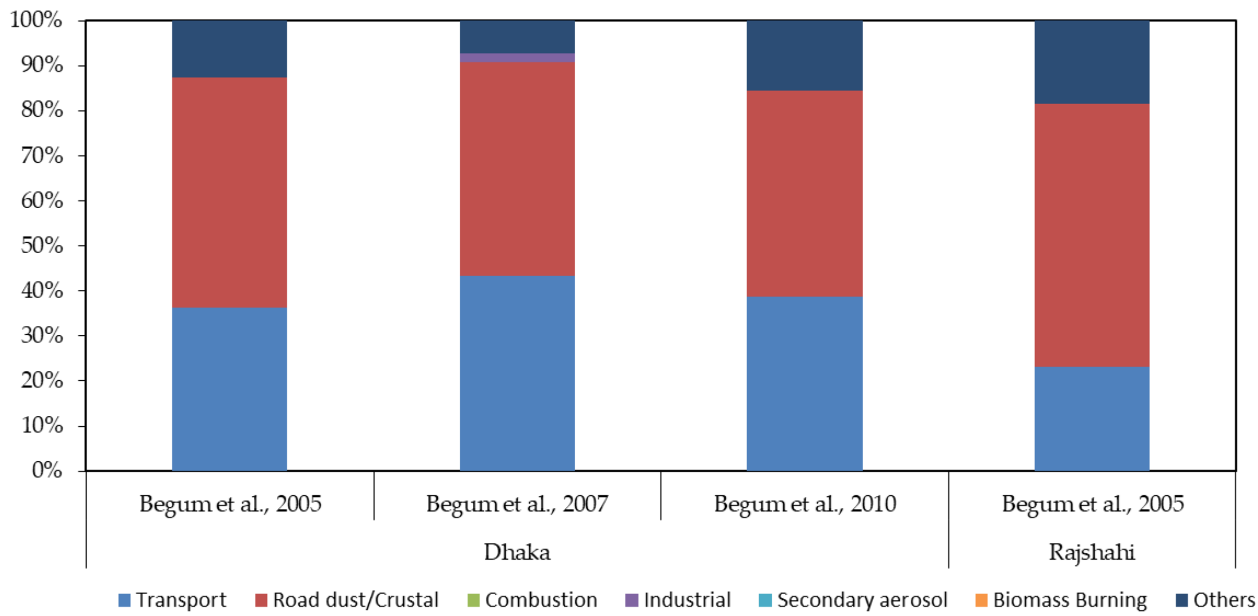
In Bangladesh, Begum *et al.* (2004) analyzed air samples of Dhaka and Rajshahia to conclude that about more than 50% of the $PM_{2.5-10}$ mass at both sites comes from soil dust and road dust. The motor vehicle including two strokes contributes about 48% of the $PM_{2.5}$ mass in case of semi-residential area Dhaka. On the other hand, the biomass-burning factor contributes about 50% of the $PM_{2.5}$ mass in Rajshahi. In another study, it was observed that 30-50% of particulate Matter (PM) collected from different part of Dhaka city was fine particles (diameter less than 2.2 µm), which are mainly of anthropogenic origin and predominately from transport related sources (Begum *et al.*, 2010). Biswas *et al.*, 2000 showed that approximately 55% of the PM_{10} are attributed to re-suspended soil dust and motor vehicle emissions. Fine particulates $PM_{2.5}$ were mostly attributed to motor vehicles (29%) and natural gas/ diesel burning (46%). Government of Bangladesh has tried to control PM emissions from anthropogenic sources. The particles of anthropogenic origin are predominately from vehicular transport sources. However, the combination of meteorological conditions, long–range transport during the winter and local sources results in PM concentrations much higher than the Bangladesh National Ambient Air Quality Standard (BNAAQS). Begum *et al.* (2013) applied Positive Matrix Factorization (PMF) to fine particle composition data from January 2007 to February 2009. They found that motor vehicles contributed less BC than the brick kiln industry. This result demonstrates the effectiveness of policy interventions to reduce vehicle emissions, as previously, vehicles represented the major contributors of BC. The authors also noted that trans-boundary transport of air pollution in the South Asian region has become an issue of increasing importance over the past several decades, although the relative amounts of local and long–range transported pollutants are not known. The studies carried out by Begum et al. identify sources on a probabilistic basis, and consequently the data on source apportionment may not reflect the real picture. Islam *et al.*, 2015 stated that trace metals concentrations in Dhaka city air were much higher than Europe and USA but comparable or slightly lower than other south Asian countries. This was the first extensive study of airborne levels of the eleven trace metals with ICP-MS in Dhaka, Bangladesh. In Bangladesh, the most recent and reliable source apportionment study was conducted in 2013 in collaboration with NILU. In Pakistan, a recent study conducted using principal component and cluster analyses, found that automobile emissions, industrial activities, combustion processes and mineral dust are major pollution sources of atmospheric particulate matter in Islamabad (Shah *et al.*, 2012). The trace elements showed a prevalence of Zinc (Zn) and Iron (Fe) followed by lead (Pb). In another study, PM_{10} and $PM_{2.5}$ aerosol samples were collected every sixth day for a whole year in Lahore. The research found ambient concentrations of $PM_{2.5}$ and PM_{10} to be among the highest ever recorded anywhere in the world (Stone *et al.*, 2012). The energy mix in Pakistan shows a predominant share of natural gas, which currently stands at about 44% of total commercial energy requirements. The balance comes from hydropower and fossil fuels with a small portion from renewable sources. Given the prevailing energy crisis and the need to meet the so far depressed but growing demand, the country needs to exploit all its domestic sources of energy including coal, hydro, wind and solar. The use of nuclear and domestic coal-based energy in the power generation sector seems inevitable in the future. There is a need for comprehensive apportionment studies to analyze the impact of in-country and trans-boundary air pollution in Pakistan.

There are various limitations of the SA studies conducted by using top-down approach. In most of the cases, it is difficult to distinguish between vehicle exhaust and non-exhaust emissions. This happens if the soils are polluted by vehicle emissions or the road dusts contain a significant soil contribution. Most of the studies pay little attention to secondary organic aerosol, which may be an important contributor to PM mass. Limited number of studies are carried out on multiple sites. Moreover, where these exist, they tend to use multiple sites within a city (e.g., CPCB, 2010) rather than using urban/rural contrasts to elucidate the importance of emissions within the city relative to the regional background (Pant and Harrison, 2011). Emissions inventory need to be spatially and chemically disaggregated. Knowledge of city specific emissions inventories for specific chemical components would give greater confidence in assigning sources to factors identified through multivariate receptor models.

The details of source apportionment studies in these countries are provided in Figure 4.

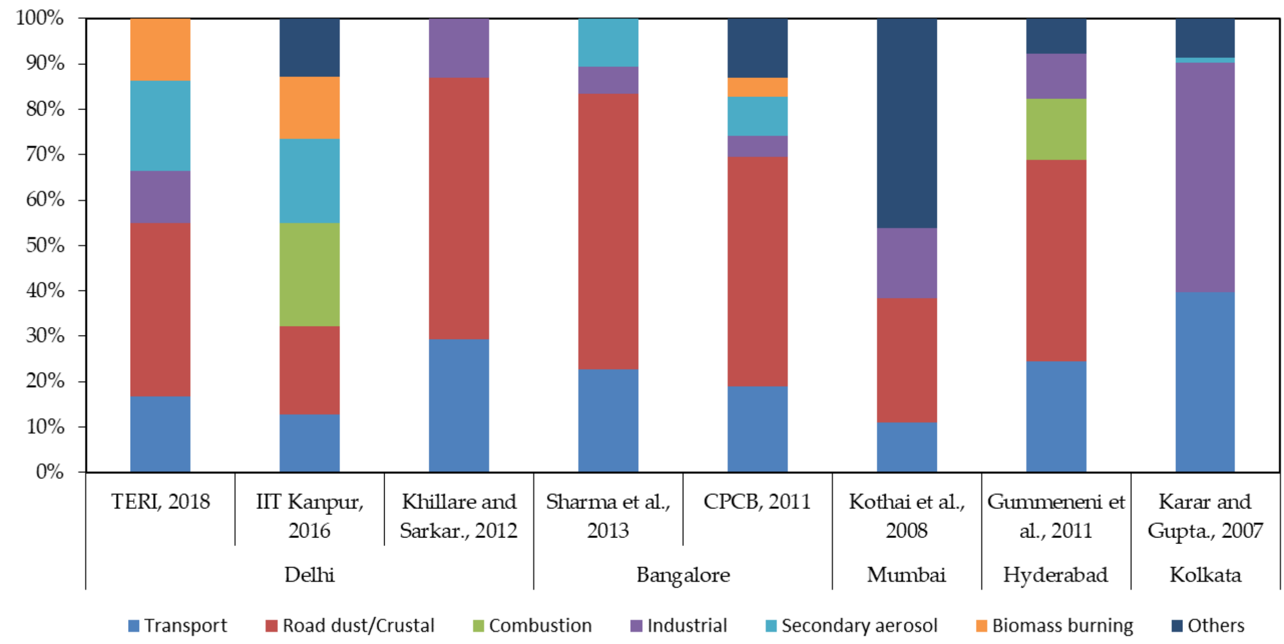
Bangladesh

Source apportionment of PM_{10}

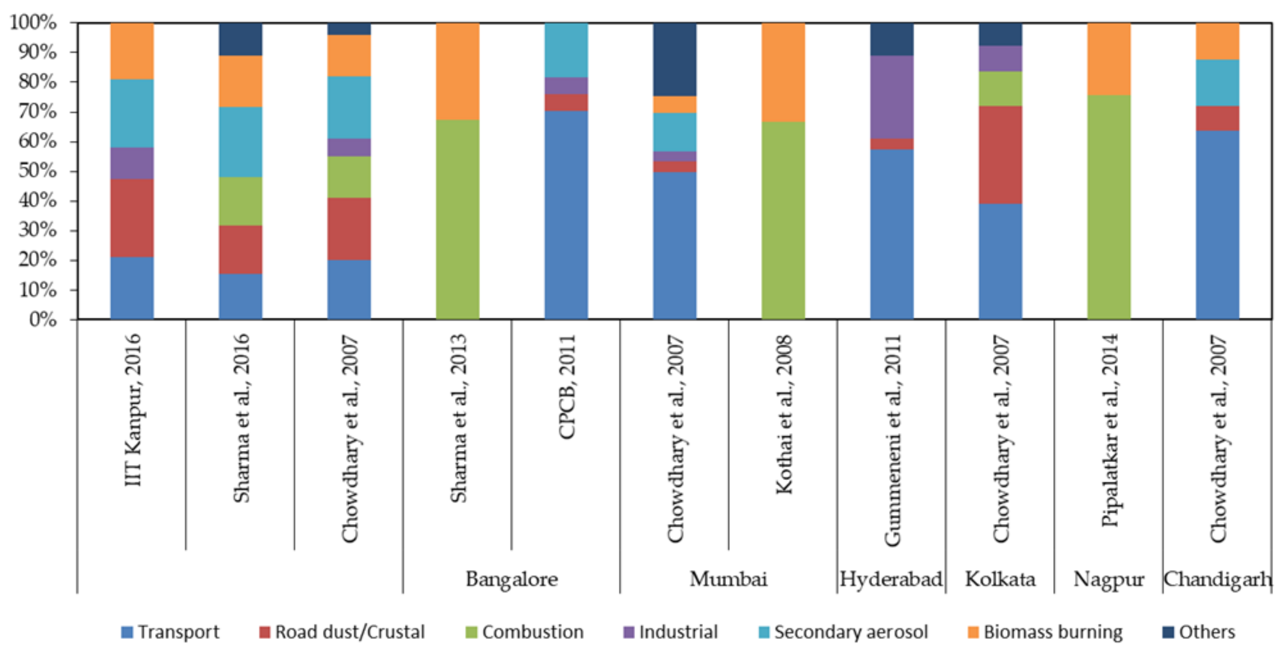


India

Source apportionment of PM_{10}

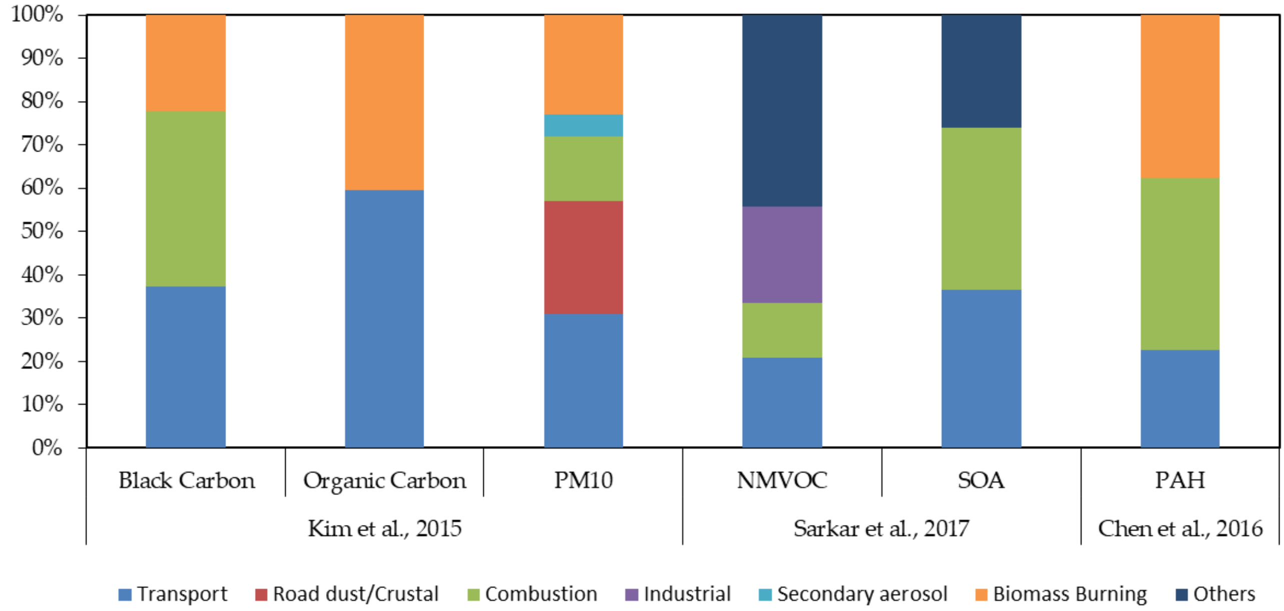


Source apportionment of $PM_{2.5}$



Nepal

Source apportionment of different air pollutants



Pakistan

Source apportionment of PM

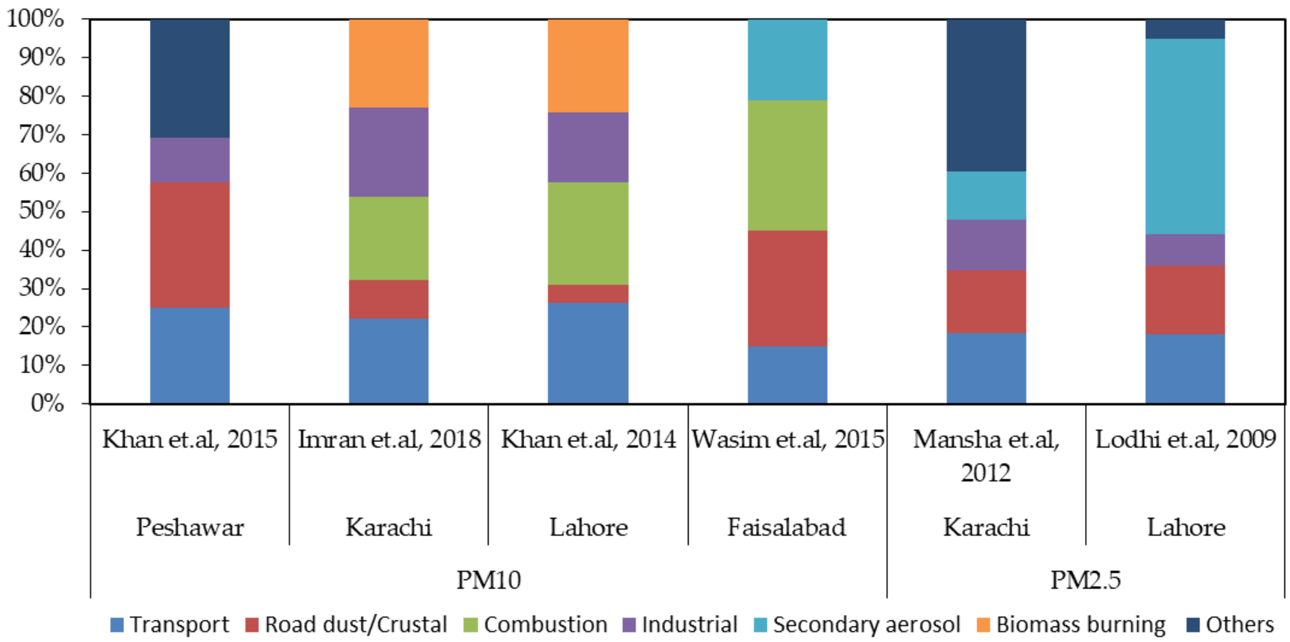


Figure 4 Review of the published literature on source apportionment studies in different countries

Health Impact Studies

Air pollution is a major threat to public health; scientific research has established an association between air pollutants like particulate matter (PM_{10} and $PM_{2.5}$), VOCs, oxides of sulphur (SO_x), oxides of nitrogen (NO_x), ozone, and carbon monoxide (CO) and their adverse health effects, especially on respiratory and cardiovascular diseases. High air pollution can cause immediate aggravated cardiovascular and respiratory illness and damage cells in the respiratory system. Chronic exposure of polluted air has permanent health effect such as accelerated aging of the lungs, loss of lung capacity and decreased lung function and development of asthma, bronchitis, emphysema, and possibly cancer etc (IARC, 2013). The most vulnerable people are persons with heart disease, coronary artery disease or congestive heart failure, lung diseases such as asthma, emphysema or chronic obstructive pulmonary disease (COPD), pregnant women, outdoor workers, older adults and the elderly, children under age 14, and athletes who exercise vigorously outdoors.

In the last twenty-five years deaths due to air pollution have increased with some quickening since 2010. Among all air pollutants, $PM_{2.5}$ contributes to the highest proportion of deaths. Bangladesh, India, and Pakistan have a higher burden of early deaths due to air pollution because of the larger populations exposed to high levels of $PM_{2.5}$ and other pollutants. In South Asia, deaths attributable to household air pollution have remained high and relatively stable with only a modest increase from 1.1 million to 1.2 million between 1990 and 2015 (Krishna e al., 2017). In Pakistan, 135,000 deaths per year are attributed to ambient air pollution, making it the leading cause of sickness and death in Pakistan, as well as reduced life expectancy by approximately 60 months (Omar et al., 2018).

The annual population-weighted mean exposure to ambient particulate matter $PM_{2·5}$ in India was 89.9 μg/m³ (67–112 μg/m³) in 2017 (Balakrishnan et al., 2018). The proportion of population using solid fuels in India was 55.5% (54·8–56·2) in 2017, which exceeded 75% in the low SDI states of Bihar, Jharkhand, and Odisha. 1.24 million (1.09–1.39) deaths in India in 2017, which were 12.5% of the total deaths, were attributable to air pollution, including 0·67 million (0.55–0.79) from ambient particulate matter pollution and 0.48 million (0·39–0·58) from household air pollution. Of these deaths attributable to air pollution, 51.4% were in people younger than 70 years. India contributed 18.1% of the global population but had 26.2% of the global air pollution DALYs in 2017. The ambient particulate matter pollution DALY rate was highest in the north Indian states of Uttar Pradesh, Haryana, Delhi, Punjab, and Rajasthan, spread across the three SDI state groups, and the household air pollution DALY rate was highest in the low SDI states of Chhattisgarh, Rajasthan, Madhya Pradesh, and Assam in north and northeast India.

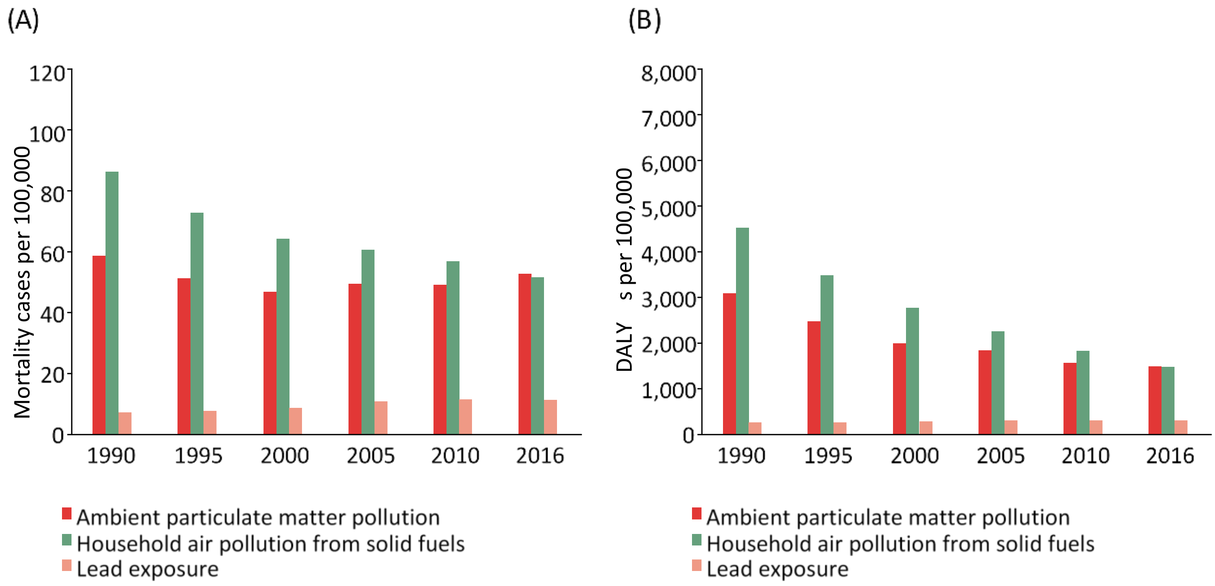


Figure 5 Mortality and DALYs caused by air pollution in Bangladesh.
Source: (IHME, 2017)

In Nepal, the number of patients in major hospitals in Kathmandu Valley suffering from chronic obstructive pulmonary disease (COPD) has significantly increased between 1992 and 2003. This increase is highest in the winter season when the air pollution is also high due to more saturation and less dispersion of pollutants in the atmosphere. The Ministry of Environment, Science and Technology (MoEST) estimated in 2005 that Kathmandu Valley's air pollution results in approximately 1,600 premature deaths per year. The number of people expected to suffer from leukaemia due to benzene exposure amounts to 1-8 persons per 100,000 and for PAH to 16-32 persons per 100,000. Globally, air pollution was responsible for 16 percent of all deaths in 2015 (Landrigan *et al.*, 2018). In Bangladesh, this proportion was nearly 28 percent and ambient and indoor fine particulate matter pollution caused about 21 percent of all deaths. There is increasing international evidence that air pollution reduces the productivity of healthy workers, including in the Ready Made Garments (RMG) industry, which in Bangladesh was significant for continued competitiveness and high GDP growth.

By 2005, the direct cost of the damage (premature mortality and morbidity) linked with outdoor air pollution in Pakistan was assessed at 1.1% of GDP or US$1.07 billion (World Bank, 2008). Outdoor air pollution alone caused more than 80,000 hospital admissions per year, nearly 8,000 cases of chronic bronchitis, and almost 5 million cases of lower respiratory cases among children under five. To put these numbers in perspective, the harm done by air pollution exceeds most other high-profile causes of mortality and morbidity that attract significantly more consideration in Pakistan. A more recent study estimated that the economic cost of air pollution is estimated is $48 billion per year, or 5.9% of GDP (Omar, 2018).

Agricultural Impact Studies

There is a two-way relationship between agricultural production and air pollution: agricultural production contributes significantly to air pollution; in turn, air pollution can impact agricultural productivity. Agriculture is the single largest contributor of ammonia pollution as well as emitting other nitrogen compounds. Conversely, there is increasing evidence that food production is also threatened by air pollution. Ozone precursor emissions (nitrogen oxides and volatile organic compounds) are of particular concern for global food security as these compounds react to form ground-level ozone. There are three major ways in which air pollutants may damage agricultural production: i) direct visible injury, usually to leaf tissue - if extensive, this can affect crop yield, and superficial damage can make the crop look less appealing to consumers, thus lowering its value; ii) direct effects on growth and yield - experiments with a range of different pollutants have shown that yields are generally reduced with increasing exposure to pollutants, even in the absence of visible injury; iii) indirect effects - even at relatively low levels, air pollutants may cause a range of subtle physiological, chemical or anatomical changes which will not lead to detectable yield reductions under optimal growth conditions. However, these changes may increase the crop's sensitivity to other stresses, thereby contributing to significant yield losses. Exposure to sulphur dioxide and nitrogen dioxide, for example, consistently leads to increased growth rates of a range of aphid pests (Belled *et al.,* 1993).

In terms of global crop losses, Asian pollution dominates worldwide losses of wheat (50-60%) and rice (more than 90%) (Arnold *et al.,* 2012). Ozone was estimated to cause relative global crop losses for soy 6-16%, wheat 7-12% and maize 3-5%. Some crops have been found to be more sensitive than others to ozone exposure, with wheat and soybean being particularly sensitive; potato, rice and maize being moderately sensitive; whilst barley has been found to be ozone resistant. Of concern is the fact that these most sensitive crops are all staple foods for the majority of the world’s population. Tropospheric ozone and black carbon have direct effects on crop yields beyond their indirect effects through climate; emissions of black carbon and ozone precursors have risen dramatically in India over the past three decades (Burney and Ramanathan, 2014). As per the study, yields in 2010 in India were up to 36% lower for wheat than they otherwise would have been in absence of climate and pollutant emissions trends, with some densely populated states experiencing 50% relative yield losses.

Other impacts

Other than health and agricultural impacts, air pollution causes a range of impacts, from poor visibility to decline in tourist footfall in extreme cases. For example, Delhi, which is notorious for being among the most polluted cities in the world, has experienced days of very poor visibility causing disruptions in air, rail and road traffic; even leading to cancellation of international sporting events. Poor air quality in Delhi NCR has led to what is being termed as reverse migration as people are forced to relocate to other cities and the countryside. Air pollution has adversely impacted domestic and international tourism. A 2018 survey of foreign tourists in India finds that air pollution is among the top concerns of tourists (apart from cleanliness, security in certain pockets, etc.). Travel agencies and tour operators say that Delhi's foreign tourist inflow has gone down by 25-30% in recent years due to pollution. This is likely to affect both transportation and tourism sectors, both of which are highly employment-oriented. Delhi's toxic air has also become a permanent feature in the travel advisories issued by countries like the US, the UK and Mexico to their citizens.

Similarly, visibility is pointed out to be concern in tourism-centric Nepal. A number of surveys have been conducted in different time periods to assess the impact of air pollution on tourism in Nepal. Findings of the Departing Visitors Survey conducted among 1,702 tourists between May and June 2001 by MARG Nepal indicate that the quality of air is the number one area where tourists feel improvement is needed (Business Age, 2001). Another survey of tourist perception on Kathmandu's air quality was conducted between April and June 2005. The survey had 2,800 respondents, 69% of whom rated the city's air quality as poor while 77% felt that the air quality outside Kathmandu was better. A substantial number of tourists also experienced difficulty in breathing (49%) and had visibility problems (58%) during their stay (KEVA, 2005). Visibility in urban areas of Nepal is said to have reduced over the years due to, inter alia, high pollution levels. This has led to some tourists wanting to get away from urban areas as soon as possible, which could impact the income from tourism.

Developmental Impact Studies

Studies have made an attempt to estimate the economic burden of air pollution for the economy. As discussed above, air pollution burdens the economy by increasing morbidity and mortality among the population, adversely affecting productivity of labor, reducing agricultural outputs, and impacting tourism both by creating adverse conditions for tourists and by affecting cultural and historical buildings. It also causes economic burden through mortality and sickness rates which leads to economic costs in terms of remediation or restoration (UNICEF, 2015).

According to a World Bank report, air pollution costs the global economy more than $5 trillion annually in welfare costs, with the most devastating damage occurring in the developing world (World Bank, 2015). By 2005, the direct cost of the damage (premature mortality and morbidity) linked with outdoor air pollution was assessed at 1.1% of Pakistan's GDP or US$1.07 billion (World Bank, 2008). Outdoor air pollution alone caused more than 80,000 hospital admissions per year, nearly 8,000 cases of chronic bronchitis, and almost 5 million cases of lower respiratory cases among children under five.

World Bank's 'Cost of Pollution' report shows that India lost $505.1 billion (PPP adjusted) in the year 2013 or 7.69% of total GDP. The Indian government conducted a similar study of damage caused by pollution in in the country in 1999 and estimated the cost at $14 billion annually: amounting to close to 4.5%–6% of GDP (Managi and Jena, 2008). Such estimates rely on a mixture of lost production due to closure of sites due to pollution; health impacting workers resulting in lost labour hours as well as healthcare costs. A national-level economic assessment of environmental degradation in India establishes the enormous cost air pollution imposes on India's economy. The cost of serious health consequences from particulate pollution is estimated at 3 per cent of India's GDP (World Bank, 2015). Market costs to the Indian economy are projected to increase eightfold to over USD 280 billion by 2060–this is more than 7% of India's current GDP (in 2005 Purchasing Power Parities exchange rates). The social costs from mortality due to air pollution would increase 15 to 33 times, as both the number of premature deaths and the value per death increase (OECD, 2017).

A recent study estimated cost of health burden of $PM_{2.5}$ air pollution was at 10 percent of the welfare loss in Bangladesh (US$370 million) (Narain and Sall, 2016). The annual productivity loss of healthy workers in the RMG industry caused by ambient air pollution is estimated at US$90 million annually, a significant figure as it points to a potential vulnerability of Bangladesh's wage competitiveness in this nationally important export sector. The treatment and time costs of illness attributed to inadequate health are estimated at US$130 million. Finally, the lost income due to IQ loss in children exposed to lead near ULAB sites is estimated at US$50 million**.** Copenhagen Consensus Center, 2016 analyzed benefit-cost of cleaner brick kiln technologies in Bangladesh on the basis of project report of ADB 2012, UNDP 2015 and UNFCC 2014 and estimated social benefit of cleaner technologies based on recent advances in health assessment of $PM_{2.5}$ developed by Global Burden of Disease. The study concluded that benefit of reducing mortality using VSL and valuation of DALY at GDP per capita were higher than the cost of implementation of cleaner technology. This reflects the population distribution in Bangladesh: adverse effects on the health and life expectancy of economically productive adults affects individual health expenditure, and will have a long term effect on national GDP.

Tourism is one of the main industries that contribute largely to the Nepal economy. A number of surveys have been conducted in different time periods to assess the impact of air pollution on this major industry. Findings of the Departing Visitors Survey conducted among 1,702 tourists between May and June 2001 by MARG Nepal indicate that the quality of air is the number one area where tourists feel improvement is needed (Business Age, 2001). A more recent survey of tourist perception on Kathmandu's air quality was conducted between April and June 2005. Th e survey had 2,800 respondents, 69% of whom rated the city's air quality as poor while 77% felt that the air quality outside Kathmandu is better. A substantial number of tourists also experienced difficulty in breathing (49%) and had visibility problems (58%) during their stay (KEVA, 2005). Clean Energy Nepal/Environment and Public Health Organization (CEN/ENPHO) estimated an avoidable cost of US$1.86 billion per year on health due to air pollution, which indicates that the total expenses would be an additional burden on economic development of Kathmandu Valley. Benefits of reducing benzene and PAH concentrations to half their current values would amount to US$ 30-70 million per year.

Indoor air pollution

Biomass fuel or biofuel, refers to any solid plant or animal-based material deliberately burnt by humans. Wood is the most common biofuel, but use of animal dung and crop residues is also widespread (DeKoning *et al.*, 1985). Estimates by World Resources Institute (WRI) show that nearly half of the world population depends on solid biomass fuel and about two-thirds of all households in the developing countries still rely primarily on unprocessed biomass fuel for their daily cooking and other domestic energy needs (WRI, 1998). In many of these households, fuel is burnt indoors on open fires or poorly functioning stoves, often with no means of ventilation or smoke extraction. As a result, very large numbers of women and young children are exposed to high levels of air pollution, every day of the year. Poverty is one of the main barriers to the adoption of cleaner fuels and biofuels will continue to be used by the poor for many decades (Bruce et al.., 2000). According to World Health Organization, the greatest global burden of air pollution exposure occurs not outdoors in the cities of the developed countries, but indoors in poor rural communities due to use of unprocessed biofuel (WHO, 1987).

Biomass smoke contains many thousands of substances, many of which damage human health. Most important are particulates (small and large), carbon monoxide, nitrous oxides, sulphur dioxide, formaldehydes and polycyclic organic matter which includes carcinogens, such as benzopyrene (DeKoning et al., 1985). Small particles of diameter less than 10 microns (term PM_{10}) and less than 2.5 microns ($PM_{2.5}$) are “able to penetrate deep into the lungs and appeared to have the greatest health damaging potential” (USEPA, 1997).

As per estimates of the USEPA, in developing countries, the ambient levels of PM10 and carbon monoxide range between 300-3000µg/m^3 and 2-50 ppm, respectively. As per USEPA guidelines, the recommended exposure value for 24-h average PM_{10} and $PM_{2.5}$ concentrations are 150µg/m^3 and 65µg/m^3, respectively and 8-h average carbon-monoxide standard is 9 ppm or 10mg/m^3. However, in rural households, these levels are exceeded on a daily basis by a factor of ten, twenty and sometimes more (USEPA 1997). In developing countries, women generally cook for the family and are typically exposed to these very high levels of pollution for between 3 and 7 hours each day over many years (Engler *et al.*, 1998). Women often carry their children with them while they cook and both mothers and children spend considerable time in the kitchen and inhale smoke (Albalak, 1997).

Biomass fuel use has consistently been linked with many adverse health effects including Acute Respiratory Infection (ARI), Chronic Obstructive Pulmonary Disease (COPD), low birth weight and cancers. World health Organization (WHO) estimates that pollutants from biomass use cause about 1.5 million premature deaths per year among women and children from respiratory illnesses (WHO, 2006). Overall, biomass fuel use has been linked to 39 million disability-adjusted life years (DALY), a measure of potential life years lost (Eva *et al.*, 2006).

Biomass fuel use has been associated with at least 4 percent of the disease burden in developing countries (Muray and Lopez, 2003). A number of epidemiological studies have shown that indoor air from biomass fuel significantly increase the risks of COPD and ARI among women and children (Mishra, 2003; Kirk *et al.*, 2000; Bruce *et al.*, 2000). However, in most of these studies individual level exposure data, such PM2.5, are missing. Cooking with solid biofuel also substantially increases the risk of developing active tuberculosis (Misra *et al.*, 1997) and also causes eye problems. There is consistent evidence that indoor air pollution (IAP) increases the risk of childhood acute respiratory infections and there is also association with birth-weight, infant and perinatal mortality, pulmonary tuberculosis, some forms of cancer and cataract (ITDG, 2002). Although the risks are poorly identified, indoor air pollution may be responsible for nearly two million excess deaths in LDCs and around 4% of the global burden of disease (Bruce *et al.*, 2000).

In Bangladesh, India and Nepal, biomass fuel is the primary source of household energy for cooking. Recently, a study by Columbia University in Bangladesh showed that some rural women in Bangladesh are exposed to fine air particle (i.e., $PM_{2.5}$), of 32-5000 μg/m^3 from biomass, which is 70 times higher than the country's outdoor, health-based standard. The study shows strong associations between high levels of $PM_{2.5}$ and respiratory illness and reduced lung function among the study participants. Furthermore, the study also shows a strong association between biomass combustion and future risk of cancers (ITDG Report, 2001).

Dutta *et al.*, 2018 stated that women and children are disproportionately affected by health effects from Household Air Pollution (HAP). They further stated that exposure to air pollutants results in adverse pregnancy outcomes such as stillbirth, low birth weight, miscarriage, and retarded fetal growth. Khandker *et al.*, 2014 stated that improved cooking stove use reduces COPD and respiratory infection among children in rural communities in Bangladesh.

Summary

A range of modelling studies has been carried out for India, but similar studies are not available for Bangladesh, Nepal or Pakistan. In any case, there is a need for systematic approach to modelling air quality in cities, industrial and rural areas in all four countries, to identify national sources of air pollution. While there is anecdotal evidence relating to transboundary air pollution, there is clearly a need for a regional study of transboundary issues. This should address the sources of airborne particulate matter, and precursors for smog and ozone formation, as well as atmospheric chemistry processes, wind-borne transport and dispersion, and levels experienced in cities and rural areas throughout the region.

Studies of the contribution of different sources to emissions of air pollutants at a sector level have been carried out by national and international agencies. There is a need to carry out source apportionment studies using modelling techniques to inform understanding of the sources of ambient pollution concentrations in different cities and rural areas in each country. There is reasonable understanding of the health and environmental effects of exposure to air pollution, and the associated economic costs. It will be straightforward to apply this understanding to the results of air quality modelling studies to quantify and monetize the health benefits of interventions to improve air quality.

The health effects of exposure to indoor air pollution are difficult to quantify, but are known to be highly significant in Bangladesh, India and Nepal where the use of biomass for domestic cooking and heating is widespread. Further information is needed in relation to Pakistan. In these countries, a program should be implemented to reduce dependence on biomass by making alternative, cleaner fuels and sources of heat available.

Chapter 3

Institutional Framework

Bangladesh

Bangladesh has Ministry of Environment and Forest dealing with environmental issues and concerns, which leads the Department of Environment. Figure 6 provides an organogram of the Department of Environment, which shows that there is a national directorship for air quality management, reporting to the Director-General and Additional Director-General. It has twenty-one district offices in various districts which are controlled and managed by divisional and regional offices. This indicates that the organizational structures are in place to enable a high priority to be placed on strategic management of air pollution, if required, resources and expertise can be made available.

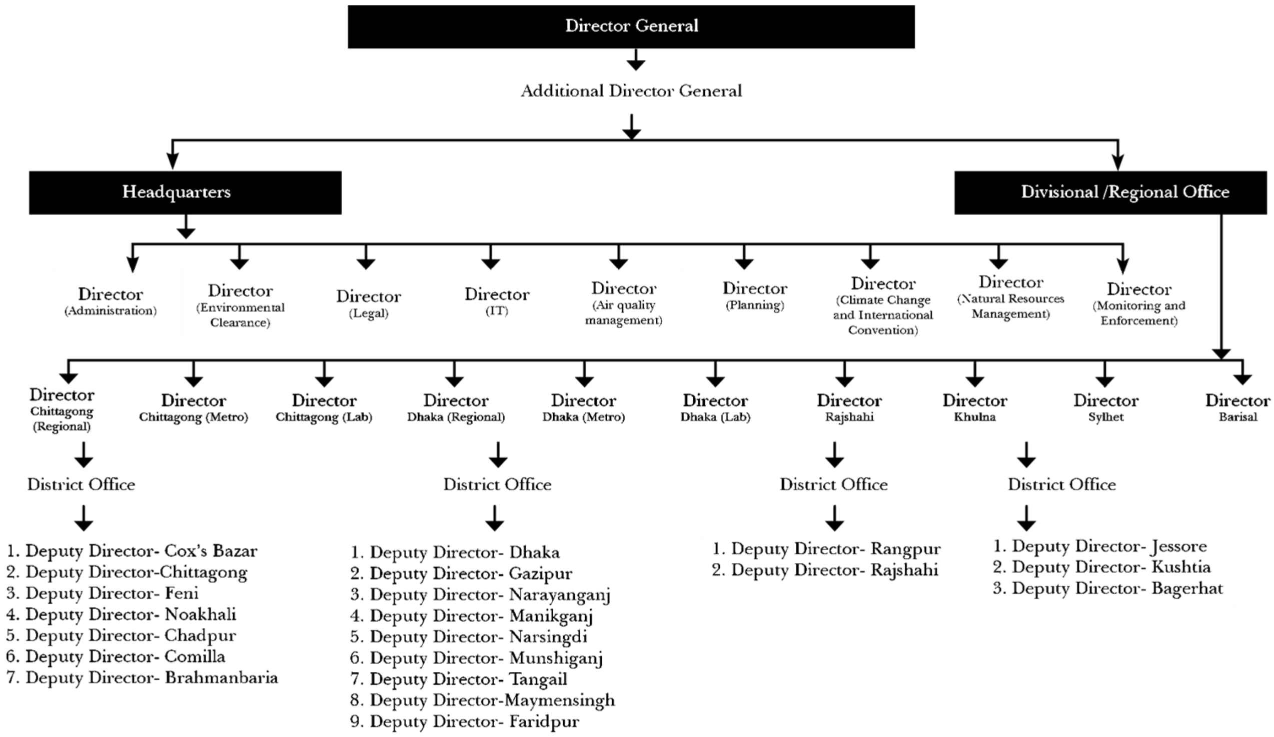


Figure 6 Institutional framework of Air Quality Governance in Bangladesh

Article 18A of the Bangladesh Constitution states that '*The State shall endeavour to protect and improve the environment and to preserve and safeguard the natural resources, bio-diversity, wetlands, forests and wild life for the present and future citizens.*" From time to time, the High Court gives directions or verdicts, such as a judgment and order directing the Government to phase out all three wheelers with two-stroke engines from Dhaka within 2002 and to replace them with clean transport alternatives. The Government's petition for leave to appeal against the said order was rejected by the Appellate Division (Civil Petition for Leave to Appeal No. 749 of 2002).

The Environment Conservation Act, 1995 and the Environment Conservation Rules, 1997have been enacted by the Parliament. Under the Rules of 1997, Ambient Air Quality Standards, Vehicular Exhaust Emission Standards, River Transport (Mechanized) Emission Standards and Gaseous Emission for Industries or Projects Standards have been set. The Environmental Conservation Act, 1995 also contains laws as regards the protection of environmental health and control of environmental pollution. The Supreme Court in two cases held that the “right to life”, which is enshrined as a fundamental right, includes the right to a healthy environment. The Bangladesh Judiciary and courts have a role in ensuring enforcement of emission standards and air quality standards.

India

India has a federal governmental structure. It has a nationally elected Central Government and a government at the State/province levels which is further divided into municipalities, corporations etc. There are strong linkages between the Central and State Governments for governance and implementation of various Laws and Acts. The Ministry of Environment, Forests and Climate Change (MoEF&CC) is the nodal agency in the administrative structure of the Central Government for the planning, promotion, co-ordination and overseeing the implementation of India’s environmental and forestry policies and programmes. The primary concerns of the Ministry are implementation of policies and programmes relating to conservation of the country’s natural resources including its lakes and rivers, its biodiversity, forests and wildlife, ensuring the welfare of animals, and the prevention and abatement of pollution. While implementing these policies and programmes, the Ministry is guided by the principle of sustainable development and enhancement of human well-being. Ministry formulates policies and enacts legislation at the national level. MoEF, CPCB, and SPCBs form the regulatory and administrative core, while other ministries and bodies are also involved through various functions, policies, and schemes to promote AQM. In addition, there is a network of government and nongovernmental institutions, organizations and laboratories involved in monitoring, reporting, and conduct of AQM studies. The institutional framework to control air pollution in India is given in Figure 7.

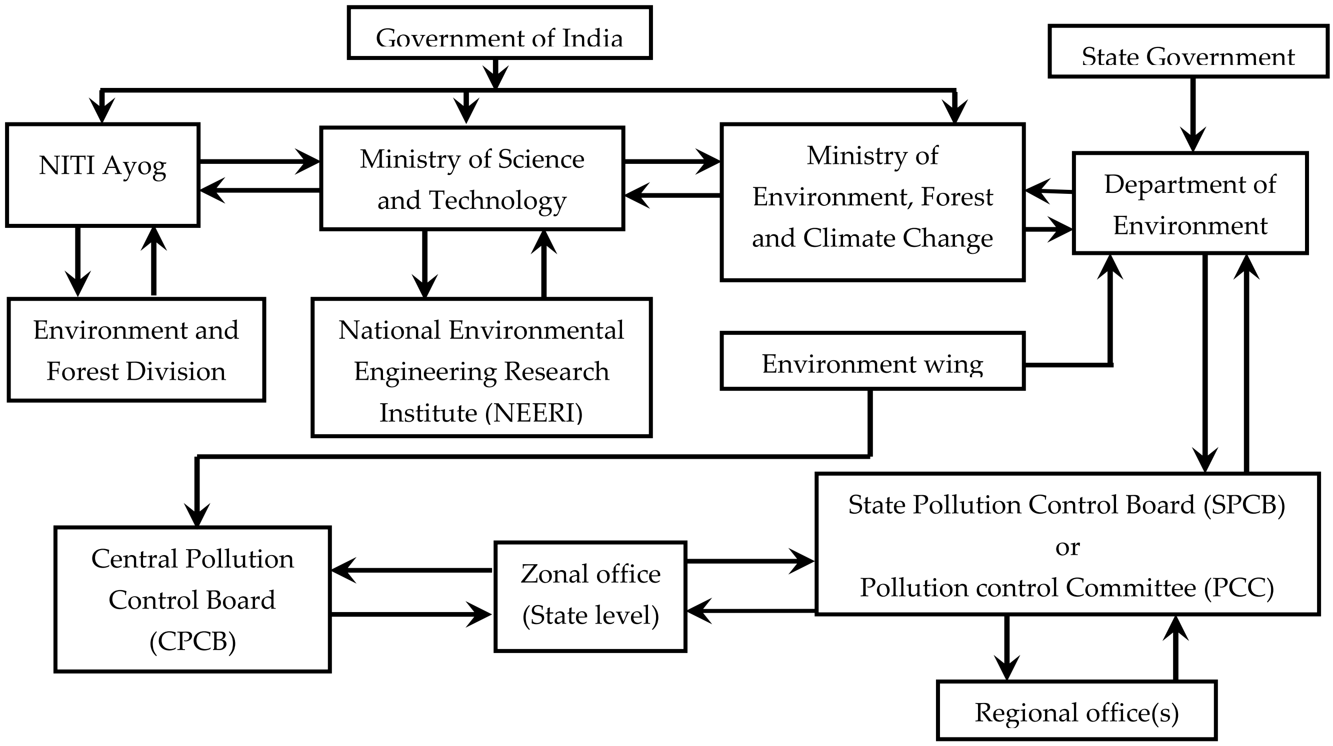


Figure 7 Institutional framework of Air Quality Governance in India

The guidelines for carrying out ambient air quality monitoring were developed by CPCB under the Air (Prevention and Control of Pollution) Act 1982, Environment (Protection) Act 1986, and the Environment (Protection) Rules 1986 with intent to provide a comprehensive document that elaborates a standard methodology to be followed by agencies involved in monitoring (CPCB Guidelines for Ambient Air Quality Monitoring, 2003). Initially NAMP had its focus on four air pollutants viz., Sulphur Dioxide (SO_2), Oxides of Nitrogen as NO_2, Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter or Particulate Matter of less than 10µ size (commonly called PM_{10} or RSPM). In 2009, a revision of National Air Quality Standards of India was published by MOEF with the aim of redefining NAMP as a health centred initiative (CPCB Revised National Ambient Air Quality Standards, 2009). The revised standards merged industrial, residential and rural areas with a uniform air quality standard as opposed to lower permissible limit for industrial locations in the previous version. This change was accompanied by addition of a second category of location which was designated as ecologically sensitive areas. Additionally, other pollution parameters such as $PM_{2.5}$, Ozone, Ammonia (NH_3), Benzene, Benzo-α-pyrene (BaP) , Arsenic (As) and Nickel (Ni) were added to the existing list considering toxic nature of these pollutants.

Nepal

Nepal has adopted federalism in 2015 and hence, it is in transition for converting its institutional framework to a federal multi-level political system. Up till now, the framework implemented in Nepal is provided in Figure 8. The Environment Protection Council's role is to provide guidance and suggestion to Government of Nepal. The Ministry of Forests and Environment promulgates policies and measures to control air quality problem and the Department of Environment is responsible for the implementation of these policies. The role of Environmental Pollution Control and Monitoring Section is to monitor the implementation and air quality status in the country.

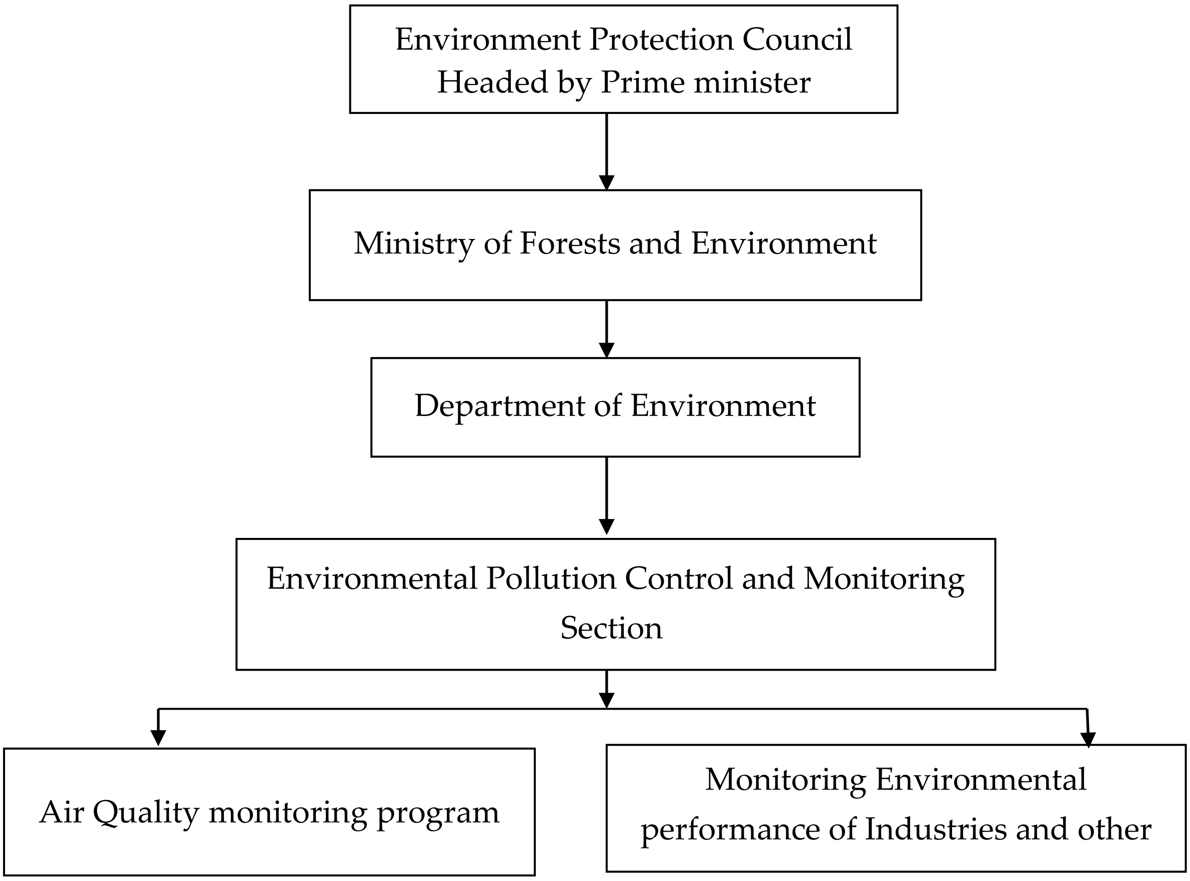


Figure 8 Institutional framework of Air Quality Governance in Nepal

Pakistan

The Environmental Protection Agency is the principal environmental regulatory agency in Pakistan, managed by the Ministry of Environment, which has been empowered by the Pakistan Environmental Protection Act (PEPA) 1997. Following the 18th amendment to the Constitution of Pakistan in 2010, provincial Environmental Protection Departments (EPD) became focal points for implementation of the environmental regulations within each of the four provinces. These EPDs are also responsible for the designing of the air quality networks and monitoring the air quality.

The 18th amendment has resulted in a gap between federal and provincial government. There is a lack of co-ordination between the provinces and the federal government. This produces a disconnect in policy and response. In particular, the provincial authorities do not consider the issue of trans-boundary pollution to be under their jurisdiction and hence do not take action on this issue.

This is exacerbated by a lack of expertise to deal with issues relating to air quality in the provincial authorities, and by a lack of monitoring and modelling data, resulting in disorganized and potentially misguided efforts to address air quality problems. Coordination among provinces and the federal government must be strengthened to address this problem.

Mapping of institutions and multilateral programs

In each of the countries, consultations were held with various stakeholders involving government departments, pollution control boards, academic and research institutes, NGOs, and international organisations which fund the multilateral and bilateral research projects, and individual experts. Some of the organisations consulted in each country are provided below. The South East Asian Regional (SEAR) Countries are committed to cooperate and coordinate for air quality monitoring and prevention of air pollution in the region under the Malé declaration. (Malé Declaration, 1998)[1]. Examples of programmes and projects funded through bilateral and multilateral agencies are also provided.

Bangladesh

No.	Sector	Name of Consultee organizations
1	Government department	Ministry of Environment, Forest and Climate Change (MoEFCC)*
2		Department of Environment, Government of Bangladesh
3.		Ministry of Power, Energy and Mineral Resources
4.		Ministry of Agriculture
5	International finance organization	The World Bank, Bangladesh
6		Asian Development Bank, Dhaka office
7	Academic/ research	Department of Geography and Environment, University of Dhaka
8		Air Quality Research and Monitoring Center, Dhaka University
9		Bangladesh University of Engineering and Technology (BUET)
10		Bangladesh University of Health Sciences, Daressalam, Mirpur
11		Bangabandhu Sheikh Mujib Medical University (BSMMU),

[1] Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia is an intergovernmental network involving Bangladesh, Bhutan, India, Iran, the Republic of Maldives, Nepal, Pakistan and Sri Lanka. It emphasizes the need for countries to carry forward, or initiate, studies and programmes on air pollution in each country of South Asia

12	Non-governmental organization	ICDDRB, Dhaka
13		WHO, Bangladesh Country Office
14		Bandhu Chula Foundation
15		**BELA:** Bangladesh Environmental Lawyer's Association

* NACOM has already visited DoE to provide a brief about this project, and obtained some information

The Government of Bangladesh has developed a well-structured Directorate General of Environment. This has resulted in priority being given to air pollution issues. The Directorate-General is expanding its offices at district level, and plans to establish an independent research unit. The number of continuous air monitoring stations has increased, and approval of a "Clean Air Act" is in the final stages.

Air quality activities in Bangladesh are supported by a range of funders and organizations. World Bank is providing technical and financial assistance to Bangladesh government for strengthening government's capacity in Ambient Air Quality monitoring via the Clean Air and Sustainable Environment (CASE) Project as described in the boxes below. The US-Embassy in Dhaka has its own continuous air monitoring station (CAMS) at Baridhara. General people have online access to US-CAMS. The CASE project is due to finish in the summer of 2019 and it will be important to ensure funding continues to be made available to ensure that the established monitoring network can be maintained.

Satkhira CAMS station is supported by Council of South Asian Co-operative Environment Program (SACEP) Bangladesh, Atomic Energy Commission (BAEC), University of Dhaka (DU), Bangladesh University of Engineering and Technology (BUET), International Center for Diarrhoeal Disease Research, Bangladesh (ICDDR) have their own air quality monitoring system and conducting research on air quality and its health effects. International organization like The World Bank (WB), World Health Organization (WHO), UK Department of Foreign and International Development (DFID), German International Cooperation (GIZ) and Regional office of South East Asian Countries (SEARO) are providing technical support to Bangladesh government to maintain air quality and research on health effects.

The organizations such as Forum of Environmental Journalists, Bangladesh Paribesh Andolon (BAPA), Bangladesh Environmental Lawyers' Association (BELA), and the Society for Urban Environment Protection (SUEP) are working to raise awareness among the people on air pollution issues through conferences, reports, and ad campaign. Academic institutions like BUET, Dhaka University (DU) and Jahangirnagar University (JU) are contributing for AQ monitoring, analysis and develop scientific report on air pollution in the country.

Examples of some bilateral and multilateral funded projects are provided below. As can be seen there is a significant amount of effort being spent on controlling emissions from cook stoves. There has also been some work funded by the World Bank looking at ways to reduce emissions from brick kilns and from transport as well as support air quality monitoring, analysis and reporting. In addition the Ministry of Environment, Forest and

Climate Change is currently negotiating with the World Bank for a new project on Comprehensive Environment of Bangladesh as a follow up of the CASE project by starting a TA project to formulate an investment programme for Bangladesh.

In addition to these projects a city focused project is due to start in May 2019. This is entitled Strengthening Knowledge and Actions for Air Quality Improvement funded by the Asian Development Bank. It was anticipated to cover seven cities across the region including Faridpur in Bangladesh. The work program is as yet unpublished, but the original terms of reference required: a) an assessment of the current air quality situation and management practices; b) evaluation of innovative cost-effective technological and policy options for addressing air quality; and c) development of City Level Clean Air Action Plans (CAAPs) along with investment estimates for air pollution control from key sources. The monitoring aspect of this project will involve the purchase of small numbers of low-cost monitoring technology units for deployment in cities where monitoring data are not currently available.

Examples of Bilateral and Multilateral Institutional Projects in Bangladesh

Clean Air and Sustainable Environment (CASE) Project	
Project Cost: 80.25 (Million USD) **Project Duration:** July-2009 to June-2019. **Implementing Agencies:** DOE, DCC (Dhaka City Corporation) and Dhaka Transport Coordination Authority (DTCA)	**Lead Agency:** Ministry of Environment, Forest and Climate Change (MoEFCC) **Donor Agency:** International Development Association, World Bank
Objective: Improve air quality and safe mobility in Dhaka through the implementation of demonstration initiatives in urban transport and brick making **Environmental Component** Strengthening the environmental agency's capacity and capability to effectively address air pollution issues and demonstrate the effectiveness and efficacy of new approaches for reducing air pollution emissions through application to the brick industry and the transport sector **Sub-component 1A:** Capacity building for air quality management (US$ 8.55 million) This sub-component will: (i) support the newly established Air Quality Cell (AQC) at DOE; (ii) improve air quality monitoring, data analysis and reporting; and (iii) improve standards, enforcement and control for emissions reduction. **Sub-component 1B:** Brick kilns emissions management. **Sub-component 1C:** Communication campaigns and analytical studies. **Transport Component** Support capacity building through technical assistance and demonstration initiatives in urban transport in Dhaka that will focus on reducing conflict between motorized and non-motorized transport (NMT) and congestion, as well as providing safe and better mobility for those who walk and use public transport. **Sub-component 2A:** Physical improvement of traffic flow and pedestrian mobility and Institutional strengthening and regulatory review. **Sub-component 2B:** Preparation of the bus route network rationalization and franchising and Institutional strengthening and regulatory review.	

Malé Declaration Activities in Bangladesh	
Project Cost: 5.0 (Million Taka) (60,000 USD) **Project Duration:** 2002- 2016 (Some activities are still going on). **Implementing Agencies:** DOE	**Donor Agency:** UNEP
Objective: Support implementation of activities in support of the Malé Declaration • Installation of a Trans-Boundary air pollution monitoring center at Sathkhira. • Conduct studies on health impact of air pollution. • Studies on Impact of Ozone on agricultural product	

Market Development Initiative for Bondhu Chula	
Project Cost: 5.50 (Million USD) **Project Duration:** 2012 - current **Implementing Agencies:** DOE and German International Development Organization (GIZ)	**Donor Agency:** Bangladesh Climate Change Trust (BCCT) and German International Development Organization (GIZ)
Objective: Distribution of improved cook-stoves and provision of after sales service to: reduce pressure on forest-resources, reduce indoor air pollution, minimize health risk and reduce emission of greenhouse gases. Through the initiative, around one million improved cook stoves (ICS) have been installed. Besides DoE and GIZ, some other organizations like Bangladesh Bondhu Foundation and Infrastructure Development Company Limited (IDCOL) have undertaken initiatives for installing ICS. Through these initiatives, a cumulative number of around 3.5 million ICSs have been installed in Bangladesh.	

Strengthening Institutional Capacity to Reduce Short Lived Climate Pollutants (SLCP)	
Project Cost: 15.0 (Million Taka) (178,000 USD) **Project Duration:** Jan 2016 – June 2018 **Implementing Agencies:** DOE	**Donor Agency:** Climate and Clean Air Coalition (CCAC)
Objective: Sustainably increase the level of action taken in Bangladesh to reduce SLCPs by further promoting the coordination and the scaling-up of activities to reduce SLCPs at national level as part of the CCAC SNAP (Supporting National Action and Planning) initiative. It also aims to increase the ability of the Govt. to attend and participate in decision making processes of the CCAC and its initiatives. The CCAC's Institutional Strengthening Support workstream was developed to fund personnel recruitment in beneficiary countries to build capacity to tackle their national short-lived climate pollutant issues and interact with the Coalition and other relevant international initiatives.	

Global Clean Cooking Programme	
Project Cost: 20.0 (Million USD) **Project Duration:** 2018 - 2021 **Implementing Agencies:** Infrastructure Development Company Limited (IDCOL) and World Bank	**Donor Agency:** Global Climate Facility and International Development Association, World Bank
Objective: Remove barriers in the development of a sustainable market for the adoption of	

improved cook stoves in Bangladesh. Currently only 3 to 5 percent of households in the country use improved cook stoves. The scaling up of investment in improved cook stoves will increase demand and help extend the existing supply chain. The project will provide technical assistance to support partner organizations and local entrepreneurs to produce improved cook stoves, raise awareness, and carry out research and development of the stoves.

India

No.	Sector	Name of Consultee organizations
1	Government department	Ministry of Environment, Forest and Climate Change
2		Ministry of Petroleum and Natural Gas
3		Ministry of Road Transport and Highways
4		Ministry of Heavy Industries and Public Enterprises
5		Ministry of Health and Family Welfare
6		Ministry of Agriculture & Farmers' Welfare
7		Ministry of New and Renewable Energy
8		Ministry of External Affairs
9		Central Pollution Control Board
10		State Pollution Control Boards
11	International finance organization	DFID Delhi office
12		World Bank, Delhi office
13		Asian Development Bank, Delhi office
14		UNDP, Delhi office
15		British Council
16	Academic/Research Institutes	Indian Institute of Technology (IITs)
17		National Institute of Technology (NITs)
18		Jawaharlal Nehru University
19		TERI School of Advanced Studies
20		Delhi Technical University
21		National Environmental Engineering Research Institute
22		Indian Institute of Tropical Meteorology
23	Non-governmental Research organization	WHO SE-Asia Regional office, Delhi
24		Council On Energy, Environment and Water (CEEW)
25		Automotive Research Association of India
26		Centre for Study of Science, Technology and Policy (CSTEP)
27		Clean Air Asia

Examples of Bilateral and Multilateral Institutional Projects in India

Atmospheric Pollution & Human Health in an Indian Megacity	
Project Cost: £13million **Project Duration:** 2017-2020 **Implementing Agencies:** IIT Delhi, NPL, Univ of Birmingham, Univ of Surrey, Univ of Newcastle, IITM, IIT-Madras, IIT Bombay, IRADe, IIT-Roorke, CEH, University of Hertfordshire	**Donor Agency:** ESSO-MoES and DBT from India and NERC and MRC from UK
Objective: The programme has been defined in terms of four science themes: • emission validation and sources • processes: physical and chemical • exposure validation and health outcomes • Mitigations and interventions	

Developing strategies for control of air pollution in India and its cities	
Project Cost: INR 6.87 crore **Project Duration:** 2018-2020 **Implementing Agencies:** TERI, Shakti Foundation	**Donor Agency:** Bloomberg Foundation
Objective: To develop strategies and inform non-legislative policy considerations for control of air pollution in India at the national and city-level 2. To promote better understanding and aware of air pollution issues in India at the national and city level 3. To build a network of experts on air quality issues to advise on and help develop strategies for mitigation and control 4. To help develop air quality tools (spatial maps, forecasting tools) and improve air quality management systems in 3-5 cities. assess the source contributions and strategies for control using the validated chemical transport model	

Clean Air Project in India (CAP India)	
Project Cost: INR 6.87 crore **Project Duration:** 2019-2027 **Implementing Agencies:** To be decided	**Donor Agency:** Swiss Agency for Development and Cooperation SDC
Objective: This project will contribute to India's new National Clean Air Programme, with the aim to improve air quality with co-benefits on public health, environment and climate change. Capacity building and technical assistance through Swiss expertise will support data measurement and analysis, city level clean air action plans and awareness raising campaigns to take precautionary measures and mitigate air pollution.	

Capacity Building for Industrial Pollution Management	
Project Cost: US$ 75.39 million **Project Duration:** 2010-2018 **Implementing Agencies:** Andhra Pradesh Pollution Control Board;Ministry of Environment, Forests & Climate Change;Telangana State Pollution Control Board;West Bengal Pollution Control Board	**Donor Agency:** World Bank
Objective: The objective of the Capacity Building for Industrial Pollution Management Project for India is: (i) to build tangible human and technical capacity in selected state agencies	

for undertaking environmentally sound remediation of polluted sites; and (ii) to support the development of a policy, institutional and methodological framework for the establishment of a National Program for Rehabilitation of Polluted Sites (NPRPS).

Nepal

No.	Sector	Name of Consultee organizations
1	Government department	Ministry of Environment
2		Ministry of Health
3		Ministry of Industry
4		Ministry of Energy and Transport
5		Nepal Health Research Council
6		Ministry of Energy, Water Resources and Irrigation
7		Ministry of Agriculture and Livestock Development
8		Department of Hydrology and Metrology
9	International finance organization	DFID, Patan
10		World bank, Kathmandu
11		Asian Development Bank, Nepal Resident Mission office
12		UNDP, Patan
13		British Council, Kathmandu
14	Academic/ Research	Department of Environment Science
15		Department of Hydrology and Metrology
16		Alternative Energy Promotion Center
17		Kathmandu University
18	Non-governmental organization	NTNC
19		ICIMOD
20		Practical Action
21		SusKat (Sustainable Atmosphere for the Kathmandu Valley)
22		Clean Energy Nepal

The project "A Sustainable Atmosphere for the Kathmandu Valley" (SusKat) (Rupakheti *et al.*, 2017) initiated by the Institute for Advanced Sustainability Studies (IASS) and the International Centre for Integrated Mountain Development (ICIMOD) aims at a better understanding of the observed severe air pollution in the Kathmandu Valley and its surroundings. Apart from ambient air quality monitoring, Ministry of Environment Science and Technology (MOEST) has also initiated monitoring of trans-boundary air pollution, with the support from ICIMOD and the United Environmental Programme (UNEP). This monitoring has also been in support of Nepal's commitment under the Male Declaration on Control and Prevention of Air Pollution and its Likely trans boundary Effects for South Asia. A monitoring station has been set up at the Institute of

Agriculture and Animal Sciences (IAAS), Rampur, Chitwan to monitor both air quality and rainwater chemistry (TSP, PM_{10}, SO_2, and NOx) and rainwater analysis to estimate pH, electrical conductivity, and concentration of anions (e.g. NO_3^-, SO_4^-) and cations (e.g. Ca^{2+} Mg^{2+}, K^+, Na^+). ICIMOD has also initiated a study "Project Atmospheric Brown Cloud (ABC)", which focuses on the impact of radiation on agriculture, water budget and health. Radiation measurement is conducted at the ICIMOD headquarters, which is also known as Nepal Climate Observatory.

Central Department of Hydrology and Meteorology (CDHM) started monitoring work since 2006. They have six monitoring stations in Simara, Siraha, Dhunche, Lumbini, Kirtipur and Mustang and they monitor $PM_{2.5}$ and Black carbon at these stations. Similarly, in frequent monitoring of black carbon is also been carried out at Institute of Engineering (IoE).

Examples of Bilateral and Multilateral Institutional Projects in Nepal

A Sustainable Atmosphere for the Kathmandu Valley (SusKat)	
Project Duration: 05/2012 to 12/2020	**Donor Agency:** Institute for Advance and Sustainable Studies (IASS), Postdam, Germany
Objective: It operates across five fields of activity: improving the scientific data basis, identifying measures to reduce risks, involving key stakeholder groups, developing scientific capacities, and raising awareness among policymakers and the public. The project is conceived in several phases, with the first two phases concentrating on the scientific evidence base and establishing initial ties as a platform bringing together the range of involved stakeholders. The third phase, which began in mid-2017, will focus on capacity building and stakeholder engagement to identify and support implementation of the most promising mitigation measures.	

Air quality monitoring of Kathmandu	
Project Duration: 2017-present	**Donor Agency:** US Embassy Nepal
Objective: Initiation and installation of air quality monitoring systems at two locations in Kathmandu Valley Result: There are 2 monitoring stations in Kathmandu and data is available online	

Pakistan

No.	Sector	Name of Consultee organizations
1	Government department#	Federal Environmental Protection Agency, Islamabad
2		Ministry of Energy
3		Ministry of National Food Security and Research
4		Balochistan EPA, Quetta
5		Sindh EPA, Karachi
6		Punjab EPA, Lahore
7		Khyber Pakhtunkhwa EPA, Peshawar
8		Urban Unit, Punjab Planning and Development Dept, Lahore

9	International finance organization	Japanese International Cooperation Agency (JICA), Islamabad
10		World Bank, Islamabad
11		UNDP, Islamabad
12		WHO, Islamabad
13	Academic/ research	University of Engineering and Technology, Lahore
14		National University of Science and Technology, Islamabad
15		NED University of Engineering and Technology, Karachi
16		University of Engineering and Technology, Peshawar
17	Non-governmental organization	WWF Pakistan (Lahore)
18		IUCN Pakistan (Islamabad and Karachi)
19		SDPI
20		Pakistan Air Quality Initiative (PAQI): An initiative of Pakistan Animal Welfare Society (Lahore)
21	**Individuals**	Ahmed Rafay Alam, Environmental Lawyer
22		Asif Shuja Khan, Former D.G, Federal EPA, Pakistan

After devolution in 2010, Environment became a provincial subject which means that each Province is responsible for its own initiatives under this realm. Hence it is important to speak to each department to get an understanding of their perspective on the topic.

Domestic efforts

Progress has been made domestically to tackle air quality issues. The Pakistan Environmental Protection Agency in 2010 formulated National Environmental Quality Standards for ambient air. After consideration and due consultative process, the Pakistan Environmental Protection Council sanctioned the standards. However, Pakistan's performance in achieving or even moving towards effective air quality management is poor, and lags behind other regional countries. The industrial sector of Pakistan is the largest energy user, and its share has risen over the last years. In order to monitor and keep track of the industrial pollution the federal government introduced the Self-Monitoring and Reporting Tool (SMART) program in 2001. The Pakistan Air Quality Initiative is a program which is aimed at generating awareness of the public about air pollution and a debate on compelling EPA to publish relevant data on sources and levels of air pollution.

In the five-year plan for 2005-2010, the government initiated the Pakistan Clean Air Program (PCAP) in order to tackle, reduce and manage air pollution. The program highlighted vehicular emissions, industrial effluents, burning of solid waste and natural dust as the primary contributors to air pollution. The program delineated actions of different levels of the government to tackle the issue of air pollution. However, actual work on the program was minimal and only moved forward after the Government of Japan provided a grant to monitor air quality (discussed further below).

The court system in Pakistan is taking a role in requiring action to be taken to improve air quality. In 2018, a petition was filed by a citizen to the Supreme Court of Pakistan, protesting about the worsening air pollution. The top judges ordered the government to submit to the Court the actions taken to tackle worsening air quality. As a result of the action, brick kilns operating on traditional methods were ordered to shut down their operations until the end of the year. Furthermore, the government reacted by permitting brick kilns using the cleaner "Zig zag" technology to keep operating without shutting down. A report was produced for the High Court by the Smog Commission which summarises the current state of knowledge and highlights a range of issues including industrial pollution control and agricultural residue burning. Lahore High Court pointed out that the construction of mega train lines has caused an increase in suspended dust particles plus with electricity shortages factories are burning bad fuel for power.

The Supreme Court and the High Court of Punjab province have intervened on the matter. The Chief Minister of Punjab had issued directives to establish committees to manage and report environmental pollution. The committees have been formed at district and Tehsil (sub-district) levels. The Chief Minister ordered that air quality monitoring equipment already stationed in different cities should be repaired. He stated that smog is disruptive to life and economy, and consequently a sustainable long-term smog policy was urgently needed.

International efforts

The Pakistan Clean Air Network (PCAN) was established in 2005 and is hosted by the International Union for Conservation of Nature (IUCN). Under an agreement with ADB in 2005, IUCN helped establish PCAN and serves as its secretariat. PCAN aims to address air quality issues in Pakistan and promote better air quality management practices. Among the key achievements of the network is the establishment of Clean Air Coordination Committees for Karachi and Peshawar as well as initiating efforts to establish a policy roadmap for upgrading fuel quality for motor vehicles. It is not clear how active this initiative is at the present time but the associated network of stakeholders could be useful for future projects.

The Japan International Cooperation Agency (JICA) provided 13.7 million PKR (95,000 USD) from 2006 to 2009 to reinforce the capability of Pakistan Environmental Protection Agency (Pak-EPA) and provincial-EPAs in implementing environmental monitoring of air and water quality. An air quality monitoring network was established in the five cities of Islamabad, Karachi, Lahore, Peshawar and Quetta which included: a) fixed and mobile air monitoring stations; b) a data centre; and c) a central laboratory. The project shut down in mid-2012 due to lack of funding to continue the operation and maintenance of the equipment.

In 2014 a report was published by the World Bank entitled "Cleaning Pakistan's Air Policy Options to Address the Cost of Outdoor Air Pollution". The book presents detailed research on Pakistan's air quality management (AQM) challenges. It describes the state of air pollution in Pakistan and, after considering the experiences of other countries with AQM programs, it identifies a comprehensive set of steps to improve

Pakistan's air quality. Many of these actions are still valid and are included in the section on recommendations in this report.

A new investment by the World Bank was approved in May 2018. This is the Punjab Green Development Program (see overview in box below). Under Result 1 the Program will support the Environmental Protection Department (EPD) of Punjab in improving its organizational structure, reforming its regulatory regime, and modernizing its administrative procedures and systems. This will include the creation of an Environmental Monitoring Center (EMC) with a network of air and water quality monitoring equipment and a reference laboratory; an Environmental Policy Center (EPC) to support sound environmental policymaking (for example, pollution management, resource uses, and climate mitigation/adaptation); and an Environmental Technology Center (ETC) to identify, pilot, and demonstrate Resource-efficient and cleaner production (RECP) and pollution control technologies for priority sectors and GHG sources. The goal is to have 30 operating air pollution monitoring stations by the end of the third year of the project (2021).

The Program will also support EPD in improving its procedures and systems, including environmental approval; grievance redress; environmental monitoring, inspection, and enforcement; interagency coordination; and environmental information disclosure and citizen engagement. TA and capacity-building activities will help strengthen the EPD's technical and administrative capacity and improve the capacity of other provincial departments to manage environmental and social issues. Finally, the Program will support industrial associations in developing their technical knowledge and understanding of available green/RECP technologies.

The Program will also tackle regulatory reforms by assisting in updating or establishing environmental policies, laws, and standards, including the following:

(a) Legislation. (i) Revision of the Environmental Protection Act 1997, and (ii) development of an environmental information disclosure and citizen engagement regulation.

(b) Policy initiatives. (i) Pollutant release and transfer register; (ii) pollution levy system; (iii) health advisory system targeting vulnerable groups (e.g., women and children); (iv) strategies for air/water quality and integrated waste management; and (v) development and implementation of a plastics management strategy and a regulation on the production and consumption of single-use plastics.

(c) Environmental standards. Revision of provincial environmental quality standards and development of new ones, including industry-specific standards.

(d) Studies. (i) Pollution impacts on public health, with a focus on vulnerable groups, including the poor, women, children, and the elderly;18 (ii) sustainable transport strategy, notably considering ways to improve vehicle fuel efficiency, promote public transport, and reduce traffic congestion and pollutant emissions; and (iii) green industrial and industrial estate development strategy.

Given the large contribution of vehicles to air pollution, the Program will support the strengthening of control over vehicle emissions. Specifically, the Punjab Transport Department will expand the scope of its existing public-private partnership (PPP) for the Vehicle Inspection and Certification System (VICS) to cover the entire fleet, including private vehicles. It will also study the institutional and regulatory framework needed to ensure that new vehicles comply with safety and emission standards, with a focus on rickshaw production. Finally, the Program will help EPD develop its capacity to test the emissions of new vehicle engines.

Finally, the Program will strengthen EPD's capacity to disclose environmental information and engage citizens in environmental management.

This program could be a huge step forward in air quality monitoring and management although the focus of the investment is in Punjab. Punjab is the most populous and industrialised Province in Pakistan and thus a good candidate for this project. However, the other Provinces all will have significant issues with air pollution and need to develop in parallel if at all possible.

As discussed in the Bangladesh section a new city focused project is due to start in May 2019. This is entitled "Strengthening Knowledge and Actions for Air Quality Improvement," and is funded by the Asian Development Bank. It was anticipated to cover seven cities across the region including Peshawar and Sialkot in Pakistan. The work program is as yet unpublished, but the original terms of reference required: a) an assessment of the current air quality situation and management practices; b) evaluation of innovative cost-effective technological and policy options for addressing air quality; and c) development of City Level Clean Air Action Plans (CAAPs) along with investment estimates for air pollution control from key sources. As noted in relation to Bangladesh, the monitoring aspect of this project will involve the purchase of small numbers of low-cost monitoring technology units for deployment in cities where monitoring data are not currently available.

Examples of Bilateral and Multilateral Institutional Projects in Pakistan

Punjab Green Development Program	
Project Cost: 200.0 (Million USD) **Project Duration:** 2018 - 2023 **Implementing Agencies:** Pakistan Environmental Protection Agency (Pak-EPA), Government of Punjab, Planning and Development Department of the Government of Punjab	**Lead Agency:** Planning and Development Department of the Government of Punjab **Donor Agency:** IDA, World Bank
Objective: To strengthen environmental governance and promote green investments in Punjab. **Result 1:** Strengthening environmental governance (a) average time to obtain Initial Environmental Examination (IEE) approval of investments with low safeguards risks, (b) stack emission and effluent discharge inspections carried out by EPA, and (c) disclosure of environmental information and citizen engagement.	

Result 2: Promoting green investments (a) volume of carbon emissions avoided from green investments, and (b) volume of new public and private capital leveraged for green investments.

Strengthening Knowledge-base and Actions for Air Quality Improvement	
Project Cost: 2.5 (Million USD) **Project Duration:** 2019 - 2021 **Implementing Agencies:** Asian Development Bank	**Lead Agency:** Not yet announced **Donor Agency:** Asian Development Bank
Objective: Enhance the knowledge and capacity of participating developing member countries (DMCs) to develop policy actions and technological solutions for air quality management. This TA will also build the business case through the preparation of City Level Clean Air Action Plans (CAAPs) along with investment plans to implement CAAPs. Possible participating cities are: Primary Cities: Erdenet (Mongolia), Peshawar (Pakistan) and Ha Noi or Ho Chi Minh (Viet Nam); and Secondary Cities: La Trinidad (Philippines), Faridpur (Bangladesh), Sialkot (Pakistan) and Vinh Yen (Viet Nam). These are still to be confirmed.	

National Ambient Air Quality Monitoring (NAAQM)	
Project Cost: 13.7 (Million PKR) (95,000 USD) **Project Duration:** 2006 - 2012 **Implementing Agencies:** Pakistan Environmental Protection Agency (Pak-EPA) and Provincial EPAs	**Lead Agency:** Pak-EPA **Donor Agency:** Japan International Cooperation Agency (JICA) assisted the Government of Pakistan
Objective: Reinforce the capability of Pak-EPA and provincial-EPAs in implementing environmental monitoring of air and water quality. Established an air quality monitoring network which included a) fixed and mobile air monitoring stations in five major cities of Islamabad, Karachi, Lahore, Peshawar and Quetta; b) a data center; and c) a central laboratory. The project shut down in mid-2012 due to lack of funding after the JICA support was phased out.	

Summary

There is at present no regional institution responsible for air quality with a focus on trans-boundary issues. It is recommended that a suitable regional institution, potentially under the auspices of the United Nations Economic and Social Commission for Asia and the Pacific, or the Male Declaration, should be set up with the support of all four national governments. The United Nations Economic Commission for Europe provides a model for carrying out a similar regional role in managing air pollution in Europe.

It is concluded that a national center of responsibility for dealing with air quality issues is likely to be the most effective means of delivering ongoing improvements in air quality. This approach has been found to be effective in delivering air quality improvements in jurisdictions as diverse as the European Union and People's Republic of China. While actions can be devolved to a sub-national or local level where appropriate, this is best delivered from a national level agency with appropriate authority to require action, backed up with technical, personnel and financial resources.

Chapter 4

Monitoring Network

Ambient Air Quality Monitoring Network

Bangladesh

Air pollution issue became public concern in the mid of 1990. Department of Environment (DoE), Government of Bangladesh is responsible for management of air pollution. DoE currently has offices at divisional levels and is planning to expand its activity at district levels (DoE Report: 2012) The government of Bangladesh launched the Air Quality Management Project (AQMP) on 26th September 2000 with assistance of World Bank (Annual report Air Quality Management Project: 2009). The project was extended to the end of 2006 and was further extended as AQM II for two years. AQMP II has now been renamed to Clean Air and Sustainable Energy (CASE).

Before 2002, the DoE used to measure total suspended particles (TSP) in a limited scale in different cities as part of their regulatory activity. With the inception of Air Quality Management Project (AQMP) in 2002, the DoE started measuring PM_{10} and $PM_{2.5}$ fraction of the PM and other criteria pollutants for regulatory purposes as mentioned in the New National Ambient Air Quality Standards (BGD, 1995). Since April 2002, the DoE is running a Continuous Air Monitoring Station (CAMS) at 11 locations (Figure 9). Monitoring capability of CAMS are Oxides of Nitrogen (NO), Carbon Monoxides (CO), Sulfur dioxide (SO_2), Ozone (O_3), Particulate Matter (PM) and methane and non-methane hydrocarbons (NMHCs). Data satisfy United States Environmental Protection Agency (US EPA) Federal Reference Method specifications—measures. Monitoring data from network stations are transferred to a central data center at the DoE office in Dhaka and concurrently database maintained by the designated officials for quality check, control, evaluation, validation and statistical analysis. Quality controlled data are then stored in the final database for further analysis, reporting, presentations and future use.

India

The basis of the present ambient monitoring programme in India was established by National Environmental Engineering Research Institute (NEERI) in 1967 which was later launched as National Ambient Air Quality Monitoring (NAAQM) programme by CPCB in 1984-85. The primary aim of NAAQM was to establish the status of ambient air quality across the country and formulate ways to manage and reduce concentrations of selected air pollutants to within permissible limits. The programme started with just seven monitoring stations in Agra and Anpara in Uttar Pradesh. Subsequently the progamme was renamed as National Air Quality Monitoring Programme (NAMP) and the air quality monitoring network was expanded from 28 to 456 monitoring stations during 1985 – 2011.

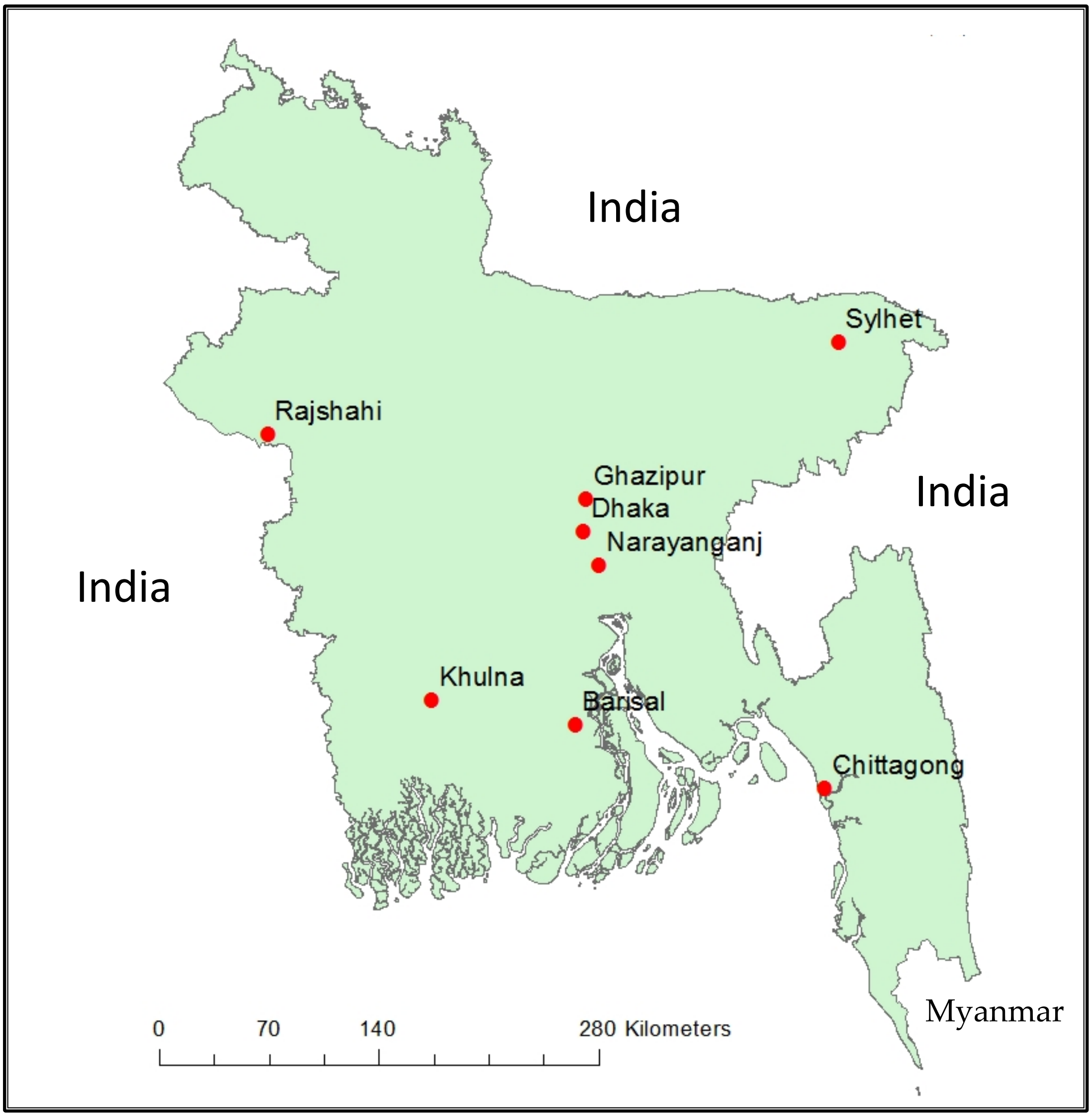


Figure 9 Ambient air quality monitoring network of Bangladesh. Official map of Bangladesh as provided by the Government of Bangladesh. Maps are used for representational purposes only, and the Government of UK does not necessarily endorse any geographical boundaries depicted in maps.

The current NAMP network is operating through the network consists of 731 operating stations covering 312 cities/towns in 29 states and 6 Union Territories of the country. There are 131 continuous monitoring stations installed in 69 cities. Figure 1 gives an overview of state-wise distribution of monitoring stations in India. The guidelines for carrying out ambient air quality (AAQ) monitoring were developed by CPCB under the Air (Prevention and Control of Pollution) Act 1982, Environment (Protection) Act 1986, and the Environment (Protection) Rules 1986 with intent to provide a comprehensive document that elaborates a standard methodology to be followed by agencies involved in monitoring (CPCB Guidelines for Ambient Air Quality Monitoring, 2003). Under N.A.M.P., four air pollutants *viz.*, Sulphur Dioxide (SO_2), Oxides of Nitrogen as NO_2, Respirable Suspended Particulate Matter (RSPM / PM_{10}) and Fine Particulate Matter ($PM_{2.5}$) have been identified for regular monitoring at all the locations. Meteorological parameters such as wind speed and wind direction, relative humidity (RH) and temperature were also monitored along with air quality parameters.

The monitoring of pollutants is carried out for 24 hours (4-hourly sampling for gaseous pollutants and 8-hourly sampling for particulate matter) with a frequency of twice a week, to have one hundred and four (104) observations in a year. The monitoring is being carried out with the help of Central Pollution Control Board; State Pollution Control Boards; Pollution Control Committees; National Environmental Engineering Research Institute (NEERI), Nagpur. CPCB co-ordinates with these agencies to ensure the uniformity, consistency of air quality data and provides technical and financial support to them for operating the monitoring stations. NAMP is being operated through various monitoring agencies. Large number of personnel and equipment are involved in the sampling, chemical analyses, data reporting etc. It increases the probability of variation and personnel biases reflecting in the data, hence it is pertinent to mention that these data be treated as indicative rather than absolute.

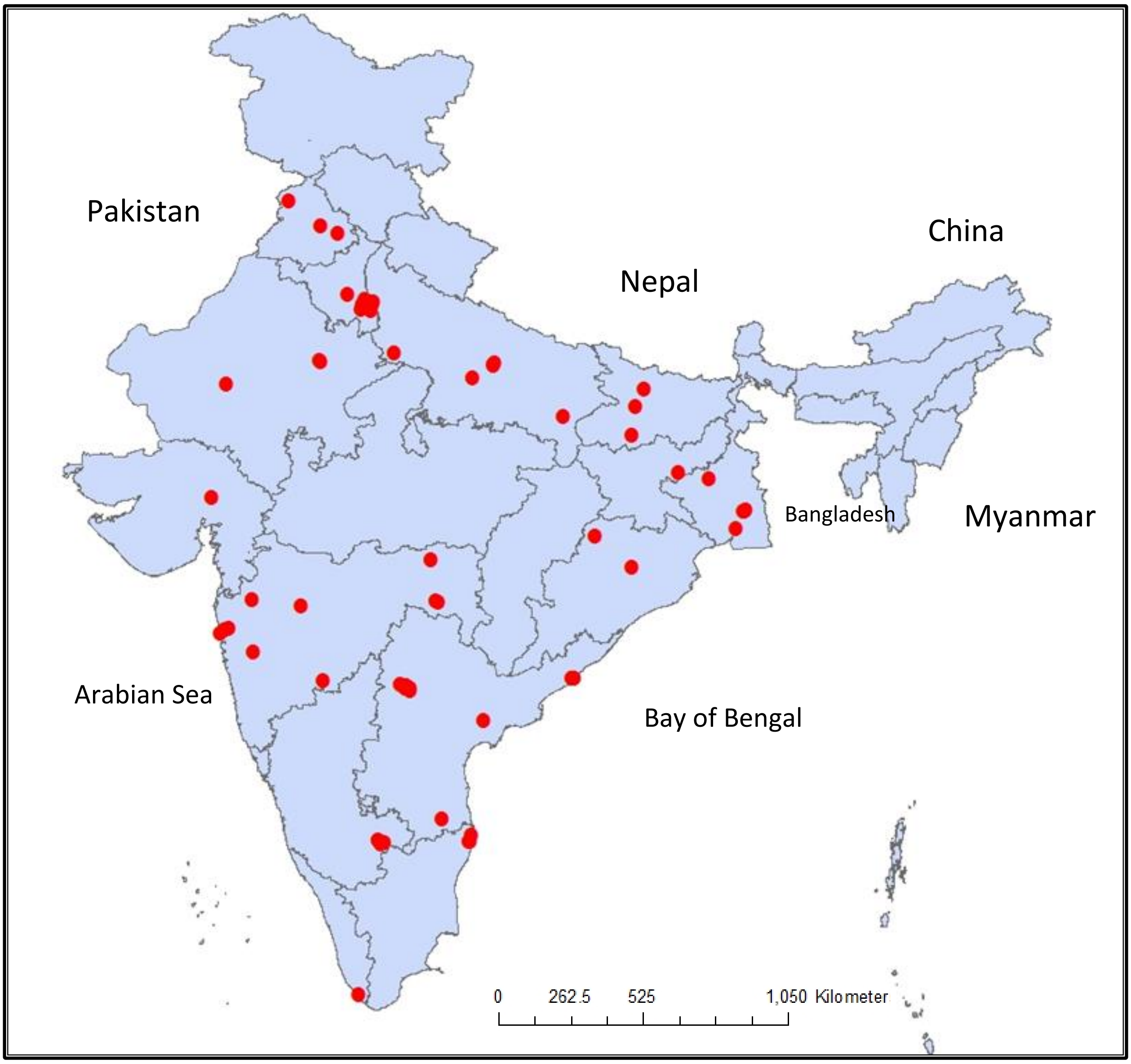


Figure 10 Continuous ambient air quality monitoring network of India. Official map of India as provided by the Government of India. Maps are used for representational purposes only, and the Government of UK does not necessarily endorse any geographical boundaries depicted in maps.

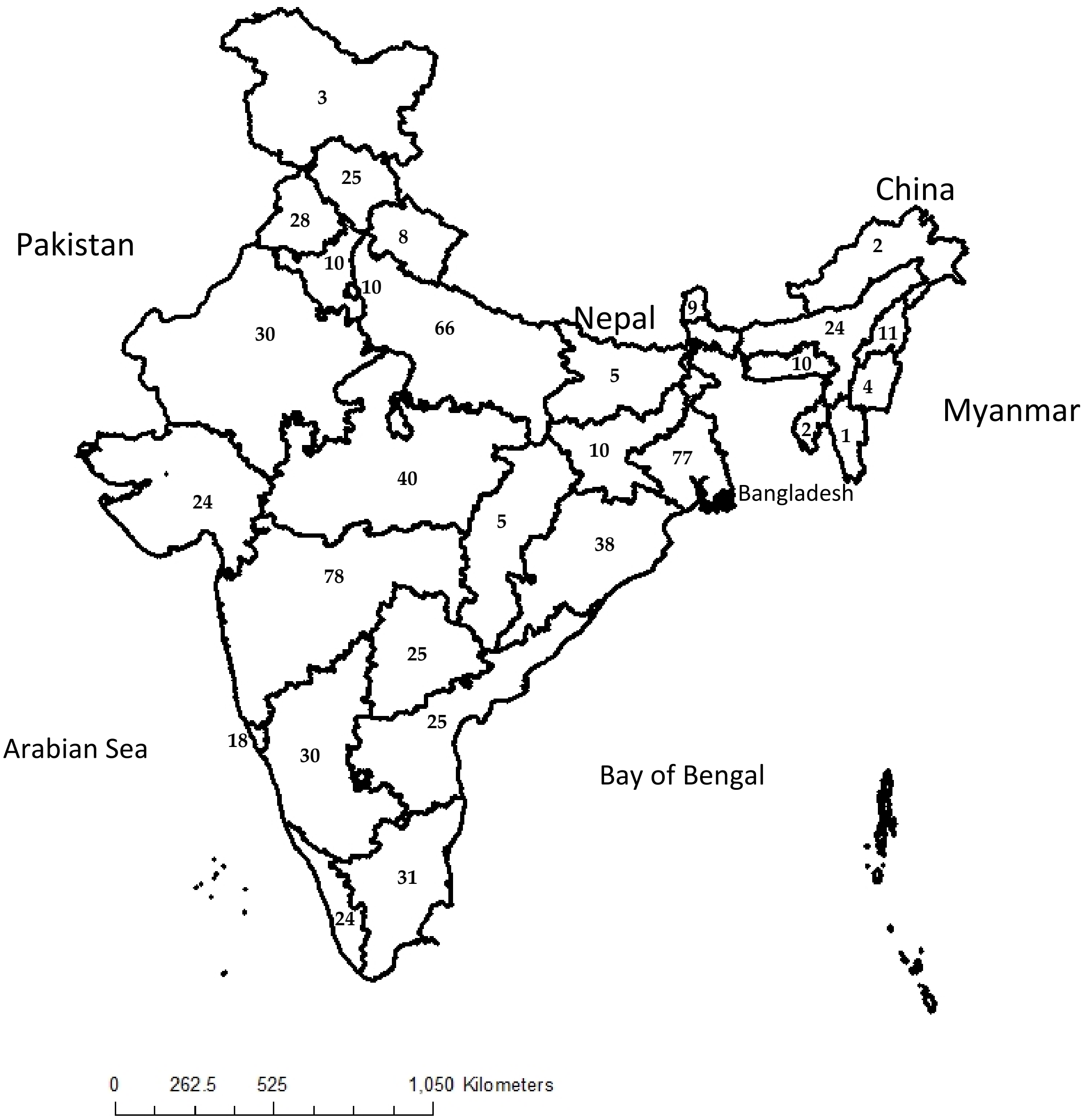


Figure 11 Manual ambient air quality monitoring network of India. Official map of India as provided by the Government of India (Numbers indicate the number of stations in each state). Maps are used for representational purposes only, and the Government of UK does not necessarily endorse any geographical boundaries depicted in maps.

Nepal

Prior to the creation of the Ministry of Population and Environment (MOPE) in 1995, no agency was assigned to monitor the quality of air in Nepal. Monitoring at that time was conducted on an ad hoc or project basis in Kathmandu, as well as in neighbouring municipalities. Routine air quality monitoring is only available for the Kathmandu Valley area. Air quality monitoring outside the Kathmandu Valley is still conducted only on project basis. In late 90s and early 2000s, with increasing public concerns on the deteriorating air quality in the valley, Ministry of Population and Environment with support from DANIDA established the permanent air quality monitoring system with six permanent stations- 2 as roadside stations (Putali Sadak and Patan Hospital), 1 residential station (Thamel), 2 urban background stations (Bhaktapur and Kirtipur) and 1 background station (Matsyagaon).

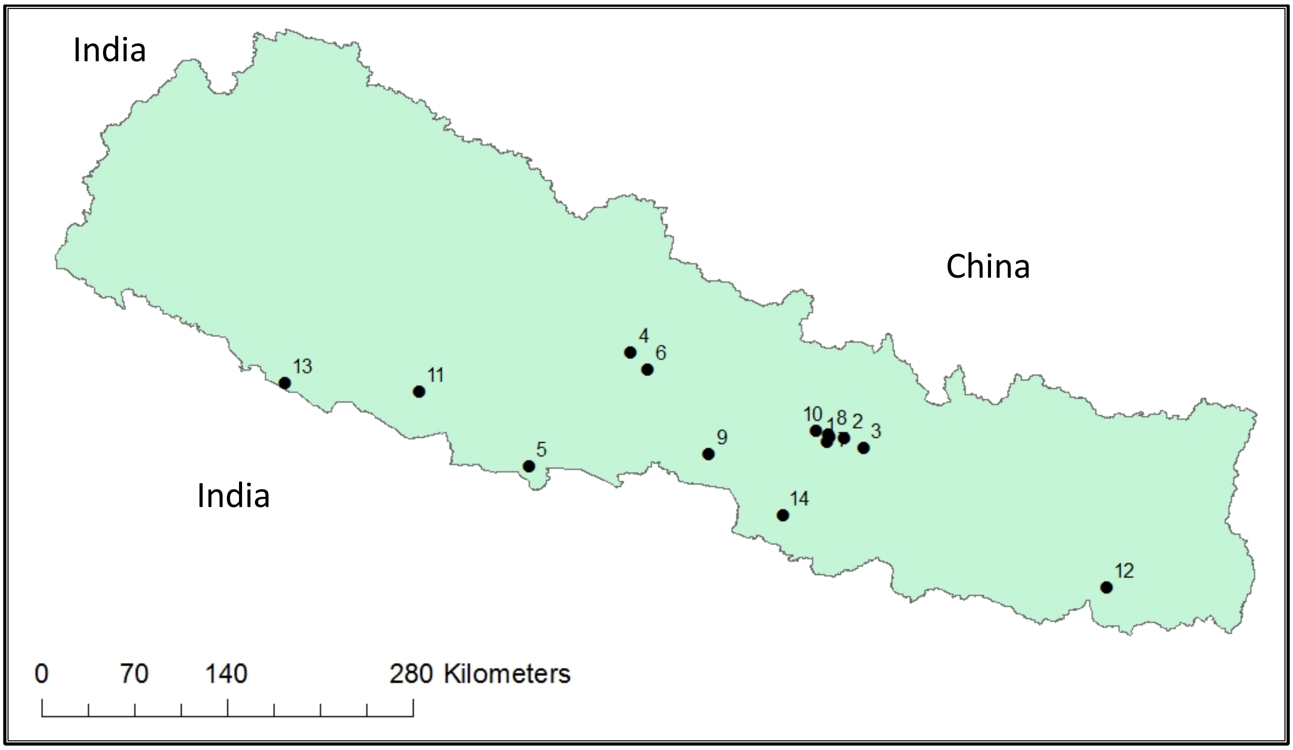


Figure 12 List of ambient air quality monitoring stations in Nepal. Official map of Nepal as provided by the Government of Nepal. Maps are used for representational purposes only, and the Government of UK does not necessarily endorse any geographical boundaries depicted in maps.

This system started in 2002 continued till 2006 and the monitoring data are available for (particulate matter (TSP, PM_{10} and $PM_{2.5}$), Carbon monoxide (CO), Nitrogen dioxide (NO_2), Sulfur dioxide (SO_2), and Benzene) at all six stations. In 2013, the Ministry has resumed air quality monitoring in three of the stations: in Bhaktapur, Machhegaun and Putalisadak by measuring PM_{10} levels on a daily basis. Currently with the initiation of Department of Environment supported by ICIMOD, US Embassy and other organizations 14 monitoring stations are in function which collect data on $PM_{2.5}$ from different part of the country.

S.No.	Station	Parameters
1	Gandaki Boarding School, Pokhara	-
2	Sauraha, Chitwan	TSP, PM_1, $PM_{2.5}$, PM_{10}
3	Simara, Bara	TSP, PM_1, $PM_{2.5}$, PM_{10}
4	Shankha Park, Kathmandu	-
5	Birendra School, Bhaktapur	-
6	Lumbini, Rupandehi	-
7	Dhulikhel, Kavre	-
8	Ratnapark, Kathmandu	TSP, PM_1, $PM_{2.5}$, PM_{10} and Black carbon
9	Nepalgunj	TSP, PM_1, $PM_{2.5}$, PM_{10}
10	Bhaisepati, Kathmandu	TSP, PM_1, $PM_{2.5}$, PM_{10}
11	Pokhara University, Pokhara	TSP, PM_1, $PM_{2.5}$, PM_{10}
12	Dang	TSP, PM_1, $PM_{2.5}$, PM_{10}
13	Jhumka, Sunsari	-
14	Pulchowk, Lalitpur	TSP, PM_1, $PM_{2.5}$, PM_{10}

Pakistan

In 2006, the first Environmental management system project was launched in the country with the support of the Japan International Cooperation Agency (JICA). The objective was to establish the basis for nationwide analysis of environmental pollution. The project was completed in three years at a cost of PKR 13.37 million. It established an air quality monitoring network which included a) fixed and mobile air monitoring stations in five major cities of Islamabad, Karachi, Lahore, Peshawar and Quetta; b) a data center; and c) a central laboratory. The project shut down in mid-2012 due to lack of funding after the JICA support was phased out. Since 2012, there has been no national air quality monitoring programme. However, due to smog issues Lahore has restarted its monitoring program. And while AQI data is being published on Punjab Environmental Protection Department website, there have been periods during which data was not made available.

National Air Quality Standard

Ambient Air Quality Standard

Bangladesh

The first set of ambient air quality standards for Bangladesh was defined in the Environment Conservation Rules of 1997. The new standards for Particulate Matter (PM_{10}, $PM_{2.5}$), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and ozone (O_3) are almost the same as the ambient air quality standards set by US EPA and by WHO, hence its standards are most stringent in terms of some pollutants as compared to other three countries.

India

Initially NAMP had its focus on four air pollutants viz., Sulphur Dioxide (SO_2), Oxides of Nitrogen as NO_2, Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter or Particulate Matter of less than 10μ size (commonly called PM_{10} or RSPM). Other pollutant parameters included Carbon Monoxide (CO), Ammonia (NH_3), Respirable Lead, Hydrogen Sulphide (H_2S) and Polycyclic Aromatic Compounds (PAHs) which were monitored at selected stations across the country by State Pollution Control Boards (SPCBs), Pollution Control Committees in respective Union Territories, other partnering agencies such as NEERI, Visveshwaraya Regional Engineering College, Nagpur and Pune, Pune University, Karmveer Ravsaheb Thorat Kala, Bhausaheb Higher Commerce and Annasaheb Murkute Science) College, Nasik and Walchand Institute of Technology, Solapur. In 2009, a revision of National Air Quality Standards of India was published by MOEF with the aim of redefining NAMP as a health centred initiative (CPCB Revised National Ambient Air Quality Standards, 2009). The revised standards merged industrial, residential and rural areas with a uniform air quality standard as opposed to lower permissible limit for industrial locations in the previous version. This change was accompanied by addition of a second category of location which was designated as ecologically sensitive areas. Additionally, other pollution parameters such as $PM_{2.5}$, Ozone, Ammonia (NH_3), Benzene, Benzo (a) pyrene (BaP), Arsenic (As) and Nickel (Ni) were added to the existing list considering toxic nature of these pollutants.

Table 1 Comparison of ambient air quality standards of different countries

Pollutants		India	Bangladesh	Pakistan	Nepal	WHO
Sulphur Dioxide (SO_2)	**Annual**	50 μg/m³	80 μg/m³	80 μg/m³	50 μg/m³	50 μg/m³
	24-hour	80 μg/m³	365 μg/m³	120 μg/m³	70 μg/m³	125 μg/m³
Nitrogen Dioxide, (NO_2)	**Annual**	40 μg/m³	100 μg/m³	40 μg/m³	40 μg/m³	40 μg/m³
	24-hour	80 μg/m³	-	-	80 μg/m³	-
PM_{10}	**Annual**	60 μg/m³	50 μg/m³	120 μg/m³	-	20 μg/m³
	24-hour	100 μg/m³	150 μg/m³	150 μg/m³	120 μg/m³	50 μg/m³
$PM_{2.5}$	**Annual**	40 μg/m³	15 μg/m³	15 μg/m³	-	10 μg/m³
	24-hour	60 μg/m³	65 μg/m³	35 μg/m³	50 μg/m³	25 μg/m³
Ozone (O_3)	**8-hour**	100 μg/m³	157 μg/m³	130 μg/m³	100 μg/m³	100 μg/m³
	1-hour	180 μg/m³	-	-	-	-
Lead (Pb)	**Annual**	0.5 μg/m³	0.5 μg/m³	1 μg/m³	0.5 μg/m³	-
	24-hour	1 μg/m³	-	1.5 μg/m³	-	-

Carbon Monoxide(CO)	**8-hour**	2 mg/m^3	9 ppm	5 mg/m^3	10 mg/m^3	10 mg/m^3
	1-hour	4 mg/m^3	35 ppm	10 mg/m^3	-	30 mg/m^3

Nepal

National Ambient Air Quality Standard (NAAQS) was introduced in 2003 and updated in 2012. These standards are generally more lenient compared with the updated 2005 WHO Guidelines; however, the NO2, CO, and Pb standards are comparable to the 2000 WHO guidelines. There is a lack of annual standards for particulate matter (TSP and PM10), which is a main pollutant of concern in Nepal. Ambient air quality standards were last revised in the year 2012, looking at the scale of air pollution problem in the country, it is urgently needed to revise the National Ambient Air quality standards at regular intervals.

Pakistan

The Pakistan Environmental Protection Agency in 2010 formulated National Environmental Quality Standards (NEQS) for ambient air. After consideration and due consultative process, the Pakistan Environmental Protection Council sanctioned the standards. In 2010, after the promulgation of the 18th amendment to the constitution of Pakistan the subject of environment was devolved to provinces. All four provinces now have their own environmental protection agencies and environmental legislation, based on the Pakistan Environmental Protection Act, 1997. The primary function of these provincial agencies is to administer and implement the policies stipulated by the PEPA. (Ahsan and Khawaja 2013). The environmental Acts notified by the provinces state that emission of effluent, waste, air pollutants, or noise pollutants exceeding standards of the NEQS are offences of the Acts and would be dealt accordingly. Pakistan improved its standards of ambient air quality of NEQS again in 2010 (and yet again in 2013) but these remain relatively less stringent. As with many other countries in the region, NEQS are less demanding than the standards of the World Health Organization.

Sectorial Emission Standard

Bangladesh

For Bangladesh, standards have been set out by Department of Environment. Discharges and emission due to construction and operation of brick kilns must comply with appropriate standards and limits that have been set out in the Environmental Conservation Rules 1997 (ECR 1997). Emission standard for particulate matter stipulated in schedule 11 of ECR 1997 is 1000 mg/Nm^3. In case of absence of other specific standards for brick projects, the standards and limits prescribed for industries is deemed applicable for the discharges and emissions arising from the brick activities.

The vehicle emission standards presently in force in Bangladesh were implemented from the Year 2005. The standards are in line with Euro 2 limits for the light duty vehicles and Euro 1 for the heavy-duty vehicles. The motorcycles and 3 – wheelers emission standards were based on the standards prevailing in South and South-East Asian countries. For ensuring that the reconditioned imported vehicles when manufactured would have met the standards specified for the new vehicles, simple inspection tests for CO and HC for the petrol/CNG vehicles and free acceleration smoke test limits for the diesel vehicles were also stipulated. The standards have been provided in *Annexure II*.

India

Transport, industries, power plants, DG sets etc. are major sources of pollution in Indian cities. As a result, emissions standards are formulated for these sources to reduce emissions and improve air quality. The legal provisions for the development of emission standards is set out under the Air (Prevention and Control of Pollution) Act, 1981, and further built upon in the Environment (Protection) Act, 1986. The standards have been provided in *Annexure II*.

Industries in India are monitored for adherence to emissions standards as prescribed by the Central Pollution Control Board under the Environment (Protection) Act, 1986. The industrial units are required to monitor the ambient air quality within their premises as well as the stack emissions. The exact locations of ambient and stack monitoring may be decided in consultation with the respective State Pollution Control Boards. The design of monitoring equipment must be approved by the CPCB (or SPCBs/PCCs). The first set of standards was developed for major industries including: Thermal power plant, cement plant, iron and steel industry, non-ferrous metallurgical industry, aluminium manufacturing industry, oil refinery, fertilizer industry. The CPCB has a system to prioritise the industries to be monitored more closely for emissions. The industries are given a colour code – 'Red', 'Orange', 'Green' and 'White', based on a number of factors including emissions of air pollutants, water pollutants, generation of hazardous waste, and consumption of resources. 'Red' being the most polluting category of industries, which should be monitored most closely.

The Vehicular emissions are regularly tested under the Pollution Under Control Program (PUC). The PUC system (for gasoline vehicles) first came into place in Mumbai in 1984. In practice, the testing is carried out under arrangements made by various regional transport offices (RTO) in each state. The implementation also depends on state rule. For example, vehicles are required to be tested four times a year for PUC in Delhi, but twice a year in most other states. The kinds of tests that a vehicle will be subjected to depends upon the type of fuel used by the vehicle (or type of engine). The vehicles using – gasoline, CNG and LPG (spark engine) are tested for CO and HC emissions. Moreover, these vehicles are also subjected to a lambda test; which is the air to fuel ratio in the tail pipe. The smoke emitted from diesel vehicles (compression engine) is subjected to a smoke opacity test.

Emission standards for diesel generators have also been notified as the gensets contribute to the pollution problem in urban area during periods of power failure (CPCB, 2017b). Nearly 70% of the total population of India lives in rural areas and do not have access to modern clean cooking energy such LPG and induction stoves. In order to address this problem MNRE launched an initiative in 1985 called the Indian National Programme for Improved Cookstoves (NPIC) which was renamed as National Biomass Cook-stove Initiative (NBCI) in 2009. Presently the programme was again renamed as Unnat Chulha Abhiyan, with some revised programme goals.

Nepal

Department of Environment (DoE) and Government of Nepal (GoN) has promulgated the standards/limit for emission from brick kilns industries in 2008. Furthermore, GoN has promulgated the standards/limit for emission from cement and crusher industries in 2012. There should be the arrangement of dust contamination removal and control units, wind breaking walls, metallic road, green belt and regular maintenance of sanitary condition within the industrial premises. Similarly, GoN has also promulgated the standards/limit for emission from industrial boilers on the basis of steam generation capacity in 2012. Besides, standard is also prescribed for chimney height calculation for industrial stacks.

GoN has promulgated the standards/limit for emission from vehicles in 2000 and there is a need to revise these standards as neighbouring countries have already adopted emission standards equivalent to higher euro norms to tackle the problem of air pollution from vehicles. However, emission standards are formulated only for CO and HC, while PM is also one of the main pollutants that is emitted by the transport sector. GoN has promulgated the standards/limit for emission for imported and operated diesel generators in 2012. The prescribed standards are similar to Euro III equivalent. The standards are prescribed in the basis of power rating of the diesel generator capacity. Ministry of Population and Environment, GoN has promulgated the standards for all biomass cook stoves including household and institutional stoves known as Nepal Interim Benchmark for solid biomass Cook stoves (NIBC) in 2016. For institutional cook stoves larger than 20 kW firepower, the emission testing requirements are optional. The standards have been provided in *Annexure II*.

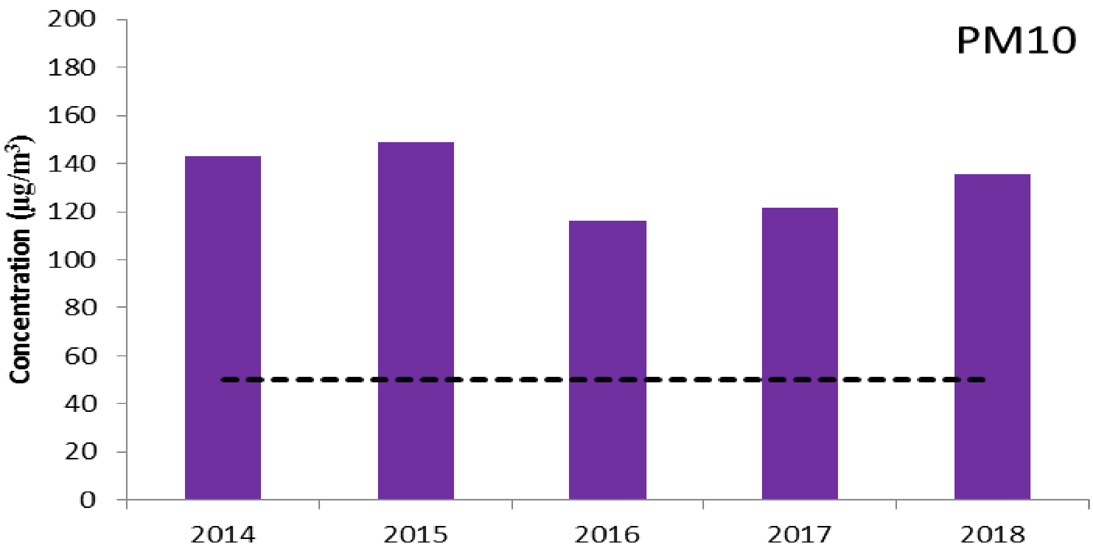
Pakistan

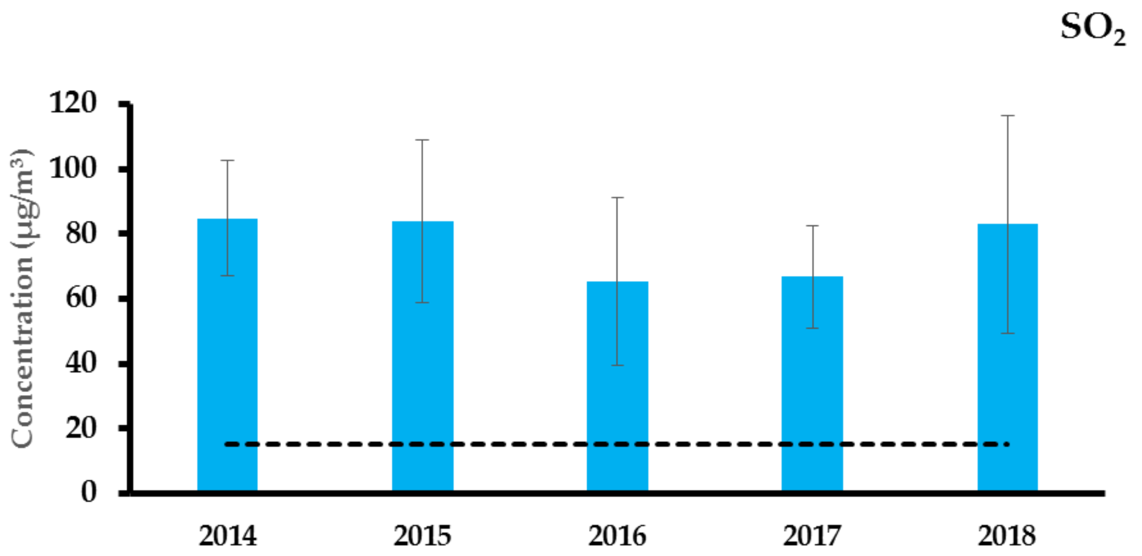
Under the Environmental Protection Ordinance, the National Environmental Quality Standards (NEQS) were notified for the first time in Pakistan in 1993. The NEQS established standards for effluents, pollution and air emissions (Ahsan and Khawaja 2013). In 1997, The Environmental Protection Ordinance of 1983 gave way to the Pakistan Environmental Protection Act (PEPA). The Act considered to be the bedrock of Pakistan's environmental legislation, stipulated that all effluents and polluting elements must be according to the standards set in the NEQS and its violation would be dealt with fines, business premises closure, imprisonment etc. depending on the nature and extent of the violation. The standards have been provided in *Annexure II*.

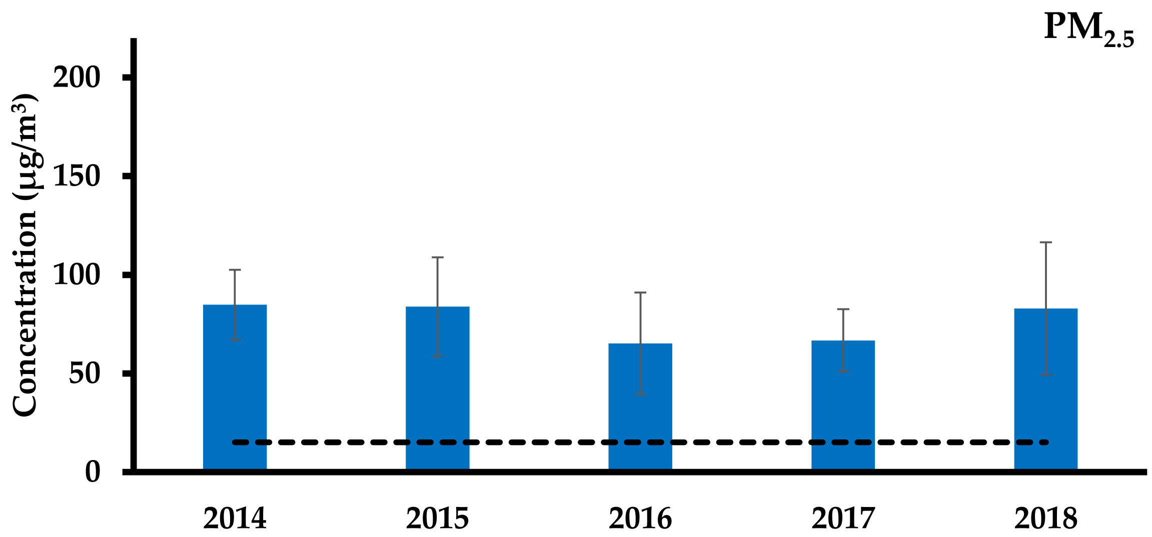
The Pollution Charges Rule, 2001, was introduced as a mechanism that would ensure participatory approach from industries, NGO's and public sector stakeholders to report and pay pollution charges. However, this initiative was not successful in influencing different sectors, posing a hindrance (Sánchez-Triana, 2014). In 2010, after the promulgation of the 18th amendment to the constitution of Pakistan the subject of environment was devolved to provinces. All four provinces now have their own environmental protection agencies and environmental legislation, based on the Pakistan Environmental Protection Act, 1997. The primary function of these provincial agencies is to administer and implement the policies stipulated by the PEPA. The environmental Acts notified by the provinces state that emission of effluent, waste, air pollutants, or noise pollutants exceeding standards of the NEQS are offences of the Acts and would be dealt accordingly.

Status of Ambient Air Quality

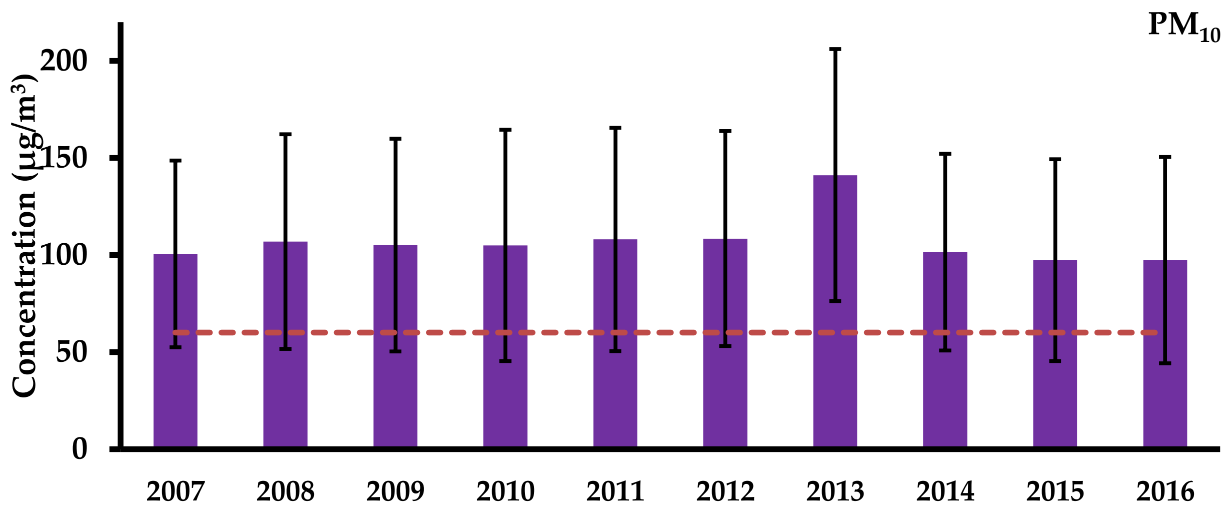
Bangladesh

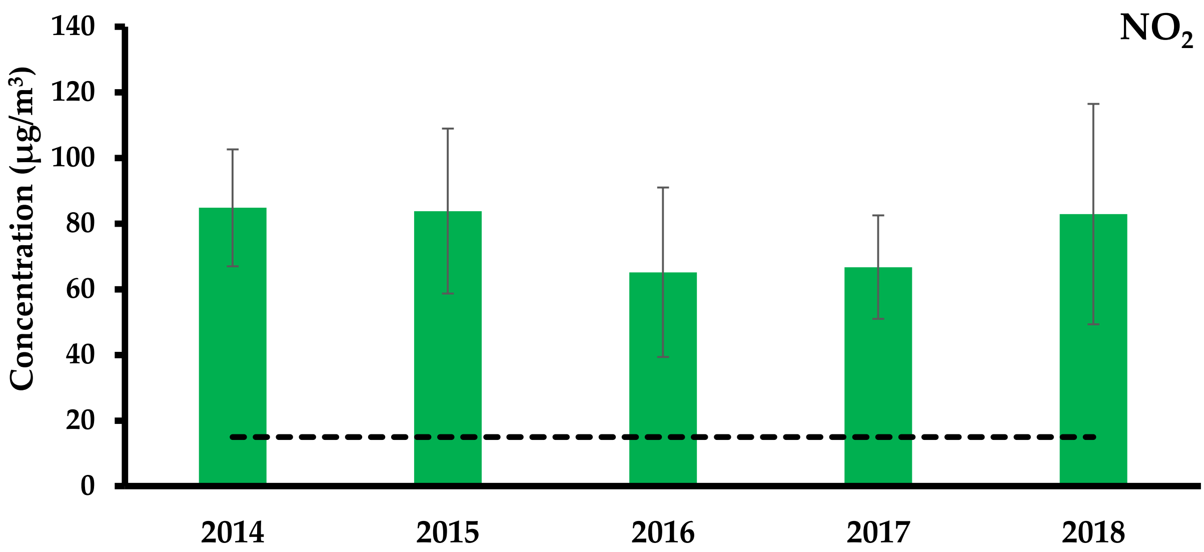


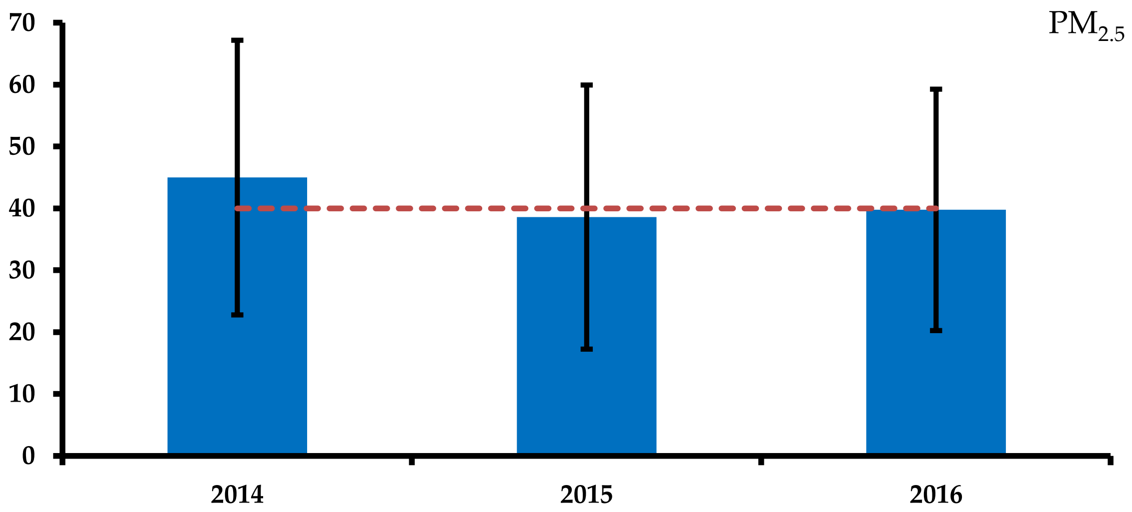

SO2
Concentration (µg/m3)
120
100
80
60
40
20
0
2014
2015
2016
2017
2018

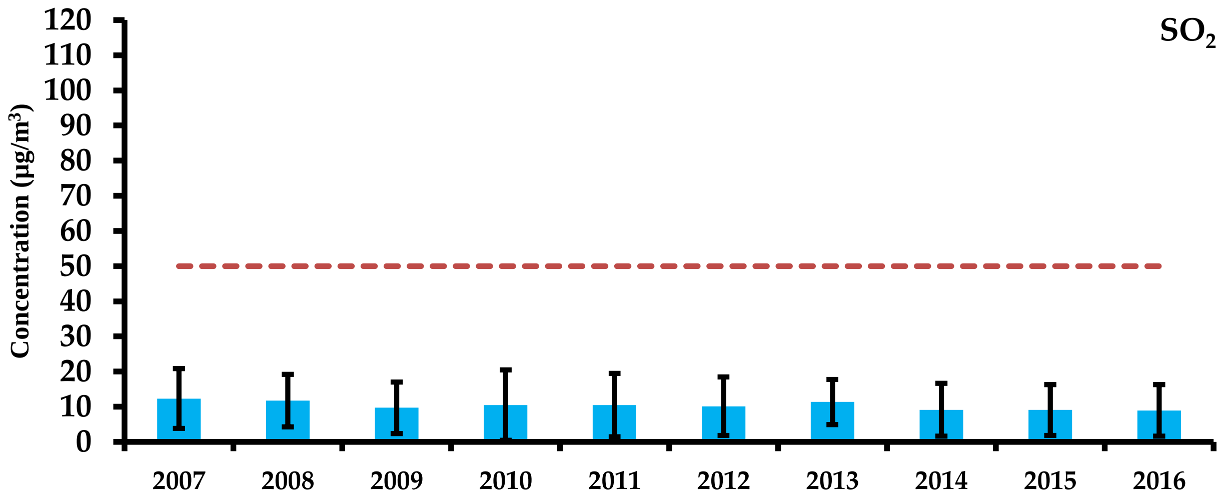

PM2.5
Concentration (µg/m3)
200
150
100
50
0
2014
2015
2016
2017
2018

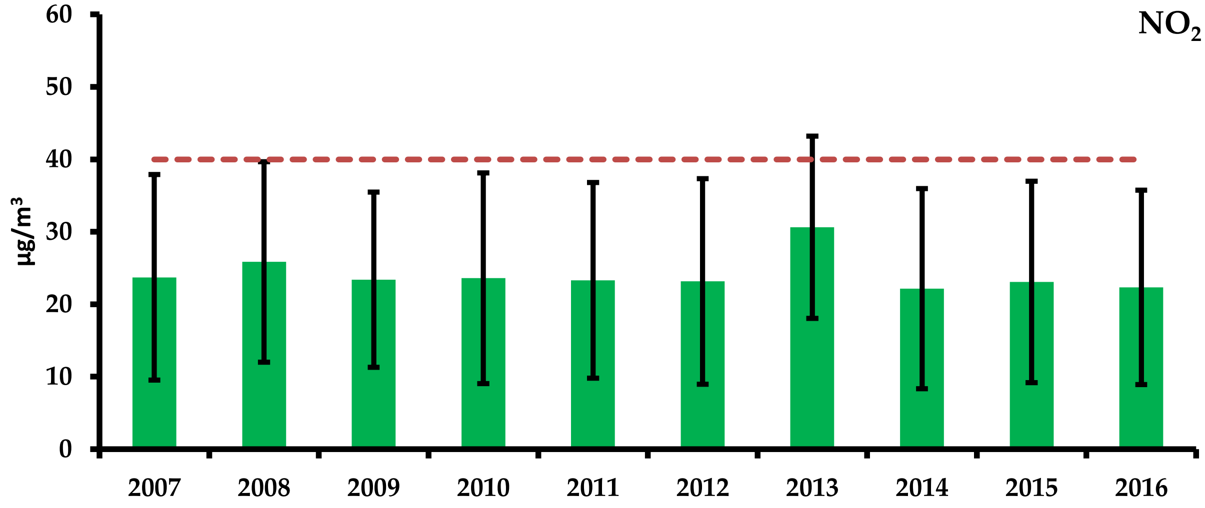
India


PM10
Concentration (µg/m3)
200
150
100
50
0
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016


NO2
Concentration (µg/m3)
140
120
100
80
60
40
20
0
2014
2015
2016
2017
2018

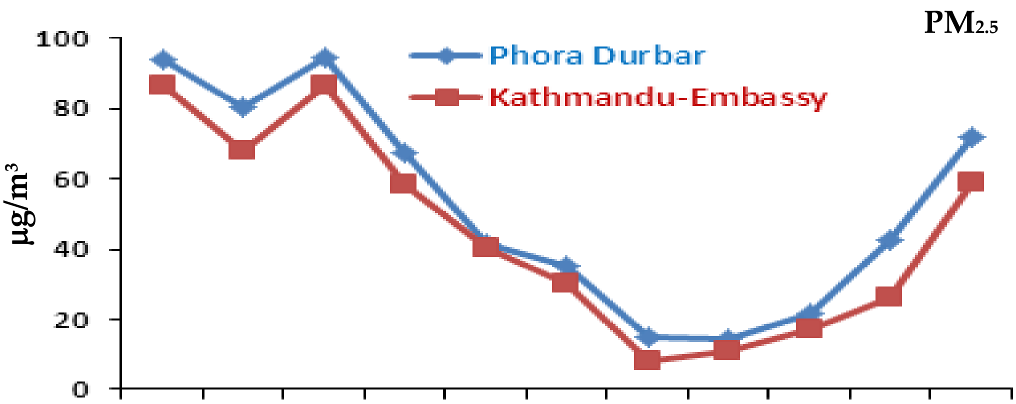

PM2.5
70
60
50
40
30
20
10
0
2014
2015
2016


SO2
Concentration (µg/m3)
120
110
100
90
80
70
60
50
40
30
20
10
0
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016



* Dotted line indicates NAAQS.

Nepal



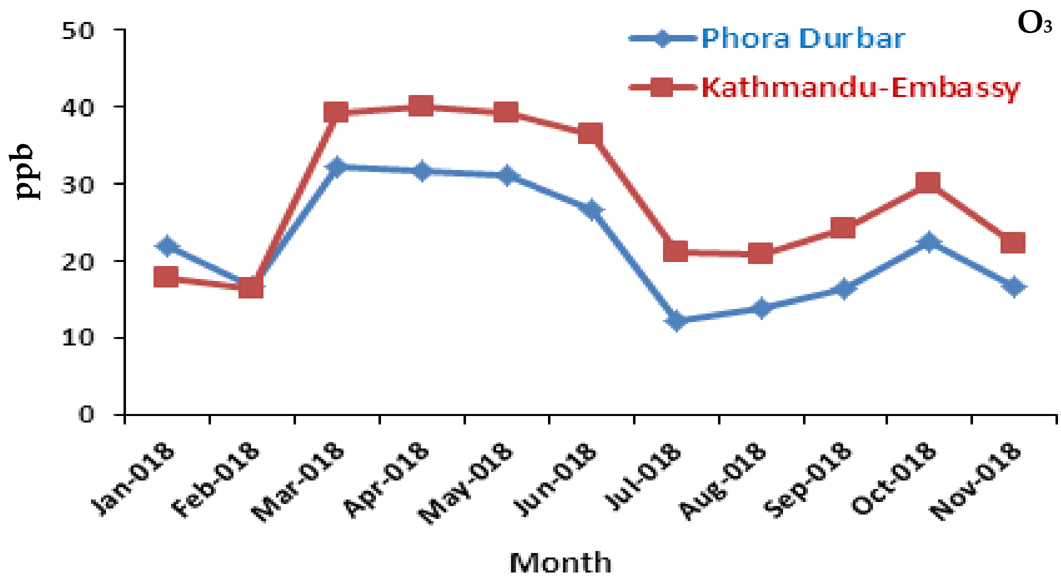


Figure 13 Ambient air quality trend in different countries

Summary

Regional: Monitoring carried out in all four countries indicates levels of airborne pollutants which are well above national standards and international guidelines. The issues are particularly acute for particulate matter (PM_{10} and $PM_{2.5}$), for which exceedances occur over much of the South Asia region. Fine particulate matter is also the pollutant which has the most significant effect on health. Levels of other pollutants, in particular nitrogen dioxide, ozone and sulphur dioxide, are also above national and international guidelines in zones throughout the South Asia region. The pattern of monitoring in each country is variable, but all valid monitoring data should be made publicly available.

Bangladesh: The Bangladesh Department of Environment has strengthened its air quality monitoring capacity, updated relevant laws and acts, continues to support increasing numbers of air quality monitoring stations, and coordinates with relevant governmental and non-governmental organizations. The DoE has set out emission standard for vehicles, industries and other sources of air pollution. The Bangladesh government has accepted WHO guidelines as the basis for the national Air Quality Index; but levels of air pollutants in Bangladesh continue to be well above the national standards and WHO guidelines.

India: Extensive monitoring is carried out in India, although the results can only be considered as indicative. A rationalization of the monitoring program to provide better quality measurements at fewer locations may be beneficial in delivering more valuable data on air quality.

Nepal: Limited air quality monitoring data is available for Nepal. Monitoring currently focuses in the Kathmandu area. While this is reasonable, as Kathmandu is by far the largest city in Nepal, extending the monitoring program to other cities and areas in Nepal would be beneficial.

Pakistan: Minimal air quality monitoring data is available for Pakistan. While there are initiatives to restart monitoring programmes in the largest cities of Pakistan, it is recommended that there is an urgent need for further investment in good quality air quality monitoring throughout the country. This will require investment in monitoring equipment, along with laboratories and other supporting services, and in recruitment and training of operational personnel.

Chapter 5

Policies Implemented

Policies and Reforms

Bangladesh

Bangladesh does not have a Clean Air Act, although an Act is currently being finalized. The primary legislation instituted to mitigate air pollution is the 1995 Bangladesh Environmental Conservation Act (ECA) and the 1997 Environmental Conservation Rules *(UNEP/SACEP/NORAD: 2001).* Government of Bangladesh has adopted a number of sector-specific policies and rules that impact on air pollution like the Environment Pollution Control Ordinance, 1977, Bangladesh Environment Conservation Act, 1995, The Environment Conservation Rule, 1997, Brick Burning Act, 1989, Bangladesh Environment Court Act. 2000, the Motor Vehicles Ordinance, 1983, and 2011. Besides, the Government has specific policies and plans on air quality, transport, energy and climate change e.g. Environment Policy, 1992, National Land Transport Policy 2004, Strategic Transport Plan 2005 and Bangladesh Climate Change Action Plan 2009. Department of Environment (DoE) is responsible for overall management of national level environmental pollutions. DoE currently has offices at divisional levels. With the growing concern of environmental pollution DoE is planning to expand its activity at district levels.

Historical Government Initiatives Fuel switching: Bangladesh Petroleum Corporation started a project to use Compressed Natural Gas (CNG) in vehicles instead of gasoline. The DoE has Enforcement Standards, and Pilot Control Programs Component- on Air Quality Monitoring and Evaluation. Dhaka City Corporation has initiated a project for improvement of the city traffic called *Dhaka Urban Transport Project (DUTP).* One possible constraint for adequate enforcement, and thus compliance with air quality rules, is the fines established in the 1995 ECA. The maximum fine for the most serious specified violations is imprisonment not exceeding 10 years or fine not exceeding 10 lac taka or both *(as amended by sec. 7 of Act 9 of 2002*).

On July 1999, the Government of Bangladesh executed the landmark decision of providing only unleaded gasoline. Other policy initiatives are Banning import of two-stroke engines, phase-wise plan to take two-stroke engine vehicles and old vehicles off the roads, promulgation of new laws and modification of old laws, Imposing extensive penalties on polluters and industries, motivating the public through promotional activities, increasing the number of public vehicles on the streets, improvement of city traffic management, improving the mass-transport system within the urban areas, and increasing parking facility, regular monitoring of the ambient air quality and vehicular emissions, public awareness campaigns. *Annexure: VI. Chronology of Policy: BW. 2018.*

Renewable Energy Target: the Bangladesh government has set a target to increase use of renewable energy and reduce Greenhouse Gas emissions. The balanced is reflected in Nationally Determined Contributions (NDC), which states an objective to reduce GHG emissions in the power, industry and transport sector by 5% below 'business-as-usual' by 2030 unilaterally and reduction of GHG up to 15% below 'business-as-usual' by 2030 if sufficient and appropriate support is received from developed countries (MoEF, 2018). The renewable energy targets for Bangladesh represent about 10% of total electricity generation, amounting to 2,470MW by 2021, and 3,864MW by 2041

The Malé Declaration on Control and Prevention of Air Pollution is an intergovernmental network between Bangladesh, Bhutan, India, Iran, the Republic of Maldives, Nepal, Pakistan and Sri Lanka and is Trans-boundary Effects of Air Pollution in nature. The Governing Council of South Asia Co-operative Environment Programme (SACEP) agreed on a joint declaration to carry forward, or initiate, studies and programmes on air pollution in each country of South Asia. The implementation of the Male Declaration was visualized in V phases. Phase I, II, III and IV was implemented successfully by UNEP in partnership with SACEP with the financial support from SIDA. The Phase V (2014-2016) promoted policy measures to control emissions of air pollution in South Asia and to ensure the sustainability and ownership of the Malé Declaration. *(Male Declaration 1998).* These South-Asian countries are signatory of the Vienna Convention for the protection of the Ozone layer (1988), Montreal Protocol on Substances that deplete the Ozone layer (1989), Kyoto protocol to the framework Convention on Climate Change (1997), Stockholm Convention on Persistent Organic Pollutants (2001) and Rio+ 20 Declaration on 'the future we want'.

Regulatory and fiscal reform: Ensure the 'polluter pays' principle can be enforced efficiently through MBIs (economic incentives and disincentives). MBIs or green tax reform require excellent monitoring, enforcement capacity and good governance. Low penalties are a problem in the fiscal and regulatory approaches. A larger penalty structure will be more visible and more effective. Prioritization of strategies linked directly to impact. Regulatory capacity building and updating of laws, rules, regulations *(Air Pollution Reduction Strategy: DoE: 2018).*

Awareness and monitoring: Keys areas for awareness raising are aware on adverse impacts of air pollution, especially on public health, regulations/options for control and reduction of air pollution and ensuring easy access to air quality monitoring data and disseminating data. Especial emphasis on awareness among children in the school and teachers *(Air Pollution Reduction Strategy: DoE: 2018).*

Technical capacity: The Air Pollution Reduction Strategy highlights capacity constraints for controlling air pollution:

- 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

Air pollution reduction strategy:

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. Two-stroke three-wheeled baby taxis (also known as scooters) were identified as a major source of PM emissions in Dhaka city. The Government of Bangladesh banned the use of two-stroke three-wheelers in Dhaka from January 1, 2003 to improve air quality in Dhaka city. Around 12,000 two-stroke baby taxis were replaced by 9,000 new four-stroke CNG baby taxis. The policy resulted in significant AQ improvements in Dhaka city. 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. Government's market friendly policy decisions contributed to the success of CNG conversion. In 2002, rules were proposed to ban buses older than 20 years or trucks older than 25 years from Dhaka city. Because older buses and trucks run primarily on diesel with no emissions mitigation technologies and banning them could have significant air quality benefits. Bangladesh government has banned the import of vehicles older than 5 years, and also reduced import duties on newer vehicles. Bangladesh has had a vehicle emissions standard since 1977, which was tightened in 2005, to correspond to Euro 2. The pollution reduction strategies are based on qualitative multi-criteria evaluation because of lack of information for quantitative benefit-cost modelling (Air Pollution Reduction Strategy: DoE: 2018).

Institutional set up and governance: The DoE should develop capacity in monitoring and enforcement, while firms and businesses should also develop capacity of monitoring and testing facilities. 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 modelling
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

India

Government of India has taken several initiatives for control of pollution in India. As the nodal agency, MoEFCC has notified ambient air quality standards and also source emission standards in some sectors like industries. Other Ministries have also been active in interventions to reduce emissions from sources within their domains. Other than central government, some of the state and city governments have also taken steps for control of pollution in their areas of jurisdiction. A list of key initiatives taken in India for air pollution control is presented below. Most of these measures have a bearing on air quality in Delhi region.

S.No	Initiatives	
	Transport sector	**Dates**
1	Notifying advanced vehicle emission and fuel quality standards– BS-IV from 2017 and BS-VI from 2020	2016
2	Introducing gas as an automotive fuel in many cities	Ongoing- 2003 onwards
3	Introduction of fuel efficiency standards for cars and in process to decide the norms for HDVs.	2015
4	Plan to introduce a voluntary fleet modernization and old vehicle scrappage program in India	2016 (currently being discussed)
5	Introducing National electric mobility mission plan 2020	2012
6	Introduction and enhancement of metro-rail and bus based public transport systems in select cities	Ongoing -2002 onwards
	Residential sector	
1	Push to accelerate the LPG penetration program for cooking in households	Ongoing – special emphasis 2015 onwards
2	Completing electrification to reduce kerosene consumption for lighting	Completed 2018
3.	Introducing energy efficiency labelling program for energy intensive home appliances like air conditioners	2006
	Power sector	
1	Ambitious targets for power generation through renewables (100 GW solar by 2022)	2015
2	Shift towards high efficiency super critical technology for power generation	Ongoing
3	Converting coal based power stations to gas based in select cities	-
4	Notifying new stringent standards for PM and new standards for gaseous pollutants for coal based plants	2015

5	Notifying new stringent standards for diesel generator sets for stand by power generation	2016
	Industrial sector	
1	Notifying and revising standards for highly polluting industries	2018
2	Pilot testing of emission trading scheme (ETS) in select industrial zones	Announced in 2010
3	Continuous monitoring of select large industries	Ongoing under the ETS
4	Zig-zag technology for brick kilns	2018
5	Banning pet-coke and FO use in industries	2017
	Others	
1	Imposition of ban on open agricultural residue burning	2015, NGT
2	Imposition of ban on refuse burning in some cities	2015 (NGT)
3	Launch of an official air quality index for Indian cities	2015
4	Setting up the Steering Committee on Air Pollution and Health Related Issues	2014
5	Developing Graded Response Action Plan (GRAP) for NCR for emergency planning	2016
6	Construction & Demolition Waste Rules	2017
7	Formulation of National Clean Air Programme (NCAP)	2018

The first air quality remediation plan was formulated in the year 2006-07. For formulating the air quality remediation plan, the Honorable Supreme Court of India, in the matter of CWP No. 13029 of 1995, passed orders on 05.04.2001, regarding formulation and implementation of action plans for control of air pollution in selected cities. The Honorable Court stressed the need for such initiatives relating to vehicular pollution in Delhi and directed that action plans for pollution control in the cities/ towns, which do not meet the ambient air quality standards, should be prepared. Following the orders from the Honorable Supreme Court, the first action plan to abate air pollution in Indian cities was formulated in the year 2006-07. The CPCB has prepared this abatement plan for seventeen cities including Agra, Ahmedabad, Bangalore, Chennai, Delhi, Faridabad, Hyderabad, Jharia, Jodhpur, Kanpur, Kolkata, Lucknow, Mumbai, Patna, Pune, Solapur and Varanasi. The aim of the action plan was to identify and implement a least- cost package of measures to improve air quality, such that the marginal costs equal the marginal benefits. This cost benefit analysis was carried out based on subjective assessment of economic and social costs, benefits, feasibility and other considerations. There were three developmental phases in the action plan i.e. immediate action, intermediate action (timescale of 5 years) and long term actions (timescale of 10 years). Sectorial measures proposed under the action plan for seventeen cities are listed in Table 20.

After formulation of remediation plan for seventeen cities, a comprehensive environmental pollution index (CEPI) was formulated by IIT Delhi and launched by CPCB in the year 2009. The CEPI is a rational number to characterize the environmental quality at a given location follows the algorithm of source, pathway, and receptor. The index captures the various health dimensions of environment including air, water and land. The present CEPI is intended to act as an early warning tool, which is handy to use. It can help in categorizing the industrial clusters/areas in terms of priority of planning needs for interventions. Initially, CEPI had been estimated for 88 selected industrial clusters/areas. Out of 88 clusters for which CEPI had been estimated, almost 50% (i.e. 43) were found to be critically polluted (i.e. CEPI ≥70). Out of the 43 critically polluted clusters, 27 were critically polluted and 16 were severely polluted for air environment.

MoEFCC has recently launched National Clean Air Programme (NCAP)-India as national level strategy for reduction in air pollution levels at both regional and urban scales. The goal of the NCAP is to meet the prescribed annual average ambient air quality standards at all locations in the country in a stipulated timeframe (long-term). Taking into account the available international experiences and national studies, the tentative national level target of 20%–30% reduction of $PM_{2.5}$ and PM_{10} concentration by 2024 is proposed under the NCAP. NCAP aims at mainstreaming and integration of air pollution considerations into the existing policies and programmes of the Government of India, including the National Action Plan on Climate Change (NAPCC). It also focusses on controlling trans-boundary flow of pollutants by linking with the NDC target of additional forest and tree cover of 2.5 to 3 billion tonnes of CO2 equivalent by 2030. There needs to be more focus on the western regions of India (Rajasthan and Gujarat) for enhanced tree cover, which will reduce wind-blown dust within the country and will also act as barriers for trans-boundary dust. The action plan also focusses on exploring air quality management at South-Asia regional level by activating the initiatives under 'Male Declaration on Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia' and South Asia Co-operative Environment Programme (SACEP).

Nepal

The government has introduced several policies, legislation and standards related to air pollution. However, these have not been followed up with comprehensive plans and programmes. With a strong back up from the 5-year national plans of the country (mainly the 8th and the 9th 5-year plans), the cases of prevention and control of pollution have been strongly reflected in the Environment Protection Act and Environment Protection Regulations of the country. The Environmental Protection act and the Environment Protection Regulation of the country came into its effect from 1997. Environmental Protection Act introduced in 1997 make legal provision to maintain clean and healthy environment by minimizing adverse impacts as far as possible.

Climate Change Policy 2011 has aimed at moving in low carbon development path, which provide co-benefits for reducing the air pollution. Government of Nepal on January 22, 2011 introduced the National Climate Change Policy which envisions a country spared from the adverse impacts of climate change, by considering climate justice, through the pursuit of environmental conservation, human development, and sustainable development--all contributing toward a prosperous society. This policy has set the target to have the National Low Carbon Development Strategy by 2014 and also a national strategy on carbon trade to benefit from CDM by 2012. Establishment of climate change centre, climate resilient infrastructures, and focus on public awareness are other areas of priority. This policy has set seven different objectives focusing on institutional strengthening, climate change mitigation and adaption, promotion of use of clean energy, strengthening the capacities of local communities; low carbon development path, institutional capacity on impact assessment, maximizing the benefits from climate finance. In order to achieve the objectives, policies for each objective are defined and altogether 61 different policies are there. This policy proposes establishing a separate ―Climate Change Fund for implementing programmes.

National Ambient Air Quality Standard (NAAQS) was introduced in 2003 and updated in 2012. These standards are generally more lenient compared with the updated 2005 WHO Guidelines; however, the NO2, CO, and Pb standards are comparable to the 2000 WHO guidelines (Table 8). There is a lack of annual standards for particulate matter (TSP and PM10), which is a main pollutant of concern in Nepal. Ambient air quality standards were last revised in the year 2012, looking at the scale of air pollution problem in the country, it is urgently needed to revise the National Ambient Air quality standards at regular intervals.

National Sustainable Transport Strategy (NSTS) (2015-2040): The NSTS emphasizes on developing a transport system that is efficient, accessible, people-centric, affordable, reliable, safe, inclusive, environmentally friendly, feasible and climate and disaster resilient. It has set a total of 19 objectives into economic, environmental and social dimensions with defined targets for each objective.

Industrial Policy 2011: This policy aims to establish the industry sector as one of the most reliable and dependable sectors by promoting the use of modern technology and environment friendly and sustainable production processes. This can be achieved by providing financial and technical support to proactive and developing industries to adopt environment friendly and energy saving technologies. The policy also has provisions to provide special facilities like no royalty for energy produced by industry for its own use and also provision to sell this energy in the market.

Foreign Direct Investment Policy 2015: Aim of the policy is to promote private sector investment in the cleaner technologies and cleaner industries through the market mechanism like Clean Development Mechanism or Sustainable Development Mechanism (Paris Agreement) on nationally prioritized sector.

Industrial Enterprises Act 2073: Under this act, industries are responsible to take care of the control of their emissions. Under the act, licenses are issued for industries that require going through EIA and IEE procedures.

Rural Energy Policy 2006 and Re Energy Subsidy Policy 2016: In Rural energy policy, 2006, rural energy is defined as renewable energy and specific strategies on subsidy for renewable energy promotion are emphasized. The sole aim of this policy is to contribute towards reduction in rural poverty and environmental conservation by ensuring access to clean, reliable and appropriate energy to the rural areas. It sets sector specific working policies on -micro and small hydro power; biogas; fuel- wood, charcoal, briquette, biomass energy, and biomass gasification; solar energy technology; wind energy technology; improved cook stove technology; improved water mill technology; and rural electrification. Renewable Energy Subsidy Policy (2016) is introduced for the implementation of rural energy policy, 2006.

Pakistan

The federal ministry for environment was set up in 1975 following the Stockholm Declaration of 1972. The ministry developed the country's first comprehensive environmental legislation; The Environmental Protection Ordinance (PEPO) of Pakistan in 1983. As a follow up to the ordinance the Pakistan Environment Protection Council as well as the Environmental Protection Agency was established to implement the vision of the PEPO. Under the Environmental Protection Ordinance, the National Environmental Quality Standards (NEQS) were notified for the first time in Pakistan in 1993. The NEQS established standards for effluents, pollution and air emissions (Ahsan and Khawaja 2013). In 1997, The Environmental Protection Ordinance of 1983 gave way to the Pakistan Environmental Protection Act (PEPA). The Act considered to be the bedrock of Pakistan's environmental legislation, stipulated that all effluents and polluting elements must be according to the standards set in the NEQS and its violation would be dealt with fines, business premises closure, imprisonment etc. depending on the nature and extent of the violation.

The Pollution Charges Rule, 2001, was introduced as a mechanism that would ensure participatory approach from industries, NGO's and public sector stakeholders to report and pay pollution charges. However, this initiative was not successful in influencing powerful groups, posing a hindrance (Sánchez-Triana, 2014). These influencers ranged from government to industrialists. The Government was not in favor of a participatory role, preferring a more proactive hardline approach accompanied by fines for non-compliance. Conversely, many industries did not want to publish their contribution to emissions, and the extent to which these emissions were deteriorating the environment.

The Pakistan Environmental Protection Agency in 2010 formulated NEQS for ambient air. After consideration and due consultative process, the Pakistan Environmental Protection Council sanctioned the standards. However, Pakistan's performance in achieving or even moving towards effective air quality management is minimal and lags behind other regional countries.

In 2010, after the promulgation of the 18^{th} amendment to the constitution of Pakistan the subject of environment was devolved to provinces. All four provinces now have their own environmental protection agencies and environmental legislation, based on the Pakistan Environmental Protection Act, 1997. The primary function of these provincial agencies is to administer and implement the policies stipulated by the PEPA (Ahsan and Khawaja, 2013). The environmental Acts notified by the provinces state that emission of effluent, waste, air pollutants, or noise pollutants exceeding standards of the NEQS are offences of the Acts and would be dealt accordingly.

However, the province level agencies require capacity improvement and in designing and implementing plans and policies. As provinces take the lead in implementation, the role of the Pakistan Environmental Protection Agency has been to guide the policies and assist the policies to be in line with the Pakistan Environmental protection Act 1997. Pakistan improved its standards of ambient air quality of NEQS again in 2010 (and yet again in 2013) but these remain relatively lax. As with many other countries in the region, NEQS are less demanding than the standards of the World Health Organization.

Social, Economic and Political Aspects of Managing Pollution

There are various social, economic and political aspects of managing pollution and implementation of policies and reforms. The geopolitics of pollution exports between cities, states and countries are an important consideration in finding solutions to trans-boundary pollution issues. It is difficult to reach and agree upon cooperative solutions especially when costs and benefits are poorly understood and/or spatially mismatched. A case in point is the issue of crop residue burning in the Indo-Gangetic plains, where the political gains of allowing crop burning override health costs faced in and around regions where the burning takes place. A new study by International Food Policy Research Institute (IFPRI) and partner institutes estimates the economic costs of crop residue burning in northern India at over USD 35 billion annually. Among other factors, smoke from the burning of agricultural crop residue by farmers in Haryana and Punjab, especially contributes to Delhi's poor air, but also increases the risk of ARI three-fold for those living in districts with intense crop burning. The study clearly shows that it is not only the residents of Delhi, but also the women, children and men of rural Haryana who are the first victims of crop residue burning. Much of the political discourse in States where the practise is prevalent unfortunately ignores the immediately affected vulnerable population and remains focused on the high costs of alternatives to burning residue. It is essential to look beyond short-terms political gains and provide for long-term solutions based on appropriate technologies or business models which might be win –win for farmers, politicians and entrepreneurs. Similarly, any increase in energy prices to address environmental externalities can have a disproportionate impact on economically weaker sections whose energy expenditure may be high as a share of total expenditure. Such interventions can become politically sensitive unless accompanied by compensatory support to identified households; the latter being a complicated exercise in itself.

Another issue is that of sectoral accountability due to limited source apportionment analyses which can establish the contribution of an individual source to ambient pollution levels. This can lead to ineffectual solutions or limited participation of stakeholders. There are also issues related to structure of the polluting industry which can make effective implementation of interventions cumbersome. For instance, many of the MSME units in India operate out of non-conforming areas and are unregistered, making it difficult to ensure their compliance with pollution regulations. Finally, economic and budgetary considerations are a deciding factor, whether it is provision of adequate infrastructure for public transport by the government, management of crop residue by farmers or switching to less polluting fuels by the industry. Unless adequate resources and /or incentives are provided, these transitions are not likely to happen as soon as we would like them to.

Summary

A wide range of policy initiatives and frameworks have been adopted in the four countries under consideration. Some of these have been effective in reducing the impacts of air pollution that would otherwise have occurred – in particular:

- Setting limits on vehicle emissions
- Regulating fuel quality (e.g. lead content of petrol; sulphur content of solid and liquid fuels).

However, many policies have not been effective, with the result that air pollution in South Asia has continued to be at a high level. The reasons for this are:

- A lack of overall strategy for securing the most cost-effective improvements in air quality. This requires action at a national and regional level, as set out in Chapter 3, supported by robust measurement, inventory, modelling and source apportionment studies.
- Minimal enforcement of controls on traffic emissions. Specification of vehicle emissions standards needs to be backed up with a programme of inspection and, prevention of vehicle usage if it is found that emissions limits are not achieved.
- A lack of ambition in setting emissions controls. Setting demanding limits on emissions from vehicles and industrial sources does come at a price, but at a national level, this can be offset against the health and other benefits that will accrue from delivering these improvements. Taking a broader view of the costs and benefits of emissions control, supported by robust technical analysis, would enable national governments to fully account for costs and benefits, and support the economic case for investing in air quality improvements.
- A lack of enforcement of controls. Limits on emissions from industrial and energy sources need to be backed up with robust monitoring and independent audit/checking from a regulatory authority.
- A lack of support for air quality improvements through energy policies. For example, ongoing investment in fossil fuel or biomass combustion is likely to result in ongoing air pollution problems in the long term. In contrast, investment in low-emission or zero-emission renewable technologies such as hydro or solar power can be effective in delivering air quality improvements alongside the climate benefits from reductions in greenhouse gas emissions. The use of nuclear

power is potentially beneficial when considered from the perspective of improving air quality.

- A lack of will to tackle transboundary issues – in particular, those resulting from combustion of agricultural residues, as well as issues resulting from other sources of air pollution. A strategy to deal with transboundary pollution should be based on robust data on emissions, dispersion and atmospheric processes affecting levels of primary air pollutants and secondary pollutants including "brown haze"/smog and ozone.
- A lack of robust air quality monitoring data and modelling analysis to demonstrate the effectiveness of interventions to improve air quality

Chapter 6

Stakeholder consultations

It is important to identify the research gaps at country level so that appropriate measures can be recommended at the regional level of the South Asia. Consultation with the key stakeholder in each country is important to understand their local problems, issues and research gap. Priority areas of the stakeholder consultation in different countries were to identify technical and legal ease-of-implementation for controlling the air pollution problem in South Asian region. Stakeholder's consultation workshop was organized in each country. The objective of stakeholder's consultation workshop in different countries was to collect information regarding Ambient Air Quality existing mechanism of monitoring, status, Laws, source of trans-boundary air pollution. Detail of the stakeholder consultation workshop in each country is appended below;

Stakeholder consultation in Bangladesh

Stakeholder consultation workshop was organized on 7th January 2019 at the Department of Environment (DoE), Dhaka. The workshop was having participation of stakeholders from different sectors. Dr. S.M. Munjurul Hannan Khan, Additional Secretory, Ministry of Forest and Environment, Government of Bangladesh chaired the meeting. He stated that despite of good policies in place, monitoring is not being done properly due to under manpower. DoE staffs are overloaded with work. He also expressed necessity for support in nature of technology and resource. He emphasized developing effective network among stakeholders. Dr. Sultan Ahmed, Director General of DOE moderated the entire workshop.

Most of the participants observed that government has not much interest to discourse the air pollution problem as a national problem. The contractors of construction works do not spray water to reduce dust pollution in the working area. Significant amount air polluted from Rice Parboiling, Steel Rerolling mills, stone crusher.

Most rural mothers spend every day 3-7 hours in the kitchen and they use biomass fuel for food preparation. Combustion of biomass discharges thousands of pollutants in high concentration and the mothers are exposed to those pollutants. Many of these mothers suffer from different type of diseases like COPD, Asthma, acute respiratory tract infection (ARTI), burning of eyes, sudden headache, cardio-vascular disease, adverse pregnant outcome, etc. Government is promoting ICS (2 million installed) and LPG, to reduce indoor air pollution. Government has a target to install 30 million ICS by the year 2030. Implementation of Improved Cooking Stoves (ICS) under the leadership of DOE has brought success.

Air of Dhaka city is polluted by emissions of brick kiln industries surrounding the city and vehicles used for transport. Slow movement of vehicles and traffic jam during pick hours contributes much for air pollution. Dhaka Transport Coordination Authority (DTCA) is implementing "Bus Rapid Transport". Bangladesh government has imported some auto stop vehicles. The effect of implemented activity needs to be evaluated. Therefore, research study may be design to measure emission of these auto stop vehicles and adaptation capacity to environmental condition of Bangladesh. Increased population growth also contributes for increased traffic movement in Dhaka city that have adverse effect on air pollution and health of local residences. Government initiative to ban two stroke baby taxis in Dhaka city backed plentiful improvement of air quality. But the experts were worried that the CNG baby taxies emit trillions of fine particulate matters those are very dangerous for developing COPD. Therefore, health effects and emission components of CNG vehicles may be studied.

Stakeholders' consultation workshop in Bangladesh

Scattered researches are going on air pollution. Networking between them researchers was emphasized. Networking between different monitoring agencies and independent researchers was given priority. Capacity of other institute particularly that of BAEC may be utilized for AQ monitoring and management in Bangladesh. Regional cooperation should be strengthened. Male declaration issue should be implemented and Center of Regional Cooperation among south Asian countries should be strengthened.

No significant research on health impact from Ambient Air Pollution. NIPSOM has a regional center for air pollution monitoring. Regional monitoring plan on air pollution, create public awareness and intra-country and inter-country networking was underlined.

Capacity of DOE should be strengthened to expand offices in district level, ensure necessary manpower and logistics and develop research capacity to identify adverse effect of air pollution. Trans-boundary air pollution of a country depends on geographical position of a country. India has several coal-based power stations in border of Khulna region. Therefore, Continuous Air Monitoring Station (CAMS) has been established in Shatkhira to comply with 'Male Declaration'. It was raised in the meeting that the general people of Bangladesh have lack of knowledge on air pollution. There is need of research regarding effect of air pollution on agricultural production of Bangladesh.

Research on source apportionment study was strongly recommended. Recommendation was made for Calibrating Real Time Monitoring instrument and Biological controlling of air pollution. Recently, the DoE has developed National policy on air pollution. The "Clean Air Act – 2018" is under process of implementation.

Stakeholder consultation in India

The joint stakeholder's consultation workshop was held at The Energy and Resources Institute (TERI), India Habitat Center, New Delhi on 15th January 2019. Dr. Ajay Mathur, Director General (TERI), elaborated the importance of air quality studies. He pointed out the need and requirement of cross boundary interventions in pollution and air initiatives by Government. The long-range transport of air pollution leads to immediate action plans for different cities with different pollution sources. He also focused on the need of public consultations and participations which helps people to mobilize on to a process legal framework through which people plan and action in amendment of air pollution at least at a local level. Dr. Shruti Rai Bhardwaj (MoEFCC), emphasized on the need of assessment of the regional air quality and separately addressing the regional and trans-boundary aspects of air pollution and also focused on the required evolution of the present air pollution interventions and plans. She also pointed out the need to develop a mechanism on how localities should address the impact of international pollutant transport in air quality planning.

Air monitoring in India have evolved over the years as a robust strategy to mitigate adverse impacts of air pollution on human health. Involvement of various stakeholders ranging from national and state level governing bodies to academia in this initiative has resulted in an improved understanding of the overall air pollution scenario in India. The result is that our country has specific guidelines and strict standards to which pollution causing industries and other sectors have to comply. Still there are certain lacunae in the present framework which need to be addressed. The present state of knowledge about the air monitoring framework gathered through literature and stakeholder consultation had led to several discussion points which need to be addressed in future.

The most important issue related to the ambient air quality monitoring which needs to be dealt with immediately is the inadequate number of air monitoring locations in India. When the concern is human health there is no choice but to carry out pollution abatement strategies where beneficiaries are not limited to certain areas. The resources have to be directed towards expanding the coverage of NAMP so that the health benefits can be maximized. Additionally, none of these monitoring locations are in the rural areas of the country. Policy makers, Government and researchers have focused their attention on air quality in the urban areas, neglecting the ambient air quality in the rural areas. So there is an urgent need to include rural areas also in the current monitoring network which will be useful in determining the rural air quality management plans. background stations and road side monitoring also required to enhance the representativeness and quality of the data retrieved from monitoring stations. Analytical quality control and calibration of monitoring instruments were emphasized in the discussion.

Participants of the Stakeholders' consultation workshop in India

Public participation plays a key role in the successful implementation of air quality interventions. For this, it is necessary to get a sense of the priorities and current levels of awareness so that public engagement efforts can be better defined and implemented. Present AQI is interpreted in six color categories which confuse people. Therefore, there is a need to make interpretation of present AQI simpler, which can be easily perceived by common people.

There is a need to include research led innovations in monitoring technologies which can enhance the quality and quantity of monitored data. The innovations in this sector are very crucial and there is a need to incentivize researchers/manufacturers so that there is a push factor which results in invention of practical as well as affordable pollution monitoring systems. More research needs to be driven towards the reliability on the data of the low-cost sensors.

Since transport sector is one of the major contributors to the overall air quality of a region, following PUC norms and proper Inspection & Maintenance (I&M) system must be strengthened. The discussion with the stakeholders suggests that the ambient air quality standards should be revised at least every five years for individual pollutants, especially for the industrial sector standard must be revised and regulated frequently. Apart from monitoring of major industries, stringent norms must be intervened to address pollution levels from small scale industries.

Agriculture stubble burning is one of the important sectors that contributing towards the deteriorating air quality of India. The agriculture crop residues can be utilized as biomass for thermal power generation or in biomass gasification unit for generating electricity. Limited number of source apportionment studies has been carried out in the country due to huge cost implications. Rather than going for a detailed source apportionment study for all non-attainment cities, Government must undertake emission inventory-based study for non-attainment cities across pan India. A comprehensive air quality management plan is the need-of–the-hour to achieve the targets in a timely fashion. There is a need to review these interim targets continuously on regular basis.

Stakeholder consultation in Nepal

Department of Environment (DOE) is in the process of increasing the monitoring network to 56 locations against the currently existing 14 stations. Air quality index (AQI) is not yet established because of lack of data. DOE is in the process of developing AQI in collaboration with US.

In addition to the existing monitoring network, there are other agencies like CDHM, DRISTI Kathmandu, Institute of Engineering (IOE), Nepal Academy of Science and Technology (NAST), Nepal Health Research Council (NHRC), etc. are also monitoring ambient air quality

Participants of the Stakeholders' consultation workshop in Nepal

There are standard for DG sets, Boiler, Incinerator, Chimney stack (general standard), indoor air quality, and National ambient air quality standard which were last modified in 2012. APEC is government body which works through private organization to promote improved cookstoves in rural villages by providing subsidy and thereby reduced emissions from biomass burning to about 60% in rural households. Impact analysis of the improved cookstoves on health has not yet established.

These emission standards are revised with ISO certification, periodically.

In urban areas, electric stoves are used. The Government of Nepal is promoting the use of electric stoves in place of LPG as some components of LPG is carcinogenic.

Hospitals/Industries are monitored on regular basis and have found to be violating the emission standards due to which they are not reporting the results. DOE has penalized 18 out of 39 hospitals monitored for violating the emissions standard.

Protocol for emission monitoring in industries and hospitals do exist in Nepal 2012 and s monitoring is done on an annual basis after establishment of DOE. Manpower is a concern due to which regular auditing of industries is a challenge.

Installation of incinerators in hospitals is mandatory and since they are not meeting the emission standards, Ministry of Health has published notice on banning the incinerator in Hospitals. Dust generated from construction activities is a major contributor of air pollution especially in Kathmandu valley.

Most of the industries in Nepal do not have APCD, the penalization charge for not installing the APCD's in industries has increased to 25 lakhs from 2 lakhs.

Major fuels used by industries in Nepal are diesel, furnace oil, coal and biomass (rice husk). Agricultural residue, briquettes and pellets are also emerging as fuels.

There is no extensive research happened in the field of source apportionment study in Nepal. However, studies are being conducted on dispersion modelling of Kathmandu valley in collaboration with DOE.

Air pollution inventory of Kathmandu valley and Lumbini region along with emission map for different cities were developed.

To maintain the clean air in Kathmandu valley, studies showed that domestic emission should be reduced by 80%, transport emission by 30% and industries emission by 40%. in Kathmandu valley. Similarly, in Lumbini region, 70% emission from industries sector should be reduced to maintain national emission standards.

Stakeholder consultation in Pakistan

The Stakeholders' consultation workshop of Pakistan was arranged at the Sustainable Development Policy Institute (SDPI), Islamabad on 27th December 2018.

The discussion opened with a brief introduction of the topic and started off with the observation that air pollution has now taken center stage in Pakistani media, public and policy circles and questioned the transformation. Furthermore, factors that are responsible for the issue of smog and air pollution were highlighted.

- Punjab banned crop residue burning back in 2014 but the actual implementation of the ban is questionable and has not been optimally enforced.
- Awareness has significantly increased in both public and government spheres. The linking of the smog and air pollution issue with India also helped bring this issue to the forefront.

- Multiple private entities are generating their own data relating to air pollution but the government still lacks any consolidated data over air pollution.
- The issue moved to the involvement and centrality of the Environmental Protection Agency and it was mentioned that Pakistan have to move beyond the EPA in responding to the air pollution issue.
- Brick kilns and use of fossil fuels are the major sources of the air pollution and even CNG has the potential to aggravate the problem.
- Data regarding NAQS must be met. However, process optimization is lacking. In case of sectors, brick kilns are targeted as their black smoke has high visibility and the lesser visible polluters are not as such targeted. Furthermore, it was added that the issue of social media has helped to greatly highlight the issue.
- Data which international agencies have on the subject regarding Pakistan is flawed and skewed because they are done in a limited frame work and very specific places.
- It was suggested that the essential requirement of the hour is a source apportionment study which would enable Pakistan to understand there ranking among other countries.
- It was asked how JICA had assisted the government in setting up monitoring equipment and the process and outcomes to which it was replied that federal EPA approached JICA for the assistance and equipment.
- It was suggested to employ Phd students to investigate air pollution in different cities to counter the problem of data and funds and it was stated that there is need to assess short to medium term requirement or recommendation on the subject
- It was added that industries have a significant influence and leverage in the political system that allows them to operate freely and even when fined or penalized still continue operating.
- It was recommended to use zig-zag technology in the brick manufacturing and how that would result in greater productivity and efficiency. To this the brick kilns owners did not respond positively. The operators observed the zig-zag method there increased productivity and profits.
- It was highlighted that how government in different projects is streamlining the use of zig zag model bricks for different projects to ensure economic viability of such initiatives.
- The energy outlook of the country was discussed upon, to which it was responded that coal power plants would compensate for shortfall in energy.

Detail of the Stakeholders' consultation workshop in each country is given in the *Annexure III*.

Chapter 7

Public Perception Survey

The South Asia breathes one of the poorest qualities of the air in the globe. The exposure to the poor ambient air is the second most important health risk factor in the region. The governments of different countries of South Asia have already taken and planning to take steps to improve the air quality of their respective countries vis-à-vis the region. However, “unless people can participate meaningfully in events and processes that shape their lives, human development paths will neither be desirable nor sustainable” (UNDP, 2013). Further, the general people without any gender bias should be able to influence the policymaking and be accountable for the results. Keeping this in mind, an internet based random survey was conducted in four countries of the South Asia to understand the perception of common people towards the air pollution scenario and different abatement strategies to combat air pollution.

A survey questionnaire (*Annexure IV*) was framed to understand the basic demographical background, perception on air pollution and accountability of the respondent to the air pollution problem of the respective country. A total of 2046 people were surveyed, out of which 1164 were from India, 264 from Bangladesh, 493 from Pakistan and 125 from Nepal. In the survey population, 39% were female. Among the respondent from different countries 38%, 44%, 32% and 33% were female from Bangladesh, India, Nepal and Pakistan respectively (**Figure 14**).

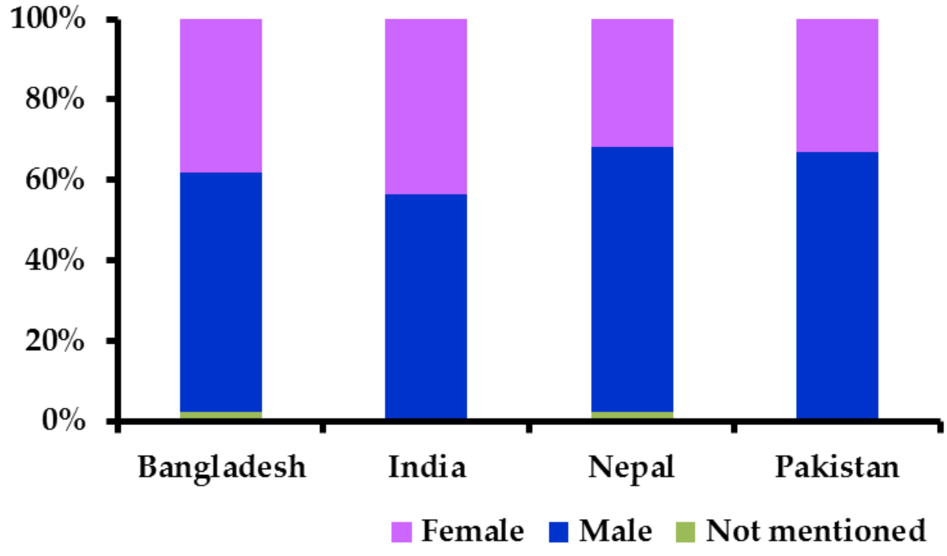


Figure 14 Gender distribution of survey population in different countries

More than 60% of the total population in the South Asia lives in the rural area. The survey was conducted through online mode; it was hypothesized that it would not capture the rural population of the area as most of the rural areas of the South Asia are not well connected with internet facility. However, the survey population comprised of 13% of rural population. Among the surveyed population of different countries, 23%, 14%, 11% and 16% are from the rural areas of Bangladesh, India, Nepal and Pakistan respectively (**Figure 15**). Although, the majority of the survey population (72%) were from the Urban areas of the respective countries as hypothesized.

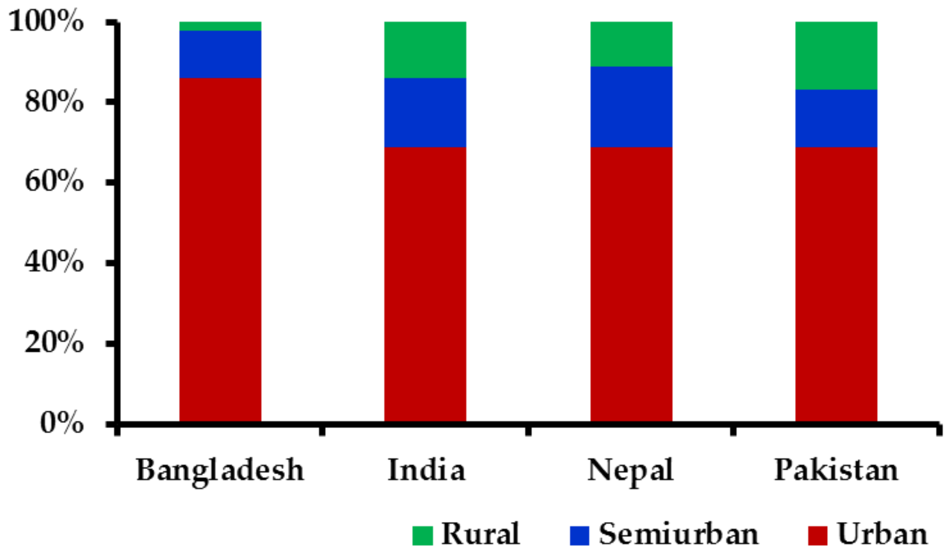


Figure 15 Demographical distribution of the survey population of different countries

Majority of the survey population were graduate by education, employed and below 40 years age. More than 98% of the survey population believes that the air pollution is a major problem of their country and most of them were aware that their respective country is having a national ambient air quality standard.

According to the perception of the surveyed population, the transport sector is the major source of pollution in India, Nepal and Pakistan; while construction activities are the major source of ambient air pollution in Bangladesh. It was surprisingly noted that the people of all four countries believes that the road dust is the second most important source of ambient air pollution (Figure 16). It is also to be noted that there is not much difference in the top five sources of ambient air pollution in four countries according to the perception of the sample population.

According to the public perception survey the other sector seems to be more important contributor than sectors like Mining, Power plant and Brick kiln in Bangladesh, India and Nepal – this suggest that detail study is required to address the other sector in those countries. As mentioned earlier, that different countries of the South Asia region have already implemented several actions to improve the air quality of their restive countries, the perception of common people in Bangladesh and Nepal suggests that Road cleaning and management is the most important measure to control the ambient air pollution. However, public perception in India suggests shifting from coal-based electricity to renewable electricity could reduce the ambient air pollution (**Figure 17**). The people of Bangladesh, India and Nepal have the perception that the LPG penetration in the residential sector for cooking purpose is having least impact on improving the ambient air quality.

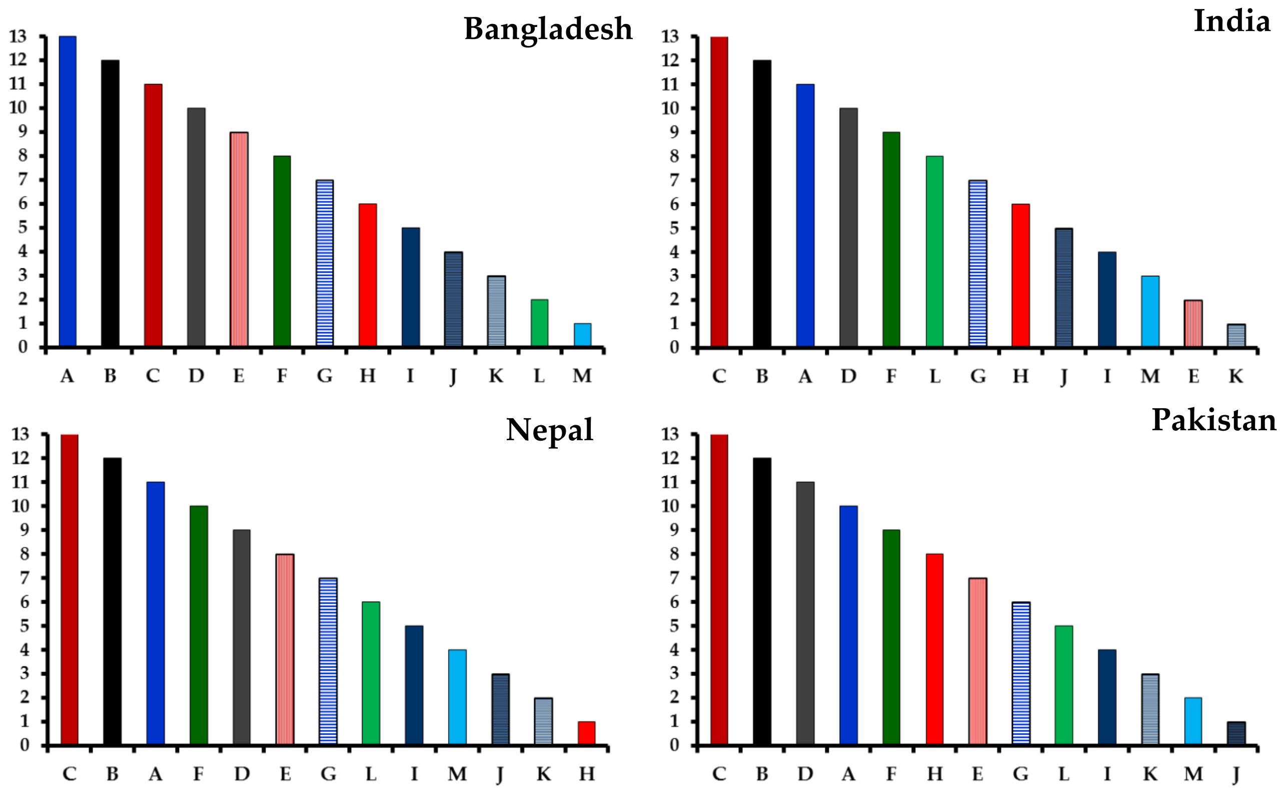


Figure 16 Perception on sources of ambient air pollution

Survey was conducted on a 13-point scale where 13 indicate most prominent source and 1 indicate least prominent source. ***A****. Construction activity;* ***B****. Road dust;* ***C****. Transport;* ***D****. Industry;* ***E****. Brick kiln;* ***F****.Waste burning;* ***G****. Residential fuel burning;* ***H****. Power plant;* ***I****. Diesel generator;* ***J****. Other;* ***K****. Mining activity;* ***L****. Agricultural residue burning;* ***M****. Cross border pollution*

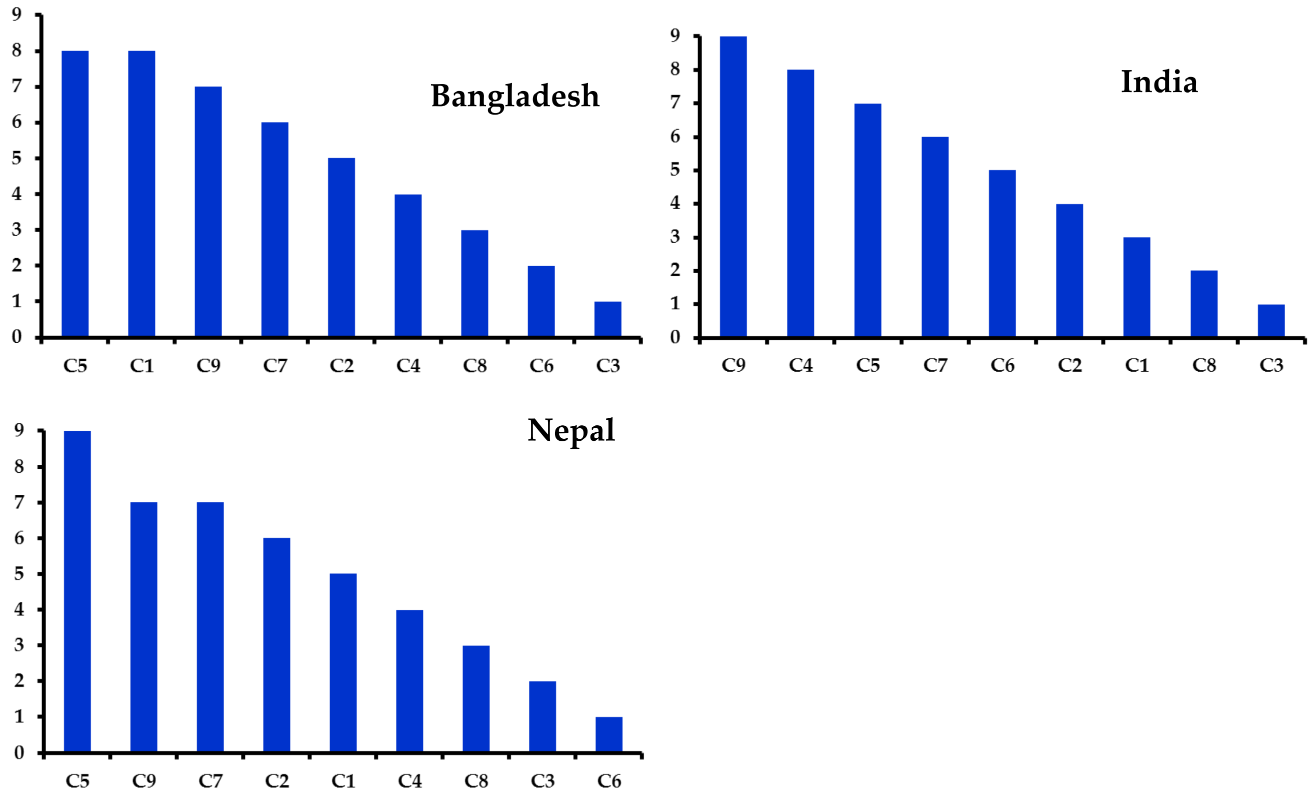


Figure 17 Public perception on effectiveness of different control measures to improve the air quality in different South Asian countries

'9' in the scale indicate 'Most effective' and '1' indicate 'Least effective'. **C1.** Transport emission control; **C2**. Industrial emission control; **C3**. LPG/PNG penetration in the residential sector; **C4**. Controlling open burning of waste/agro-residues; **C5**. Road cleaning & management; **C6**. Ban on cracker burning; **C7**. Controlling dust emission from construction activities; **C8**. Controlling the use of diesel generators; **C9**. Shifting from coal-based electricity to renewable electricity

After receiving the public perception on the effectiveness of different control strategies to improve the air quality, it is important to understand public opinion in the development future action plan to control ambient air pollution to effectively involve public perception in policy intervention. The public perception survey of four countries suggests that public awareness buildup, enhancement of public transport and government initiative to a clean air mission will be the most important governmental policy requirement to improve the air quality (**Figure 18**). While, policies like improving the in-use vehicular inspection system and congestion pricing are least important to improve the air quality in all four countries.

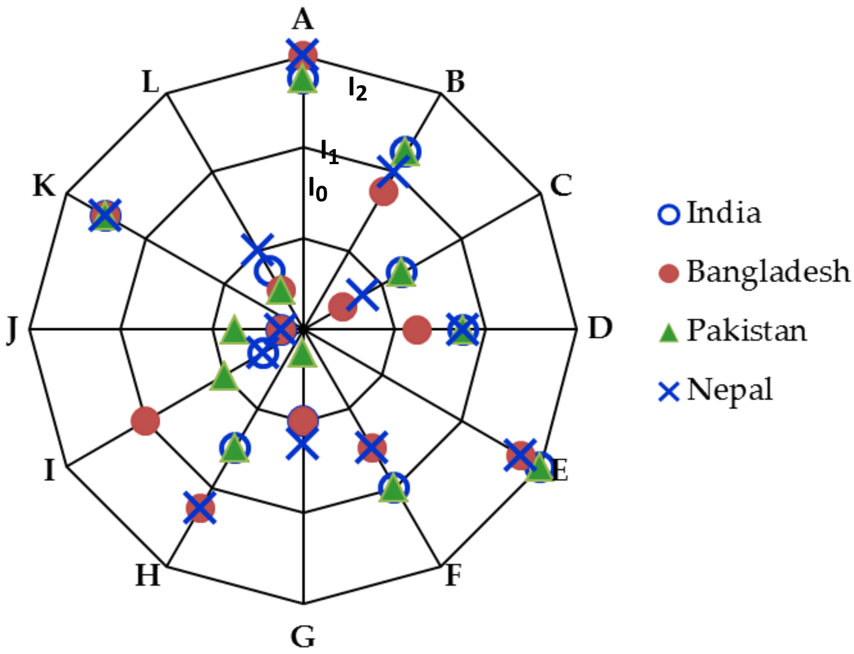


Figure 18 Kiviat diagram representing public perception on importance of different governmental polies to improve air quality in different countries

A. Clean Air Mission; B. Waste to Energy; C. Car Pool; D. Enhancement of Electric Mobility; E. Enhancement of Public Transport; F. Enhance use of Renewable Energy; G. Improve automobile engine; H. Improve automobile fuel quality; I. Cleaner Industrial Process; J. Congestion pricing; K. Public awareness; L. Improve in-use vehicle management program. I_0: Least important; I_1: Moderately important and I_2: Most important

Policies related to cleaner industrial processes are moderately important in Bangladesh and Pakistan; while it is less important in India and Nepal (Figure 5). Industrial emission standard is already well implemented in India; while industries are not the major source of pollution in Nepal according to this perception survey – these might have attributed to public perception on least importance to develop policies related to cleaner industrial processes In India and Nepal.

It is important for the general public to be accountable for the successful implementation of any governmental policies to improve the air quality. More than 70% of the people participated in the survey are ready to pay extra, if some policies to improve air quality required that. We have made an effort to understand the specific income group of people who are ready to pay extra for which category of initiatives. The study indicate that people of all four countries across all income class are not ready to pay extra for Electric mobility, while most of the people from the Low Income and Medium Income group of people are ready to pay extra for Better Public Transport system and most of the people from the High Income group are ready to pay extra to Organize Seminars to Develop Public Awareness (Figure 19).

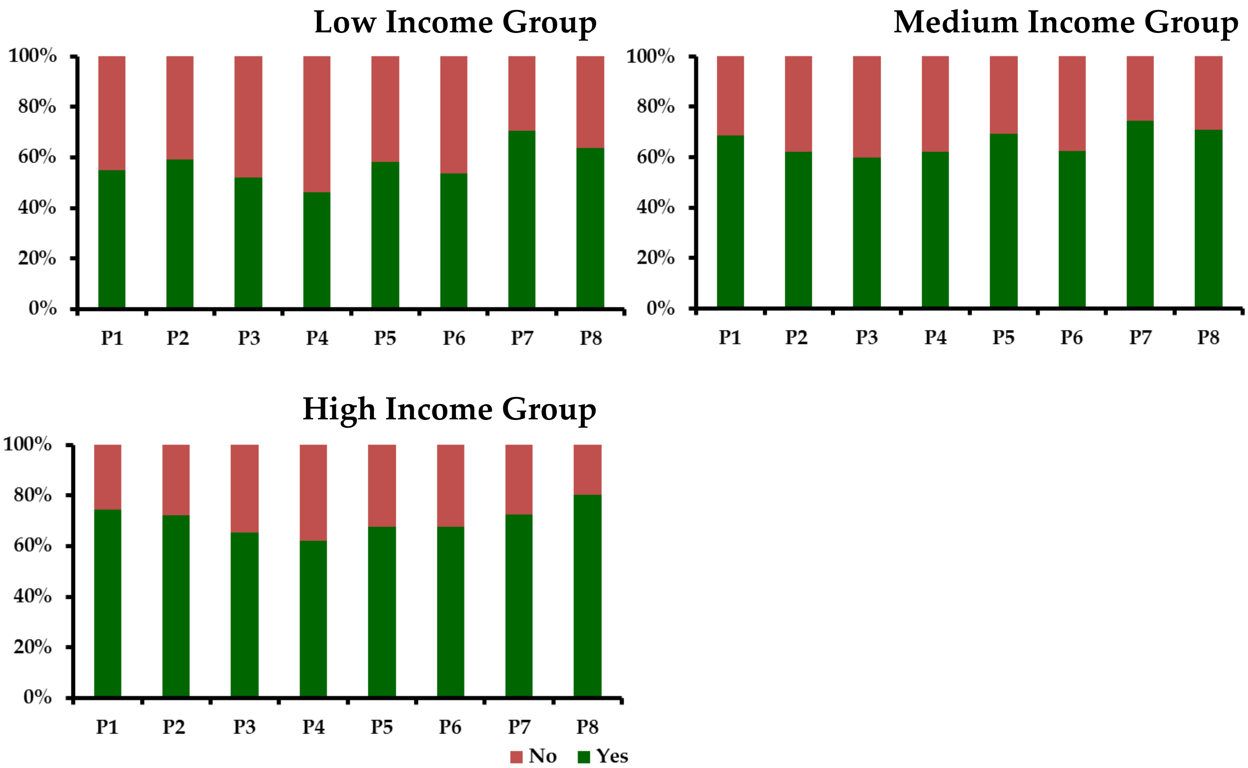


Figure 19 Willingness of people among different income classes to pay extra to improve the air quality

Low income group: *<$150 per month;* ***Medium Income Group***: *$150 to $420 per month;* ***High Income Group***: *Above $420 per month.* ***P1***. *Energy efficient electrical devices;* ***P2***. *Energy efficient automobile technology;* ***P3***. *Clean automobile fuel (diesel/gasoline);* ***P4***. *Electric mobility; P5. Power generation from renewable (like solar roof-top);* ***P6***. *Shifting to LPG/PNG for residential cooking;* ***P7***. *Better Public Transport facility; P8.* *Organizing community awareness campaigns & seminars*

Chapter 8

Gaps & Recommendations

Key areas that need to be focused on in South Asia are given below:

1. **Understanding of the issue**
    - Limited policy understanding of the state of air quality
        - Limitations of number and coverage of monitoring stations
        - Differences in types of monitors manual/ continuous
        - Limitations and differences in air quality parameters monitored
    - Limited knowledge of sectorial and geographical (including trans-boundary) contribution to ambient air quality
    - Limited (uncertain) understanding of the impacts of air pollution
2. **Weak enforcement and related issues**
    - Stringent ambient air quality standards but no interim targets
    - Lack of horizontal and vertical coordination and collaboration within levels of the Governments of the countries to improve air quality
    - Limitations of capacities in the regulatory bodies: financial, manpower, skills
    - Limitations in industrial emission standards (especially for gaseous pollutants)
    - Absence of controls over fugitive sources of NH_3 and VOCs
    - Weak vigilance and enforcement of sectoral standards
3. **Limited focus on regional scale approach**
    - No regional scale monitoring, and modelling based assessments & planning
    - Absence of inter-governmental (state to state) (country to country) cooperation, and collaboration for regional scale air quality improvement
    - Technical knowledge exchange and collaborative research on sectorial and trans-boundary contributions to pollution
    - Integrated assessment of policies, action plans and projects to develop regional action plan
4. **Awareness and Prioritization**
    - Limited public awareness
    - Inadequate political prioritization of the issue and resource allocation
    - Perception based air quality planning and actions
    - Inadequate information dissemination and absence of air quality forecasting framework

Prioritised Recommendations

Regional:

1. Conduct studies to better understand trans-boundary pollutant dispersion through monitoring and modelling.
2. Develop an intergovernmental regional cooperative platform to provide policy guidance, technical assistance, and training to key stakeholders to prepare and implement national programs that can successfully address regional air pollution issue.
3. International co-operation to reduce transboundary pollution, under the auspices of an existing body such as UNESCAP or Malé Declaration, with participation by other international organizations like UNDP, FAO, UNIDO, IEA, ADB, WB, etc.

Country Specific:

Nepal

1. It is important for all countries to have robust air quality monitoring networks to understand the pollutants of most concern, particularly across all provinces in Nepal as majority of monitoring stations are set up in and around Kathmandu
2. Prepare national or city-scale "bottom-up" emission inventories (i.e. inventories based on reports and estimates of activity and associated emissions). For example, such inventories would assemble data on sources including traffic movements, energy use, and industrial/agricultural production combined with appropriate emission factors to provide estimated emissions at a national or city level, and with geographical breakdown to the best available resolution.

Bangladesh

1. Undertake source apportionment studies using detailed air quality models, and develop to provide analyses of future trends and assessment of potential air quality improvement options, to support Air Quality Strategy and policy development at national and city level.
2. Undertake studies on various intervention options along with cost-benefit analysis to assess the optimum solutions for air quality improvement.
3. Traffic is a major problem in Bangladesh, especially in major cities like Dhaka, hence, there is a need for improvement in public transportation by the use of mass rapid transport etc.

India

1. Modelling based studies on intervention and control options to assess the no-risk and low-risk control options for improving air quality

2. Pilot projects for improving air quality using newer technologies for reducing emissions from various sources like industries, biomass burning, power plants, etc.
3. Setting up of state-of-the-art laboratories for standardised protocols and calibrations of equipment to obtain comparable results as there are a number of studies conducted in India, however, these results are not comparable.

Pakistan

1. For Pakistan, there is a clear priority to reinstate a working air quality monitoring network with robust QA/QC and data management. The province of Punjab will be the focus of a large investment in this area from the World Bank but the other provinces also require support. To focus further still, Karachi would be recommended for investment with regard to air pollution monitoring followed by Peshawar and Hyderabad based on their population size.
2. The devolution of air quality responsibilities from national to state authorities in Pakistan has led to a weakening in air quality expertise and oversight. It is therefore recommended to review existing arrangements in detail and propose an improved institutional framework for Pakistan to include: strengthening of all provincial EPAs to improve their monitoring, enforcement, and planning capacities, and improve coordination mechanisms between provincial and national EPAs; identifying options for a central body with a clear mandate for AQM, and with responsibilities for intersectoral and intergovernmental coordination and collaboration; review and recommend improvements to existing clean air relevant policy and regulatory frameworks. It is possible that coordination with the World Bank Punjab project would provide valuable opportunity for cross province knowledge sharing and a template for other provinces to follows.

Other Recommendations: Regional

1. Understanding of the issue

- Monitoring
  - Optimal and scientific development of monitoring Network based on manual, continuous, low cost and satellite-based measurements
  - Definitive studies to calibrate and standardize manual, continuous, low cost and satellite-based measurements
  - Identification of key pollutants of concern for the region and consistent monitoring all across
- Source apportionment studies at regional and national scales along with emission inventory development for hotspot cities

- Indigenous studies for generation of scientific evidence for improved understanding of the impacts of air pollution
    - Indigenous dose-response for health and agriculture
    - Indigenous economic analysis for assessment of economic damage
    - Regional scale air quality- climate interaction study to assess aerosol impacts over climate and vice-versa

2. Strengthening enforcement and related issues

- Setting up interim targets for control of pollution based on assessment of existing strategies and most feasible (technically and financially) solutions for control
- Lack of horizontal and vertical coordination and collaboration within the countries to improve air quality
    - Strengthening the legal framework
    - Setting up high level monitoring committees
    - Linking financial allocations to efforts for control
- Limitations of capacities in the regulatory bodies: financial, manpower, skills
    - Needs assessment at boards
    - Mix of technological and manual options
    - Fiscal mechanisms for financial strengthening of the bodies
    - Involvement and empanelment of reputed third parties for assistance
- Limitations in industrial emission standards (especially for gaseous pollutants)
    - Comprehensive review and industrial standard setting using BAT approach
- Absence of controls over fugitive sources of NH_3 and VOCs
    - Learning from the developed countries
- Weak vigilance and enforcement of sectoral standards
    - Learn and customize vigilance and enforcement mechanisms
    - Use of fiscal instruments

3. Awareness

- Develop AQI and strategies for wider dissemination of AQ information, its impacts and advisories
- Design and implement high level joint sensitization programs for MPs and MLAs
- Design and implementation of a campaign to reinforce awareness about challenges and opportunities of air pollution (ambient and indoor).

- Target audience like national or local level decision makers, different government sectors involved, universities, research institutes, schools, and the general public (through media).
- Campaign should highlight local, regional implication of air pollution including its effects on health, society and economy and other co-benefits of air pollution control.

4. **Promoting and developing regional scale approach**

- Develop an intergovernmental regional collaborative program to provide policy guidance, technical assistance and training to key stakeholders to prepare and implement national programs that can successfully address regional air pollution issue.
- International co-operation to reduce transboundary pollution, under the auspices of an existing body such as UNESCAP or Malé Declaration, with participation by other international organizations like UNDP, FAO, UNIDO, IEA, ADB, WB, etc
- Organize personnel exchange program to speed up capacity development for regional policy design, monitoring & evaluation including possibility of 'secondment' to International Development Organization(s) engaged in air pollution control programs.
- Facilitate interaction, collaboration and alliance building between members of the network country and key stakeholders, to support the implementation of the Regional Action Plan, as well as to foster experience and information exchange and identification of opportunities of opportunities for shared action and collaboration.
- Co-organize a major biannual regional air quality, health effects conference/workshop including technology exhibit to explore wide range options and opportunities to facilitate and encourage regional networking and knowledge dissemination.
- Evaluation of the impact of the policy interventions on atmospheric pollutants in collaboration with national and regional (international) institutions. This should form a sound basis to institutionalize standardized decision-making process and stakeholder involvement.
- Enhance the scientific understanding of regional air pollution including source contribution, variable ambient concentration, health and environmental impact, economic impact, technology options and policy interventions.
- Air Quality Forecasting at regional and national scale and assessment of long-range transport of the suspended particulates
- Implementation of a monitoring and evaluation framework which could be used to evaluate the implementation of any action plan at national and regional level.

- Design and implementation of an online platform at regional level to compile all key air pollution related data.
- International co-operation to address crop residue burning, this could be under an existing body, eg. FAO
- International study of future energy resources to limit increasing use of coal and other fossil fuels

INDIVIDUAL COUNTRY RECOMMENDATIONS

Bangladesh

Research gaps identified

Research on source apportionment throughout Bangladesh particularly in industrial zones and big cities. It would be useful to carry out such studies and a design model to identify trans-boundary transfer of air pollution in regional countries. Simultaneously research on health effects of air pollution should be done to have evidence-based data in Bangladesh.

Air quality policy

- The policy framework and enforcement regime needs to be strengthened to effectively address mounting environmental degradation and pollution. The available benchmark data suggests that Bangladesh's regime for environmental protection is not as strict as in some other countries in Asia.

Air quality modelling and source apportionment

- Bangladesh government's air pollution reduction strategies are based on qualitative multi-criteria evaluation because there are no data on quantitative benefit-cost modelling. Research and development to address the knowledge and information gaps so that future strategies can be based on quantitative modelling.
- 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. This would enable strategic air quality modelling studies to be carried out in Bangladesh to link emissions, control measures and progress towards achieving air quality standards.
- 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);

Capacity building

- Co-operation and coordination among various stakeholders, from regulators to businesses to the general public. Capacity building and knowledge retention. Institutional reform to ensure coordination and governance
- The DoE should develop capacity in monitoring and enforcement, while firms and businesses should also develop capacity of monitoring and testing facilities.
- Develop capacity of DOE to carry out research on ambient air pollution and its health impact
- Develop capacities for following institutions/individuals.
  - Monitoring ambient air pollution in major cities and pollution hot-spots. (e.g., industrial areas);
  - Laboratories (e.g., in relevant educational institutions) in measurement/ monitoring of air quality;
  - Organizations/ professionals in developing/ updating emission inventory, air quality models;
  - 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;
- Ensure vehicle emissions inspectors have sufficient manpower and required logistics to enforce laws for vehicle emission.

Engagement and co-ordination

- Disseminating research findings and background research data widely in order to enhance cooperation among researchers.
- Co-operation, coordination and collaboration among various government agencies other than DoE/MoEF.
- Cooperation and coordination among research/ educational institutions, professional groups, international/ regional organizations involved in various activities related to air pollution.
- Cooperation among relevant Government, Non-Government Organizations, research/ educational institutions, donor agencies and international/ regional organizations.
- Coordination and co-operation among stakeholders on strategies which have multiple benefits across different sectors
- Development of a platform for information sharing among research institutions, professional bodies, governments and other stakeholders

- Awareness and motivation about air pollution across sectors. Keys areas for awareness raising are aware on adverse impacts of air pollution, especially on public health, regulations/options for control/reduction of air pollution and ensuring easy access to air quality monitoring data and disseminating data. Especial emphasis on awareness among children in the school and teachers.

Enforcement

- Establish satellite air quality control office to all 64 districts, particularly taking enforcement action on violations and supporting preventative maintenance of air monitoring equipment.
- Set up larger penalty structure and prioritization of strategies linked directly to impact. Regulatory capacity building and updating of laws, rules, regulations

Technical controls

- Research on technological innovations to make rice residue removal less costly.
- 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 cook stove and alternative/ less polluting fuel for domestic use;
- Research and development to address the knowledge and information gaps
- Regular water spray should be carried out to reduce air pollution from construction sector work.

Nepal

- Air quality policy: The policy framework and enforcement regime needs to be strengthened to effectively address mounting environmental degradation and pollution. The available benchmark data suggests that Bangladesh's regime for environmental protection is not as strict as in some other countries in Asia.
- Air quality modelling and source apportionment: Research and development to address the knowledge and information gaps so that future strategies can be based on quantitative modelling.
- 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. This would enable strategic air quality modelling studies to be carried out in Bangladesh to link emissions, control measures and progress towards achieving air quality standards.

India

Research gaps identified

Air quality monitoring in India has evolved over the years as a robust strategy to mitigate adverse impacts of air pollution on human health. Involvement of various stakeholders ranging from national and state level governing bodies to academia in this initiative has resulted in an improved understanding of the overall air pollution scenario in India. The result is that India has specific guidelines and strict standards to which pollution causing industries and other sectors have to comply. Still there are certain lacunae in the present framework which need to be addressed. The present state of knowledge about the air quality monitoring framework gathered through literature and stakeholder consultation had led to several discussion points which need to be addressed in future.

Key Priority Areas

- AAQ monitoring in India is primarily managed by CPCB through NAMP by involving state level pollution control boards and pollution control committees. The most important issue which needs to be dealt with immediately is the inadequate number of air monitoring locations in India. When the concern is human health there is no choice but to carry out pollution abatement strategies where beneficiaries are not limited to certain areas. The resources have to be directed towards expanding the coverage of NAMP so that the health benefits can be maximized.
- Additionally, none of these monitoring locations are in the rural areas of the country. Policy makers, Government and researchers have focused their attention on air quality in the urban areas, neglecting the ambient air quality in the rural areas. So there is an urgent need to include rural areas also in the current monitoring network which will be useful in determining the rural air quality management plans.
- The present AQI is interpreted in six color categories which confuse people. Therefore there is a need to make interpretation of present AQI simpler, which can be easily perceived by common people.
- Data auditing, background stations and road side monitoring also required to enhance the representativeness and quality of the data retrieved from monitoring stations
- To ensure the quality of data, analytical quality control and calibration, repair of instruments and evaluation of ambient air quality monitoring stations are must.
- Public participation plays a key role in the successful implementation of air quality interventions. For this, it is necessary to get a sense of the priorities and current levels of awareness so that public engagement efforts can be better defined and implemented.

- The monitoring guidelines and standards need to be re-examined from time to time considering the dynamic state of environment and ever changing socio-political scenarios. Thrust should be given for maintaining quality of data generated with the help of well-defined procedures so that the relevant measures can be taken to combat air pollution.
- Promoting and implementing public awareness programme with social aspects at rural level will help to eliminate traditional causes and issues affecting air quality.
- Future perceptions must be targeted in every two/five years by modifying existing AQI for improving air quality
- There is a need to include research led innovations in monitoring technologies which can enhance the quality and quantity of monitored data. The innovations in this sector are very crucial and there is a need to incentivize researchers/manufacturers so that there is a push factor which results in invention of practical as well as affordable pollution monitoring systems.
- To resolve the issue of reliability of low cost sensors, more research is required to validate the accuracy of low cost sensors with the existing monitoring techniques.
- Government must identify reliable certified sensors for deploying at different regions and the sensors are to be re-calibrated for different pollutants from time to time.
- Since the transport sector is one of the major contributors to the overall air quality of a region, following PUC norms and proper Inspection & Maintenance (I&M) system must be strengthened
- Remote sensing I& M system can be implemented at peripheral highway or toll plazas
- Recycling, scrapping, fitness certification system, with improved technology mechanism must be enhanced for all categories including commercial vehicles and HDVs.
- Chassis dynamometer testing facility and diesel emissions control system should be developed
- Standards should be revised at least every five years for individual pollutants. Especially for the industrial sector standard must be revised and regulated frequently. Apart from monitoring of major industries, stringent norms must be enforced to address pollution levels from small scale industries
- DG set standards need to be stringent since they contribute significantly to poor air quality levels.
- To deal with issues related to stubble burning, agriculture crop residues may be utilized as biomass for thermal power generation or in biomass gasification unit for generating electricity
- Proper ex-situ and in-situ management planning must be implemented for specific sectors like implementation of zig-zag technology for brick kiln industries
- Considering the importance of air quality models for their use in EIA and air quality management plan, and to account for chemistry between the pollutants,

there is a need to move towards more advanced Chemical Transport Models which will help in developing more robust results. The use of air quality models in identifying the most useful interventions for control of air pollution is limited and hence there is a need to improve it.

- Limited number of source apportionment studies has been carried out in the country due to major cost implications. Moreover most of studies done till date is for metro cities. Rather than going for a detailed source apportionment study for all non-attainment cities, Government must undertake emission inventory based study for non-attainment cities across India.
- Air quality management plan should be prepared to achieve the targets in a timely fashion. There is a need to review these interim targets continuously on regular basis.

Pakistan

Research gaps identified

- The following research gaps were identified:

1. The World Bank Punjab Green Development Program will address the issue of lack of air pollution monitoring in the State of Punjab however there is a severe lack of information on ambient air quality across all provinces in Pakistan. Initiatives to recommence and expand the previous monitoring programmes across all provinces with air pollution issues need to receive proper funding and support.
2. There is no "bottom up" emissions inventory for Pakistan which can be used to identify and characterize air pollution sources in Pakistan.
3. Because of the absence of monitoring and inventory data, there are no source apportionment studies which would use air quality models to identify the sources of pollution which are making the greatest contributions to public exposure, so that investments can be made in mitigating these emissions and their impacts on health and the environment. Such studies would take account of seasonal and geographical factors which affect source apportionment of air pollution. These studies could be used to reconcile differences in "top down" emissions inventories, and could be calibrated against independent data sources such as satellite measurements
4. There is little information on natural and transboundary sources of air pollution.
5. Addressing items 1 to 4 would enable an integrated air quality management programme to be developed with the aim of achieving national and international air quality standards and guidelines.
6. There is little information on interactions between climate change and air pollution in Pakistan.

Key Priority Areas

The current environmental regulatory apparatus is weak, and air quality management institutions experience various challenges that compromise their capacity to tackle this issue successfully. This is because of insufficient capacity in terms of skilled personnel at the federal and provincial levels and inconsistencies in legislations that put provincial governments at odds with the federal government. All of these factors contribute to poor enforcement and very limited progress towards improving air quality, which is critical for sustainable urban development.

Based on the research discussion in this document, including the stakeholder discussions in Appendices 1 and 2, the following recommendations are proposed. Note that some of these will be covered within the World Bank Punjab Green Development Program, but the recommendations are still relevant to the other provinces in the country where the investment is not being applied.

Recommended actions	Time frame
Building institutional capacity for air quality management (AQM)	
Revise clean air relevant policy and regulatory frameworks for legal ambiguities to improve its implementation success	Medium term
Establish a central apex body with a clear mandate for AQM, and with responsibilities for intersectoral and intergovernmental coordination and collaboration	Short term
Strengthen provincial EPAs to improve their monitoring, enforcement, and planning capacities, and improve coordination mechanisms between provincial and national EPAs	Short term
Build the capacity of city governments to improve urban planning and develop alternative modes of transportation	Medium term
Explore the synergies and co-benefits with climate change mitigation efforts	Long term
Strengthening air quality monitoring	
Establish a reliable air quality monitoring network focusing on pollutants such as PM2.5, SO2, NO2, CO, VOCs	Short term
Develop a detailed mobile source emissions inventory	Short term
Develop an inventory of industrial sources with the identification of key polluter enterprises	Short term
Develop an inventory of other sources, including residential, natural and transboundary sources	Short term
Explore and create opportunities on clean production technologies for industries in public-private partnership mode	Short to medium term
Globally the use of satellite data is employed to assess situation of air pollution. EPA should engage Space and Upper Atmosphere Research Commission (SUPARCO) to acquire their data on the subject and work accordingly. The need of collaboration in this regard is the key. The dearth of data on air pollution compels us to use satellite imagery	Medium term
Establish a centralized depository to review and analyze data	Short term

Recommended actions	Time frame
collected from across the country by the network for monitoring air quality.	
Bolstering the legal and regulatory framework for AQM	
Adopt and enforce pollution charges targeting fuels according to their pollution contributions, based on the polluter pays principle.	Short term
Adopt and enforce a more serious penalty system for noncompliance with air quality laws and regulations	Short term
Adopt and enforce higher fuel efficiency standards and environmental taxes for less efficient vehicles	Medium term
Adopt and enforce revised NEQS to ensure that the permissible ambient concentrations of all pollutants are consistent with the levels recommended by the WHO	Short term
Ensure that public bodies responsible for air quality management and enforcement have sufficient resource and expertise to carry out their enforcement duties, and to deliver air quality monitoring, inventory, modelling and management projects to a high standard	Medium term
Engage with private sector bodies as a partner, but ensure that private sector companies and individuals do not influence standard setting and enforcement	Medium term
Extend and enforce a robust program of motor vehicle emissions inspection	Medium term
Adopt and enforce a system for regulating emissions from diesel generator plant	Medium term
Engage in cross-border dialogue to understand and address transboundary pollution issues	Medium term
Develop a programme to encourage or enforce a move away from agricultural residue burning towards less polluting methods of managing residues	Medium term
Public disclosure and information dissemination	
Foster creation of informed citizenry through distribution of information regarding health impacts of air pollution, and firms violating environmental regulations	Short term
Ensure all air quality monitoring data produced by public bodies is freely available online.	Short term

Annexure I

Studies based on dispersion modelling

Study	Type of model used	Study period	City	Objective
Kumar et al., 2018	AERMOD	Mar 15 – Feb 16	Delhi	The study focused on determination of SO_2 and NO_2 pollution in the ambient air
Gadhavi et al., 2015	Lagrangian model	2009-11	Gadanki	The study focused on determination of BC pollution in the ambient air
Gulia et al., 2015a	AERMOD	June-December 2012	Amritsar	The study focused on assessing the urban air quality around heritage site in Amritsar city.
Gulia et al., 2015b	CALPUFF and AERMOD	Jul 2005	Bellary	Assessed NOx concentrations in near field region of a steel industry
Kumar et al., 2015	WRF and AERMOD	May 2011	Mumbai	Contribution of vehicular pollution in ambient air quality of Chembur area in Mumbai city is modeled using AMS/EPA Regulatory Model (AERMOD).
Gulia et al., 2014	AERMOD, ADMS-Urban and ISCST3	-	Delhi	Three state-of-the-art air quality models namely AERMOD, ADMS-Urban and ISCST3 have been used to predict the air quality at an intersection in Delhi city, India, followed by their performance evaluation and sensitive analysis under different meteorological conditions.
Behera et al., 2014	ISCST3	2007-2017	Kanpur	Study explored the possible control strategy to reduce ambient levels of nitrogen oxides (NOx) in Kanpur city, India.
Guttikunda and Goel., 2013	ATMoS	2008-2011	Delhi	A multi-sectoral emissions inventory for 2010 was modeled using the ATMoS dispersion model and local meteorology

				to estimate health impacts in terms of premature mortality and morbidity effects.
Khare et al., 2012	AERMOD, ADMS-Urban, ISCST3 and CALINE 4	2007	Delhi	Four state-of art air quality models i.e. AERMOD, ADMS- Urban, ISCST3 and CALINE4 and two codes i.e. GFLSM and DFLSM (based on Gaussian principle) have been used to predict the air quality of an urban intersection of Delhi, India, followed by their performance evaluation.
Guttikunda and Jawahar., 2012	ATMoS	2010	Pune, Chennai, Indore, Ahmedabad, Surat and Rajkot	Presents the results of an application of the SIM-air modeling tool in six Indian cities i.ee Pune, Chennai, Indore, Ahmedabad, Surat, and Rajkot.
Banerjee et al., 2011	GFLSM and ISCST3	-	Pantnagar	Source-contribution to ambient NO_2 concentration is assessed
Kansal et al., 2011	ISCST3	2004-05	Delhi	Study investigated how the ambient air quality of Delhi would improve if the World Bank emission guidelines (WBEG) for the thermal power plants were to be implemented.
Kesarkar et al., 2007	WRF and AERMOD	Apr 2005	Pune	Meteorological parameters required by AERMOD were computed using the Weather Research and Forecasting (WRF) Model (version 2.1.1). Using this system, the dispersion of respirable particulate matter (RSPM/PM10) over Pune, India has been simulated.
Behera et al., 2011	ISCST3	2007	Kanpur	The study discerns the sources responsible for high PM_{10} levels in Kanpur city.
Sharma et al., 2007	ISCST3	2004	Kanpur	Study explored the possible control strategy to reduce ambient levels PM_{10} in Kanpur city, India
DoEnv, 2018	CTM	2018	Kathmad	Objective id to develop an air quality

			u Valley and Lumbini	management plan for Kathmandu valley and Lumbini region.
Rupakheti et al., 2017	WRF-STEM	2013	Lumbini	The objective of the study was to understand and document the level of air pollution, diurnal characteristics and influence of open burning on air quality in Lumbini.
Mues et al., 2017	WRF and WRF-CHEM	Feb-May 2013	Kathmandu valley	Study evaluated the performance of WRF-CHEM model to simulate black carbon concentrations in Kathmandu Valley.
Zhong et al., 2016	WRF-Chem v3.5	2007	Godavari, Lalitpur	Objective was to study the air quality in East Asia region
ICIMOD, 2012	The Air Pollution Model (TAPM)	2007-08	Kathmandu valley	Objective of the study was to perform rapid urban assessment of air quality for Kathmandu, Nepal.
Regmi and Kitada, 2003	Chemical Transport Model	Feb-Mar, 2001	Kathmandu valley	To assess the exposure to air pollution based on numerically simulated pollutant field
World Bank, 1996	Multi source, Gaussian plume model	October, 1996	Kathmandu valley	Study aimed to assist in the design and implementation of policies, monitoring and management tools to restore air quality in Kathmandu Valley.

Studies based on statistical modelling

S.No.	Study	Type of model used	Study period	City	Objective
1	Upadhyay et al., 2018	multiple linear regression (MLR)	2010-12	India	The study has projected spatial distribution of anthropogenic $PM_{2.5}$ till 2040 over India.
2	Kanakiya et al., 2015	Spatial interpolation techniques such as inverse distance	February, March and April year 2015.	Pune	Spatially interpolated the pollutant concentrations by using the spatial interpolation tool in GIS

		weighing, kriging, splining and nearest neighbor			
3	Sharma et al., 2013	Statistical model	2003-2006	Delhi	The study proposed an integrated and scientifically robust methodology that is generic in nature and could well be used for assessing the air quality compliance criteria laid out by the NAAQS for India, besides suggesting percent reduction in source emissions to those pollutants that exceed the NAAQS.
4	Kumar and Goyal., 2011	Statistical model (Principle Component regression technique)	2000-2006	Delhi	The study forecasted the short–term daily AQI through previous day's AQI and meteorological variables using principal component regression (PCR) technique.
5	Goyal et al., 2006	Statistical model (Multiple linear regression, Box-Jenkins time series ARIMA model and a combination of the two)	July 2000–June 2002	Delhi	The study applied three statistical models to forecast daily averaged concentration of RSPM in urban Delhi and Hong Kong
1	Gurung et al., 2017	Land Use Regression (LUR) model	2014	Kathmandu Valley	Objective of the study was to develop a LUR model to characterize intra-urban variation of nitrogen dioxide (NO_2) in urban areas of Kathmandu Valley, Nepal

Annexure II

Sector Specific Emission Standards of different Countries

Bangladesh

Diesel vehicles

Vehicle type	Emission Standards (g/km)			Test Procedure
	CO	HC + NOx	PM	
1	2	3	4	5
(i) Light duty (Not more than 8 seats in addition to driver & max. weight upto 2.5 tons)				
New Type Approval (TA)	2.72	0.97	0.14	91/441/EEC
Conformity of Production (COP)	3.16	1.13	0.18	
Imported used	3.16	1.13	0.18	
(ii) Medium duty (More than 8 seats in addition to driver but less than 15 seats & weight more than 2.5 tons but upto 3.5 tons)				
New Type Approval (TA)	6.9	1.7	0.25	93/59/EC
Conformity of Production (COP)	8.0	2.0	0.29	
Imported used	8.0	2.0	0.29	

Petrol vehicles

Vehicle type	Emission Standards (gm/km)		Evaporative Emissions (g/test)	Test Procedure
	CO	HC + NOx		
1	**2**	**3**	**4**	**5**
(2 and 3 wheeled) 4-stroke	4.5	3.0	-	ECE-40
Light duty (Not more than 8 seats in addition to driver and max. GVW 2.5 tons	2.2	0.5	2.0	94/12/EC
Medium duty (More than 8 seats in addition to driver but less than 15 seats & GVW more than 2.5 tons but max. 3.5 tons)	5.0	0.7	2.0	96/69/EC

India

Brick Kilns

Bull's Trench Kiln (BTK)		
Parameter	**Category**	**Limiting Concentration (mg/Nm^3)**
Particulate Matter	Small Medium Large	1000 750 750
Stack height (m)	Small Medium Large	22 or induced draft fan operating with minimum draft of 50 mm WG with 12 metre stack height. 27 or induced draft fan operating with minimum draft of 50 mm WG with 15 metre stack height. 30 or induced draft fan operating with minimum draft 50 mm WG with 17 metre stack height.
Category Small BTK Medium BTK Large BTK	Trench width (m) <4.50 4.50-6.75 Above 6.75	Production (bricks/day) Less than 15,000 15,000-30,000 Above 30,000
Down-Draft Kiln (DDK)		
Parameter	**Category**	**Limiting Concentration (mg/Nm^3)**
Particulate Matter	Small/medium/large	1200
Stack height (m)	Small Medium Large	12 15 18
	Small Medium Large	Production (bricks/day) Less than 15,000 15,000-30,000 Above 30,000
Vertical Shaft Kiln (VSK)		
Parameter	**Category**	**Limiting Concentration (mg/Nm^3)**
Particulate Matter	Small/medium/large	250

Stack height (m)	Small Medium Large	11 (at least 5.5m from loading platform) 14 (at least 7.5 m from loading platform) 16 (at least 8.5 m from loading platform)
Category small VSK medium VSK large VSK	No. of shafts 1-3 4-6 7 or more	Production (bricks/day) Less than 15,000 15,000-30,000 Above 30,000

Thermal Power Plants (TPP)

Parameter	**Standards**
TPPs (units) installed before 31st December 2003	
Particulate matter (mg/Nm^3)	100
Sulphur dioxide, SO_2 (mg/Nm^3)	600 (units capacity smaller than 500 MW 100 (units having capacity of 500 MW and above)
Oxides of Nitrogen, NO_x (mg/Nm^3)	600
Mercury, Hg (mg/Nm^3)	0.03 (units having capacity of 500 MW and above)
TPPs (units) installed after 1st January 2003 up to 31st December 2016	
Particulate matter (mg/Nm^3)	50
Sulphur dioxide, SO_2 (mg/Nm^3)	600 (units capacity smaller than 500 MW) 100 (units having capacity of 500 MW and above)
Oxides of Nitrogen, NO_x (mg/Nm^3)	300
Mercury, Hg (mg/Nm^3)	0.03
TPPs (units) installed from 1st January 2017	
Particulate matter (mg/Nm^3)	30
Sulphur dioxide, SO_2 (mg/Nm^3)	100
Oxides of Nitrogen, NO_x (mg/Nm^3)	100
Mercury, Hg (mg/Nm^3)	0.03

Industries

Industry	PM	SO_2	NOx	CO	HCL	HF	Hg*	Cd+TI	Gr I	Gr. II
	(mg/ Nm^3)	(mg/ Nm^3)	(mg/ Nm^3)	(% v/v)	(mg/ Nm^3)	(mg/ Nm^3)	(mg/ Nm^3)	(mg/ Nm^3)	(mg/ Nm^3)	(mg/ Nm^3)
Cement	30 - 100	100 - 1000	600 - 1000		10	1	0.05	0.05	0.5	0.1
Small boilers	150-1600	-	-	-	-	-	-	-	-	-
Foundaries	150-450	-	-	-	-	-	-	-	-	-
Lead glass	50-1200	-	-	-	-	-	-	-	-	-
Soft coke	150-350	-	-	-	-	-	-	-	-	-
Beehive hard coke oven	150-350	-	-	-	-	-	-	-	-	-
Briquette (coal)	150-350	-	-	-	-	-	-	-	-	-
Boilers using agriculture waste as fuel	250-500	-	-	-	-	-	-	-	-	-
Sponge iron plant	50-100	-	-	1%	-	-	-	-	-	-

Diesel Generator set

Genset on LPG and CNG		
Power category	**CO (g/kwh)**	**NOx+NMHC or NOx+ RHC (g/kwh)**
Up to19 kw	≤3.5	≤7.5
< 19 kw upto 75 kw	≤3.5	≤4.7
< 75kw upto 800kw	≤3.5	≤4.0
Genset on gasoline and kerosene		
Displacement (cc)	**CO (g/kwh)**	**HC+NOx (g/kwh)**
Up to 99	≤250	≤12
99 and upto 225	≤250	≤10
>225	≤250	≤8
Genset on diesel upto 800 kw		

Power category	NO_x+HC (g/kwh)	CO (g/kwh)	PM (g/kwh)
Up to 19 kw	≤7.5	≤3.5	≤0.3
< 19 kw Up to 75 kw	≤4.7	≤3.5	≤0.3
< 75kw Up to 800kw	≤4.0	≤3.5	≤0.2

Residential Cookstoves

Type of Biomass Cookstove	Standard Performance Parameters		
	Thermal Efficiency (%)	CO (g/MJd)	PM (mg/MJd)
Natural Draft Type	Not less than 25	≤ 5	≤ 350
Forced Draft Type	Not less than 35	≤ 5	≤ 150

Nepal

Brick Kilns

Type of Kiln	Suspended Particulate Matter (Maximum Limit)	Height of Chimney (Minimum Limit)
Bull's Trench Kiln	600 mg/Nm³	17 meter
Bull's Trench Kiln, Natural Draught (Fixed Chimney)	700 mg/Nm³	30 meter
Vertical Shaft Brick Kiln	400 mg/Nm³	15 meter

Industries

Type	Quantity	Emission limit
Cement industry	Total Suspended Particulate Matter	Less than 500 μg/Nm³
Crusher industry	Total Suspended Particulate Matter	Less than 600 μg/Nm³

Industrial boilers

Steam Generation Capacity of Boiler (kg/hour)	Particulate Matter Emission Limit (mg/Nm³)
Less than 2000	1200
2000 to less than 10000	800
10000 to less than 15000	600
15000 and above	150

Vehicles

Types of Vehicles		CO% by Volume	HC (ppm)
Four wheelers 1980 or older		4.5	1000
Four wheelers 1981 onwards		3	1000
Two-wheelers (two stroke)		4.5	7800
Two-wheelers (Four – stroke)		4.5	7800
Three Wheelers		4.5	7800
Type of fuel	**Types of vehicles**	**CO% by Volume**	**HC (ppm)**
Gas	Four wheelers vehicles	3	1000
Gas	Three wheelers	3	7800
Diesel	Older than 1994	-	75
Diesel	1995 AD onward	-	65

DG sets

Category (kW)	CO (g/kWh)	HC+ NOx (g/kWh)	PM (kWh)
<8	8.00	7.50	0.80
8 ~ 19	6.60	7.50	0.80
19 ~ 37	5.50	7.50	0.60
37 ~ 75	5.00	4.70	0.40
75 ~ 130	5.00	4.00	0.30
130 ~ 560	3.50	4.00	0.20

Residential Cookstove

Total Emission	Indoor	Indoor + Chimmney
High Power $PM_{2.5}$ (mg/MJ_d)	≤41*	≤979
Low Power $PM_{2.5}$ (g/min/L)	≤1	≤8
High Power CO (g/MJ_d)	≤8*	≤16
Low Power CO (g/min/L)	≤0.09	≤0.20
Indoor Emission Rate		
$PM_{2.5}$ (mg/min)	≤5	
CO (g/min)	≤0.42	

Pakistan

Diesel Vehicles

Type of vehicle	Category/class	Tiers	CO	HC+ NOx	PM	Measuring method	Applicability
Passenger car	M1: with reference mass (RW) Up to 2500 kg, cars with RW 2500 kg to meet n1 category standards	Pak -II, IDI Pak-II DI	1.0 1.0	0.7 0.9	0.08 0.10	NEDC (ECE 15+ EUDCL)	All imported and local manufactured Diesel vehicles with effect from 01-07-2012
Light commercial vehicles	NI-I (RW <1250 KG) NI-II (1250 KG< RW <1750 kg) NI-III (RW <1700 kg)	Pak-II IDI Pak-II DI Pak-II IDI Pak-II IDI Pak-II IDI Pak-II DI	1.0 1.0 1.25 1.25 1.50 1.50	0.70 0.90 1.0 1.3 1.2 1.6	0.08 0.10 0.12 0.14 0.17 0.20		

Gasoline Vehicles

Type of vehicle	Category/class	Tiers	CO	HC+ NOx	Measuring method	Applicability
Passenger cars	MI: with reference mass (RW), up to 2500 kg. Cars with RW over 2,500 kg to meet NI standards	Pak-II	2.20	0.5	NEDC (ECE 15 EUDCL)	All imported and new models* locally manufactured Petrol vehicles with effect from 1st July 2009**
Light	NI-I	Pak-II	2.20	0.5		

Type of vehicle	Category/class	Tiers	CO	HC+ NOx	Measuring method	Applicability
commercial vehicles	(RW<1250 kg) NI-NI-II (1250KG > kg RW<1700 kg) NI-III (RW> 1700 kg)	Pak-II	4.0 5.0	0.65 0.08		
Motor rickshaws and motor cycles	2.4 strokes <150cc 2.4 strokes > 150cc	Pak-II Pak-II	5.5 5.5	1.5 1.3	ECER 40	

Industries

Parameter	Source of emission	Standards
Smoke	Smoke opacity not to exceed	40% or 2 Ringlemann Scale or equivalent smoke number
Particulate matter	A. Boiler and Furnaces (1) Oil fired	300
	(2) Coal fired	500
	(3) Cement kilns	300
	B. Grinding, crushing, Clinker coolers and related processes, Metallurgical Processes, converter, blast furnaces and cupolas.	500
Hydrogen Chloride	Any	400
Chlorine	Any	150
Hydrogen Fluoride	Any	150
Hydrogen Sulphide	Any	10
Sulphur Oxides (2)(3)	Sulfuric acid/ Sulphonic acid plants Other plants except power plants operating on oil and coal	1700
Carbon Monoxide	Any	800
Lead	Any	50
Mercury	Any	10
Cadmium	Any	20
Arsenic	Any	20
Copper	Any	50
Antimony	Any	20

Parameter	Source of emission	Standards
Zinc	Any	200
Oxides of Nitrogen	Nitric acid manufacturing unit. Other plants expect power plants operating on oil and coal: Gas fired Oil fired Coal fired	3000 400 600 1200

Annexure III

Detail of the Stakeholder consultation workshops

Bangladesh

Venue: Department of Environment, Dhaka

Date: 7th January, 2019

List of participants in the workshop is given in the Table A1.

Dr. S.M. Munjurul Hannan Khan, Additional Secretory, Ministry of Forest and Environment, Government of Bangladesh chaired the meeting. He stated that despite of good policies in place, monitoring is not being done properly due to under manpower. DoE staffs are overloaded with work. He also expressed necessity for support in nature of technology and resource. He emphasized developing effective network among stakeholders. Dr. Sultan Ahmed, Director General of DOE moderated the entire workshop.

Most of the participants observed that government has not much interest to discourse the air pollution problem as a national problem. The contractors of construction works do not spray water to reduce dust pollution in the working area. Significant amount air polluted from Rice Parboiling, Steel Rerolling mills, stone crusher.

Most rural mothers spend every day 3-7 hours in the kitchen and they use biomass fuel for food preparation. Combustion of biomass discharges thousands of pollutants in high concentration and the mothers are exposed to those pollutants. Many of these mothers suffer from different type of diseases like COPD, Asthma, acute respiratory tract infection (ARTI), burning of eyes, sudden headache, cardio-vascular disease, adverse pregnant outcome, etc. Government is promoting ICS (2 million installed) and LPG, to reduce indoor air pollution. Government has a target to install 30 million ICS by the year 2030. Implementation of Improved Cooking Stoves (ICS) under the leadership of DOE has brought success.

Air of Dhaka city is polluted by emissions of brick kiln industries surrounding the city and vehicles used for transport. Slow movement of vehicles and traffic jam during pick hours contributes much for air pollution. Dhaka Transport Coordination Authority (DTCA) is implementing "Bus Rapid Transport". Bangladesh government has imported some auto stop vehicles. The effect of implemented activity needs to be evaluated. Therefore research study may be design to measure emission of these auto stop vehicles and adaptation capacity to environmental condition of Bangladesh. Increased population growth also contributes for increased traffic movement in Dhaka city that have adverse effect on air pollution and health of local residences. Government initiative to ban two stroke baby taxis in Dhaka city backed plentiful improvement of air quality. But the experts were worried that the CNG baby taxies emit trillions of fine particulate matters those are very dangerous for developing COPD. Therefore, health effects and emission components of CNG vehicles may be studied.

Photographs of the workshop

Table A1 List of participant in the stakeholders' consultation workshop in Bangladesh

Stakeholder Consultation Workshop
On
Scoping Study: South Asian Air Pollution
Venue: Department of Environment
January 07, 2019

Registration

Serial	Name of the Participants	Designation and Institution	Contact details	Signature
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4	Md Ziaul Haque	Director DoE	01817008703	
5 X	Dr. Saleemul HuQ	Director, ICCCAD	0177 975 4662	
6				
7				

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Serial	Name of the Participants	Designation and Institution	Contact details	Signature
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Serial	Name of the Participants	Designation and Institution	Contact details	Signature
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India

Venue: The Energy & Resources Institute, India Habitat Center, New Delhi

Date: 15th January, 2019

List of participants in the workshop is given in the Table A2.

A joint stakeholder's consultation meeting was held in The Energy and Resources Institute (TERI), New Delhi with support from Department for International Development (DFID), United Kingdom, on 15th January 2019. It was proposed for technical discussions and other related deliberations between different stakeholders working in the area of ambient air quality monitoring, human health and related data forecasting & econometric modeling. The meeting was held to discuss the air quality management scenario, research gaps and recommendations from various stakeholders on specific tasks for improving air quality to develop an effective air quality management framework in India. TERI is undertaking the study in four south Asian countries: India, Bangladesh, Nepal and Pakistan. The main aim of the study was to access the current state of the evidence of air pollution in above mentioned countries and identify the research gaps and priority areas at country level and regional-scale.

Dr. Sumit Sharma (TERI), Director TERI in his opening remarks welcomed the participants and briefed them about the air quality scenarios, major pollution contributing sources and activities. He also elaborated the air pollution, as a complex regional problem that is also subject to hemispheric and even global influences.

Dr. Ajay Mathur, Director General (TERI), elaborated the importance of air quality studies. He pointed out the need and requirement of cross boundary interventions in pollution and air initiatives by Government. The long-range transport of air pollution leads to immediate action plans for different cities with different pollution sources. He also focused on the need of public consultations and participations which helps people to mobilize on to a process legal framework through which people plan and action in amendment of air pollution at least at a local level.

Dr. Shruti Rai Bhardwaj (MoEFCC), emphasized on the need of assessment of the regional air quality and separately addressing the regional and trans-boundary aspects of air pollution and also focused on the required evolution of the present air pollution interventions and plans. She also pointed out the need to develop a mechanism on how localities should address the impact of international pollutant transport in air quality planning.

Mr. Anirban Ganguly (DFID South Asia Research Hub) elaborated the issues of productivity loss, research gaps and related health impacts by air pollution. He focused on the requirement of mapping of the institutional framework. He also pointed out the need of better policies research framework with combined global goals.

Air quality monitoring and its coverage in India

- The starting point of air quality monitoring is to first study if an area has an air pollution problem. Monitoring helps in assessing the level of pollution in relation to the ambient air quality standards.
- Standards are a regulatory measure to set the target for pollution reduction and achieve clean air.
- The ambient air quality in India is monitored collectively by CPCB, state pollution control boards (SPCBs), pollution control committees (PCCs), and National Environmental Engineering Research Institute (NEERI) in cities, and covers 215 cities and towns.
- A total of 700 manual monitoring stations are being operated across states. Some states have set up additional monitoring stations in cities.
- The present national air quality monitoring network is limited in scope as the recorded values are indicative and there is immense time lag in reporting the data. Also, involvement of various monitoring agencies, personnel and equipments in sampling, chemical analyses and data reporting brings uncertainty and biases.
- Different measuring techniques and instruments give varying results on ambient concentration in the same location primarily because of incorrect flow measurement and calibration. Moreover, inconsistent power supply and voltage fluctuation affect monitoring.
- Network optimization and short term reduction targets are required at least at a local level.
- Humanizing air quality index can helps people to easily understand the scenario of their surroundings.

Displaying data to the public

- Changing the colour code of AQI to some indicator which general public can understand and know the severity of the problem. Different countries have different colour codes of AQI, which may lead to misinterpretation
- Public awareness must be increased at both urban and rural levels. Create awareness among school children about the severity of air pollution and how to mitigate the issue.
- Issues and concern related to air pollution is widely spoken at city level/urban areas without realizing the fact that rural parts of the country are also affected.
- LPG penetration in rural areas and introduction of BS VI norms are some of the key strategies implemented by the Government to curb the air pollution from domestic and transport sector respectively.

Alternative/innovative methods of monitoring

- To improve the quality of monitoring network low cost sensors are good option, but should be reliable, efficient and accurate and should be accompanied with proper certification.

- Stability and reliability of low cost sensors are major issue which differs from manufacture to manufacture, therefore accuracy of instruments puts a vital question on monitoring of air of particular region
- Remote sensing is another option of monitoring air quality, which is helpful in identifying hotspots in the absence of other monitoring techniques

Emission monitoring, reporting, standards and certification

- Standards should be revised at least every five years for individual pollutants, especially for the industrial sector standard must be revised and regulated frequently
- Apart from monitoring of major industries, stringent norms must be intervened to address pollution levels from small scale industries since such type industries doesn't have proper disposal mechanism thereby instead of disposing off they incinerate the waste which results in emission of toxic gases.
- Since transport sector is one of the major contributors to the overall air quality of a region, following PUC norms and proper Inspection & Maintenance (I&M) system must be strengthened as transport emissions are generated from old and improper maintenance of vehicles

Source apportionment and status of air quality modelling in India

- The CPCB has come up with a list of non-attainment cities in India and these cities have to come up with a set of action plans
- Detailed scientific studies are required for identification of major sources of air pollution and their contribution to the ambient air quality of a region to arrive at sector specific strategies to control the pollution, which is cost and time intensive.
- Rather than going for source apportionment study Government must undertake emission inventory based study for non-attainment cities across pan India.
- Since air pollution in India also has trans boundary or regional effects, therefore researchers must focus source apportionment study considering meteorological aspects.
- Development of own indigenous based model for source apportionment study has also be taken into account.

Government and Public Perception of India's Air Quality ranking in World

- Ranking based on air quality data is quite misleading because there are number of actors involved like location of monitoring, number of days of monitoring, instruments used etc.
- Ranking is based on a particular pollutant, for India the ranking is based on the PM levels, which is a pollutant of concern in India. It may not be the case if we rank based on other pollutant levels
- Ranking should be done on the basis of the tons of the PM emitted per year
- When it comes toxicity ranking, the toxicity levels of PM will be different in the younger generation when compared to that measured in older generation

- Impact of same pollution levels in different population is different, so how much detrimental impact air pollutants is having on a particular human being should be the criteria of ranking and not the toxicity or pollution levels itself.

Photographs of the workshop

Gaps and Recommendations

Air monitoring in India have evolved over the years as a robust strategy to mitigate adverse impacts of air pollution on human health. Involvement of various stakeholders ranging from national and state level governing bodies to academia in this initiative has resulted in an improved understanding of the overall air pollution scenario in India. The result is that our country has specific guidelines and strict standards to which pollution causing industries and other sectors have to comply. Still there are certain lacunae in the present framework which need to be addressed. The present state of knowledge about the air monitoring framework gathered through literature and stakeholder consultation had led to several discussion points which need to be addressed in future.

- AAQ monitoring in India is primarily managed by CPCB through NAMP by involving state level pollution control boards and pollution control committees. The most important issue which needs to be dealt with immediately is the inadequate number of air monitoring locations in India. When the concern is human health there is no choice but to carry out pollution abatement strategies where beneficiaries are not limited to certain areas. The resources have to be directed towards expanding the coverage of NAMP so that the health benefits can be maximized.
- Additionally, none of these monitoring locations are in the rural areas of the country. Policy makers, Government and researchers have focused their attention on air quality in the urban areas, neglecting the ambient air quality in the rural areas. So there is an urgent need to include rural areas also in the current monitoring network which will be useful in determining the rural air quality management plans.
- The present AQI is interpreted in six color categories which confuse people. Therefore there is a need to make interpretation of present AQI simpler, which can be easily perceived by common people.
- Data auditing, background stations and road side monitoring also required to enhance the representativeness and quality of the data retrieved from monitoring stations
- To ensure the quality of data, analytical quality control and calibration, repair of instruments and evaluation of ambient air quality monitoring stations are must.
- Public participation plays a key role in the successful implementation of air quality interventions. For this, it is necessary to get a sense of the priorities and current levels of awareness so that public engagement efforts can be better defined and implemented.
- The monitoring guidelines and standards need to be re-examined from time to time considering the dynamic state of environment and ever changing socio-political scenarios. Thrust should be given for maintaining quality of data generated with the help of well-defined procedures so that the relevant measures can be taken to combat air pollution.
- Promoting and implementing public awareness programme with social aspect at rural level will help to cut traditional cause and issues affecting the air quality.

- Future perception must be targeted in every two/five years by modifying existing AQI for improving the air quality
- There is a need to include research led innovations in monitoring technologies which can enhance the quality and quantity of monitored data. The innovations in this sector are very crucial and there is a need to incentivize researchers/manufacturers so that there is a push factor which results in invention of practical as well as affordable pollution monitoring systems.
- To resolve the issue of reliability of low cost sensors, more research is required to validate the accuracy of low cost sensors with the existing monitoring techniques.
- Government must identify reliable certified sensors for deploying at different regions and the sensors are to be calibrated for different pollutants from time to time.
- Since transport sector is one of the major contributors to the overall air quality of a region, following PUC norms and proper Inspection & Maintenance (I&M) system must be strengthened
- Remote sensing I& M system can be implemented at peripheral highway or toll plazas
- Recycling, scrapping, fitness certification system with improved technology mechanism must be enhanced for all categories including commercial vehicles and HDVs.
- Chassis dynamometer testing facility and diesel emissions control system must be developed
- Standards should be revised at least every five years for individual pollutants, especially for the industrial sector standard must be revised and regulated frequently. Apart from monitoring of major industries, stringent norms must be intervened to address pollution levels from small scale industries
- DG set standards is also need to be stringent since they contribute largely to poor air quality levels.
- To deal with issues related with stubble burning, agriculture crop residues can be utilized as biomass for thermal power generation or in biomass gasification unit for generating electricity
- Proper ex-situ and in-situ management planning must be intervened for sectorial category like implementation of zig-zag technology for brick kiln industries
- By considering the importance of air quality models for their use in EIA and air quality management plan, and to account for chemistry between the pollutants, there is a need to move towards more advanced Chemical Transport Models which will help in developing more robust results. The use of air quality models in identifying the most useful interventions for control of air pollution is limited and hence there is a need to improve it.
- Limited number of source apportionment studies has been carried out in the country due to huge cost implications. Moreover most of studies done till date is for metro cities. Rather than going for a detailed source apportionment study for

all non-attainment cities, Government must undertake emission inventory based study for non-attainment cities across pan India.

- Air quality management plan should be prepared to achieve the targets in a timely fashion. There is a need to review these interim targets continuously on regular basis.

Table A2 List of participant in the stakeholders' consultation workshop in India

Stakeholder Consultation for Scoping Study for Air Pollution in India' on 15th January 2019 at TERI office, India Habitat Centre, Lodhi Road, New Delhi

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8	Atreyi	Ganguli	WHO			
9	Balraj	Bhanot	BIS			
10	Chhemendra	Sharma	National Physical Laboratory (NPL)			
11	Chirag	Bhimani	Gujarat Pollution Control Board			
12	D R	Pattanaik	The India Meteorological Department (IMD)			
13	Dhirendra	Singh	Airshed			
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26	S K	Goyal	NEERI, DELHI			
27	S K	Singh	Delhi Technological University			
28	Sagnik	Dey	Indian Institute of Technology			
29	Shruti Rai	Bhardwaj	MoEFCC			
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Nepal

Venue: Hotel Marshyangdi, Kathmandu

Date: 28th December, 2018

List of participants in the workshop is given in the Table A3.

- Department of Environment (DOE) is in the process of increasing the monitoring network to 56 locations against the currently existing 14 stations
- Air quality index (AQI) is not yet established because of lack of data. DOE is in the process of developing AQI in collaboration with US.
- In addition to the existing monitoring network, there are other agencies like CDHM, DRISTI Kathmandu, Institute of Engineering (IOE), Nepal Academy of Science and Technology (NAST), Nepal Health Research Council (NHRC) , etc. are also monitoring ambient air quality
- People are aware about air pollution in Nepal
- There are standard for DG sets, Boiler, Incinerator, Chimney stack (general standard), indoor air quality, and National ambient air quality standard which were last modified in 2012.
- APEC is government body which works through private organization to promote improved cookstoves in rural villages by providing subsidy and thereby reduced emissions from biomass burning to about 60% in rural households. Impact analysis of the improved cookstoves on health has not yet established.
- These emission standards are revised with ISO certification, periodically.
- In urban areas, electric stoves are used. The Government of Nepal is promoting the use of electric stoves in place of LPG as some components of LPG is carcinogenic.
- Hospitals/Industries are monitored on regular basis and have found to be violating the emission standards due to which they are not reporting the results. DOE has penalized 18 out of 39 hospitals monitored for violating the emissions standard.
- Protocol for emission monitoring in industries and hospitals do exist in Nepal 2012 and s monitoring is done on an annual basis after establishment of DOE.
- Manpower is a concern due to which regular auditing of industries is a challenge
- Installation of incinerators in hospitals is mandatory and since they are not meeting the emission standards, Ministry of Health has published notice on banning the incinerator in Hospitals.
- Dust generated from construction activities is a major contributor of air pollution especially in Kathmandu valley
- Most of the industries in Nepal do not have APCD, the penalization charge for not installing the APCD's in industries has increased to 25 lakhs from 2 lakhs
- Major fuels used by industries in Nepal are diesel, furnace oil, coal and biomass (rice husk). Agricultural residue, briquettes and pellets are also emerging as fuels.
- There is no extensive research happened in the field of source apportionment study in Nepal. However, studies are being conducted on dispersion modeling of Kathmandu valley in collaboration with DOE.

Photographs of the workshop

- Air pollution inventory of Kathmandu valley and Lumbini region along with emission map for different cities were developed.
- To maintain the clean air in Kathmandu valley, studies showed that domestic emission should be reduced by 80%, transport emission by 30% and industries emission by 40%. in Kathmandu valley. Similarly in Lumbini region, 70% emission from industries sector should be reduced to maintain national emission standards.
- Study on diesel vehicle which is pilot project showed that emissions from vehicles can be reduced by regular servicing of vehicle's parts such as air filter, diesel filter, and engine oil.
- ICIMOD study showed that after servicing, emission of $PM_{2.5}$ was reduced by 25 % whereas CO by 50%. Among diesel vehicles, 25% emission can be controlled by regular servicing.
- Emission from motorcycle was reduced by 90% with proper I&M practices.
- Nepal government has given subsidy for importing electric vehicles.

- Different agencies are using low cost sensors for monitoring of air quality as a part of their research. Also passive sampling method is being carried out for model predication by some agencies.

Recommendations

- DoE has amended action plan which still needs approval from ministry. DoE inspected vehicle emission in the street in collaboration with Department of Transport 1500 vehicles were tested. Out of which 60% diesel and 32% petrol driven vehicles failed the test. DoE urged to pay penalty for these vehicles. The plan which is currently not in place but will resume shortly.
- Management of traffic, regular servicing of vehicles are effective in mitigating emissions from transport sector
- Banning of 20 year old vehicles 3 wheeler tempos and importing second hand vehicles.
- Promoting use of electric vehicles and metro train can significantly reduce pollution from transport sector
- Introduction of Euro III standard vehicle and Improving the public transport system
- Ban on burning of hospital wastes and refuse during evening time especially in Kathmandu valley can significantly improves the air quality.
- Increasing the price of kerosene by government is good tools to reduce its use which consequently reduces air pollution.
- Converting all brick kilns to Zig-zag technology
- Regular monitoring of industries can significantly reduce emissions from this sector.
- Ban on registration for highly polluting brick kilns and other industries
- Roof top gardening and creating awareness among general public about the environmental and economic benefits of root top gardening.
- Calibration and maintenance of air pollution monitoring equipment and the calibration should be done periodically.
- Public awareness regarding current pollution scenario and its mitigation strategies is important. Publication of low cost sensor data on daily newspaper is beneficial to create awareness among people.
- Construction activities should be carried out by strictly following the norms

Table A3 List of participant in the stakeholders' consultation workshop in Nepal

Stakeholder Consultation for Air Quality Scenario in Nepal
28th December 2018

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Stakeholder Consultation for Air Quality Scenario in Nepal
28th December 2018

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Pakistan

Venue: Sustainable Development Policy Institute, Islamabad

Date: 27th December, 2018

List of participants: **Dr. Anjum Rasheed**, Asst. Professor, COMSATS University; **Dr. Nasreen Farah**, Former official, Hydrocarbon Development Institute of Pakistan; **Hassan Sipra**, Centre for Climate Research and Development (CCRD); **Zeeshan Virk**, Leadership for Environment And Development (LEAD), Pakistan; **Asad Mehmood**, National Energy Efficiency and Conservation Authority (NEECA); **Momi Saleem**, Heinrich Boell Stiftung (HBS) Pakistan; **Dr. Imran Khalid**, Sustainable Development Policy Institute, Islamabad; **Ahad Nazir**, Sustainable Development Policy Institute, Islamabad; **Maryam Shabir**, Sustainable Development Policy Institute, Islamabad; **Adnan Maqbool**, Sustainable Development Policy Institute, Islamabad**; Ahmed Khaver**, Sustainable Development Policy Institute, Islamabad and **Shiza Durrani**, Sustainable Development Policy Institute, Islamabad

Dr Imran Khalid opened the discussion with a brief introduction of the participants and the topic and started off with his observation that air pollution has now taken center stage in Pakistani media, public and policy circles and questioned the transformation. He asked about what are the factors that have highlighted the issue of smog and air pollution.

Dr Anjum Rasheed suggested that the air pollution phenomenon has risen to prominence due to the appearance of smog lately. Prior to smog no one highlighted the air pollution problem. However due to smog policy makers have also started focusing on the subject. Punjab banned crop residue burning back in 2014 but the actual implementation of the ban is questionable and has not been optimally enforced.

Ms Maryam Shabbir stated that awareness has significantly increased in both public and government spheres. The linking of the smog and air pollution issue with India also helped bring this issue to the forefront. The issue with the data on air pollution is significant. Multiple private entities are generating their own data relating to air pollution but the government still lacks any consolidated data over air pollution. (Multiple members suggested that government officials operated some of the data they had but since the sacking of the key person the data is under his/her placed password and now cannot be accessed).

The issue moved to the involvement and centrality of the Environmental Protection Agency and Dr Nasreen mentioned that we have to move beyond the EPA in responding to the air pollution issue. She also hinted at the link between air pollution and the wider climate change effects it might have if properly analyzed. She further added that transport, brick kilns and use of fossil fuels are the major sources of the air pollution and even CNG has the potential to aggravate the problem.

Asad Mehmood while responding to the query of data regarding the amount of pollution from brick kilns said that the main issue is that the NEQS must be met.

However process optimization is lacking. In case of sectors, brick kilns are targeted as their black smoke has high visibility and the lesser visible polluters are not as such targeted. Furthermore he added that the issue of social media has helped to greatly highlight the issue.

Zeeshan Virk posed the question about the centrality of data for research and air pollution modeling's significance to better analyze the issue.

Hassan Sipra responded that the data international agencies have on the subject regarding Pakistan is flawed. He opined that those studies that come up with such numbers if we backtrack are skewed in a sense that they are done either in very limited time frame or very specific places. Such studies and approached cannot bring out the clear picture of ground realities. He added that the data we need must also be comprehensive and across time and space. He also added the incentive structure for the brick kilns is missing. For instance the brick kilns are offered the zig zag approach without any incentive from the government. The government could provide cheaper electricity input as the zig zag model requires electricity to run the kiln (essentially the fans). Other issue he highlighted was the delinking of air pollution and the smog. The essential requirement of the hour was source apportionment study. He provided an alternative that we could acquire the source apportionment from other countries and see and place Pakistan where we believe according to other countries numbers. He opined that this would at least provide a bench mark to assess our position to move ahead from.

Dr Imran asked how JICA had assisted the government in setting up monitoring equipment and the process and outcomes. Dr Anjum Rasheed responded by stating that federal EPA approached JICA for the assistance and equipment. There were mobile and fixed monitoring equipment along with the labs where the data would be analyzed. For this JICA brought out its project to increase the capacity of the lab staff of EPA for 3 years. JICA requested the government to regularize the staff whose capacity building and trainings were done in order to make the project sustainable. The government did not regularize the project and there was a lack of serious engagement from staff. The equipment was left out to rot. As a result JICA decided not fund Pakistan in environmental realm. Other such initiatives from the NGOs have also gone sour due to government's lack of engagement and non-availability of funds.

Dr Nasreen Farah suggested employing Phd students to investigate air pollution in different cities to counter the problem of data and funds. The students' interest and the peer review process would ensure the authenticity of data.

Dr Anjum Rasheed countered by arguing that research students do not have any funding for such investigations. She stated that adequate funds are not given by universities or the government. Only NGOs provide such funds for research. She suggested restructuring and capacity building of the staff of the EPA. She stressed the need of data on the subject and the implementation mechanism must be revamped she added.

Zeeshan Virk stated that we need to assess what is the necessary short to medium term requirement or recommendation on the subject because PhD scholars would take multiple years to conclude a research. Dr Imran Khalid added that to take the question forward he asked are the government run monitoring stations and equipment enough to be able to do an apportionment study? What are the necessary requirements for doing an apportionment study?

Hassan Sipra responded that for an apportionment study we require a yearlong data on weather patterns and we require air quality monitoring station and also dedicated analysts to assess the air pollution to come up with the sources. He highlighted that as such there are no such auto analyzers. He further stressed the need of research institute to collaborate with other counterparts in other countries who have the expertise to assess and measure the air pollution phenomenon. A team of researchers would also be required here in Pakistan to dedicatedly work on the subject. He further added that the academia and the research institutes need to be aligned. When the government officials go and notify any industry of polluting the environment or penalize the industry they should also provide information to the owner regarding which research body to approach and figure out a way to reduce their emissions.

Mome Saleem added that the way forward lies in making business more responsible. She added that this would not be done in a year of two years' time. She highlighted the role of CSR and the need to engage private business to address the issue of air pollution. She highlighted the need to inject responsibility into the industrial sector. Inclusion of the private sector is the way forward she proposed.

Maryam Shabbir added that industries have a significant influence and leverage in the political system that allows for them to operate freely and even when fined or penalized still continue operating. She lamented that the governance structure and methods also need to be assessed and looked at.

Asad Mehmood detailed how the zig zag method was brought in and then operated into processes of the brick kilns. He told that ICIMOD and he were working on improving brick kilns processes and or that called ICIMOD personnel and the brick kilns association. He highlighted how they engaged the kiln owner and approached the issue on equal footing and did not lambast the brick kilns association presidents as opposed to other initiatives. He said that the project initiated with recommending to the brick kilns association presidents the new technique and how that would result in greater productivity and efficiency. To this the brick kilns owners did not respond positively. He then suggested and sent some of the operators to acquire this newer technology. He added that when the operators observed the zig zag method themselves they started believing that this method indeed increased productivity and profits. However some of the operators retrofitted the technology and said that they experienced profit losses. The issue he stated was reverting back to the same technology half way into the process and the same traditions and method of brick manufacturing. He stated that then the young individuals of the brick kiln associations were the ones who picked the method and took it forward and applied the method in letter and spirit. In some cases the owners did understand the concept but as soon as they left the kiln at night or for other engagements the workers reverted back to their own methods and techniques which reduced profits.

Once this issue was rectified then the declining profits subsided and now most of the kilns return favorably. He further highlighted that how government in different projects is streamlining the use of zig zag model bricks for different projects to ensure economic viability of such initiatives.

Dr Imran Khalid asked how the energy outlook of the country is. Adnan Maqbool responded by saying that coal power plants would compensate for shortfall in energy. He highlighted the Sahiwal coal power plant (1320MW) and added that other coal powered plants were in the pipeline of the CPEC plan. That he said would have implications for air pollution.

On the issue of NDC (nationally determined contributions) Asad Mehmood opined that those documents submitted by Pakistan did not incorporate the inputs from multiple stakeholders and different research organizations. There should have been a comprehensive mechanism to draw out such documents where all stakeholders and opinions should have been owned by the government.

Ahad Nazir suggested that the example of the foundries was the one to be emulated. Foundries associations were asked to fall under the environment compliant notifications to reduce emissions. He stressed that in their case those foundries that did not comply with the government standards or installed the necessary emissions reduction equipment and policies were shut down.

"Policy and Action Plan for Control, Mitigation, Advisory, and Protective Measures in Extreme Weather Conditions of Dense Smog in the Punjab" has been notified by the Government of the Punjab, Mome Saleem opined that this policy is multi sectorial. However no relating issues such as land use plans, agricultural policies, urban development and housing societies all have to be aligned in order to achieve progress with regards to this policy.

Key suggestions from the workshop;

- Industrialist enjoys significant political influence and leverage. There is a need of political will to address the issue and the implementation of that will into force.
- The language map of the dialogue with different sectors is essential, the framing and use of language goes a long way in approaching and addressing the issue.
- The private sector has to be brought into the dialogue as a partner, instilling more responsibility and tying them to research institutes to draw out options for reducing emissions.
- Centrality of data compels us to acquire instruments and equipment, capacity enhancing of staff, a consolidated data bank on the subject and enhancing capacity of private initiative to be able to acquire a holistic data as of now they have limited capability in terms of acquiring complete data.
- Process optimization is required in order to run and sustain air quality projects. There is immediate need to increase the capacity of the staff to sustain the projects.

Annexure IV

Air Quality Perception Survey

Basic Information

*Country

- India
- Bangladesh
- Nepal

*State/Division/Province

Which area do you belong to?

- Rural
- Semi-Urban
- Urban

Gender

- Male
- Female

Age (years)

Educational qualification (optional)

- No education
- Primary School
- Secondary School
- Graduation
- Post-Graduation
- PG Diploma

Employment status (optional)

- Student
- Employed:Government
- Employed: Private
- Employed: MNC
- Unemployed

Average monthly income of your family (optional)

- No Income
- <5,000
- 5,000-10,000
- 10,000-30,000
- >30,000

*Are you aware of air pollution?

- Yes
- No

Air Quality in your area

How would you rate the overall air quality in your area?

- Excellent
- Very Good
- Good
- Very Poor
- No Idea

Are you aware that the country has National Standards for Air Quality?

- Yes
- No

What are the main causes of air pollution in your area? Rank the 5 most important sources from dropdown menu.

Sources

Rank 1

Rank 2

Rank 3

Rank 4

Rank 5

Industry(s)	Agricultural residue burning
Power plant(s)	Road dust
Automobile	Diesel generator(s)
Mining activity(s)	Waste burning
Brick kiln(s)	Cross border pollution
Construction activity(s)	Others
Residential fuel burning	

Control Measures

Rank following emission control measures in their effectiveness to improve air quality

	Don't know	Ineffective	Somewhat Effective	Highly Effective
Transport emission control	○	○	○	○
Industrial emission control	○	○	○	○
LPG/PNG penetration in the residential sector	○	○	○	○
Controlling open burning of waste/agro-residues	○	○	○	○
Road cleaning & management	○	○	○	○
Ban on cracker burning	○	○	○	○
Controlling dust emission from construction activities	○	○	○	○
Controlling the use of diesel generators	○	○	○	○
Shifting from coal based electricity to renewable electricity	○	○	○	○

What are the additional strategies to reduce the air pollution level of the country? Rank the top 5 strategies from the dropdown menu

Strategies

Rank 1

Rank 2

Rank 3

Rank 4

Rank 5

Clean Air Initiative by govt
Enhancement of public transport
Enhancement of use of renewable energy
Introduction of congestion pricing
Encourage waste to energy conversion
Improved automobile engine technology
Strengthening the Pollution Under Control (PUC) program

Encouraging car pool
Public awareness building
Introduction of clean fuel in automobile
Introduction of cleaner industrial process
Enhancement electric mobility

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