Asian and Pacific Centre for Transfer of Technology

Assessment Report

Technological Interventions and Gaps in Air Pollution Control in Dhaka, Bangladesh

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FOREWORD

It is with great pleasure that I introduce this document: *Technological Interventions and Gaps in Air Pollution Control in Dhaka, Bangladesh*.

The Asian and Pacific Centre for Transfer of Technology (APCTT) of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), has long been dedicated to fostering innovation and facilitating the transfer of technology across our diverse member countries. APCTT's key mandate is to strengthen the technology transfer capabilities in the Asia- Pacific region and to facilitate exchange of new, emerging and environmentally sound technologies between the member countries.

This document was produced under the project "Enhanced capabilities to adopt innovative technologies for city air pollution control in select countries of the Asia Pacific" supported by the Korea ESCAP Cooperation Fund. The project objective was to support three ESCAP member States (Bangladesh, India and Thailand) to strengthen policies and city level action plans to facilitate adoption of innovative technologies for controlling air pollution. The project aimed to improve the availability of technical knowledge regarding innovative technologies, and good practices and enabling policies for air pollution control in three cities (Bangkok, Dhaka and Gurugram).

This assessment report examines the current state of air pollution technologies employed in Dhaka. It identifies the key technological needs and gaps that require urgent attention for controlling urban air pollution. As we attempt to enhance our understanding of the complexities of air pollution in key cities in Asia Pacific, the findings of this report will serve as a valuable resource for policymakers, city planners and practitioners. I hope that this report will play an important role in shaping the trajectory of air pollution control initiatives in Dhaka and other cities in Asia Pacific.

Preeti Soni
Head
Asian and Pacific Centre for Transfer of Technology
Economic and Social Commission for Asia and the Pacific

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This document: *Technological Interventions and Gaps in Air Pollution Control in Dhaka, Bangladesh* is part of a set of reports developed under the project "Enhanced Capabilities to Adopt Innovative Technologies for City Air Pollution Control in Select Countries of the Asia-Pacific" funded by the Korea ESCAP Cooperation Fund. It has been prepared under the overall guidance and direction of Dr. Preeti Soni, Head, Asian and Pacific Centre for Transfer of Technology (APCTT) of the Economic and Social Commission for Asia and the Pacific (ESCAP).

This publication was prepared by Dr. Md. Ali Ahammad Shoukat Choudhury,Department of Chemical Engineering, Bangladesh University of Engineering andTechnology, Dhaka and Dr Mohmmed Abdul Motalib from the Department of Environment (DOE) under consultancy assignments with ESCAP-APCTT. Support was received from Mr. Shamsul Islam of the Local Government Division, Ministry of Local Government, Rural Development and Co-operatives, Bangladesh; Engr. Abul Hasnat Md Ashraful Alam from Dhaka North City Corporation (DNCC); Engr. Baker and Engr. Faim from Dhaka South City Corporation (DSCC) and other officials from the Ministry of Science and Technology, Bangladesh. The report benefited from comments and suggestions from Mr. Satyabrata Sahu and Mr. Pankaj Kumar Shrivastav from the ESCAP-APCTT.

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1. BACKGROUND

Air pollution poses a formidable environmental threat to public health. Mitigating the levels of air pollution presents an opportunity for nations to alleviate the prevalence of diseases such as stroke, heart disease, lung cancer, and both chronic and acute respiratory conditions, including asthma.In the year 2019 alone, outdoor air pollution is estimated to have contributed to 4.2 million premature deaths across the globe. Notably, a significant 89% of these untimely deaths occurred in low- and middle-income countries, with the highest numbers observed in the WHO South-East Asia and Western Pacific Regions.

Toward strengthening the capacity of member States in air pollution control, the Asian and Pacific Centre for Transfer of Technology (APCTT) of ESCAP is implementing a project titled "Enhanced capabilities to adopt innovative technologies for city air pollution control in select countries of the Asia-Pacific". The project will strengthen the capacity of city officials and stakeholders (through improved availability of knowledge regarding innovative technologies and good practices; a better understanding of technology needs and gaps in three selected cities, namely Bangkok (Thailand), Dhaka (Bangladesh) and Gurugram (India); and an enhanced capacity to strengthen action plans for adoption of innovative technologies to control air pollution in the target countries. The project is facilitating the formulation of an assessment report on technological interventions and technology gaps/needs for air pollution control in Dhaka, Bangladesh. This report (Report 1) is an assessment report for Dhaka city on the same. Another report (Report 2) presents an assessment of Dhaka city action plan on air pollution control and provides recommendations for the way forward.

2. SCOPE OF WORK

2.1 Objectives

The main objectives of this study are:

1. To facilitate availability of technical knowledge regarding technologies, innovations and good practices on air pollution in Dhaka, and
2. To increase the knowledge of stakeholders for a better understanding of technology gaps and needs for air pollution control.

2.2 Activities

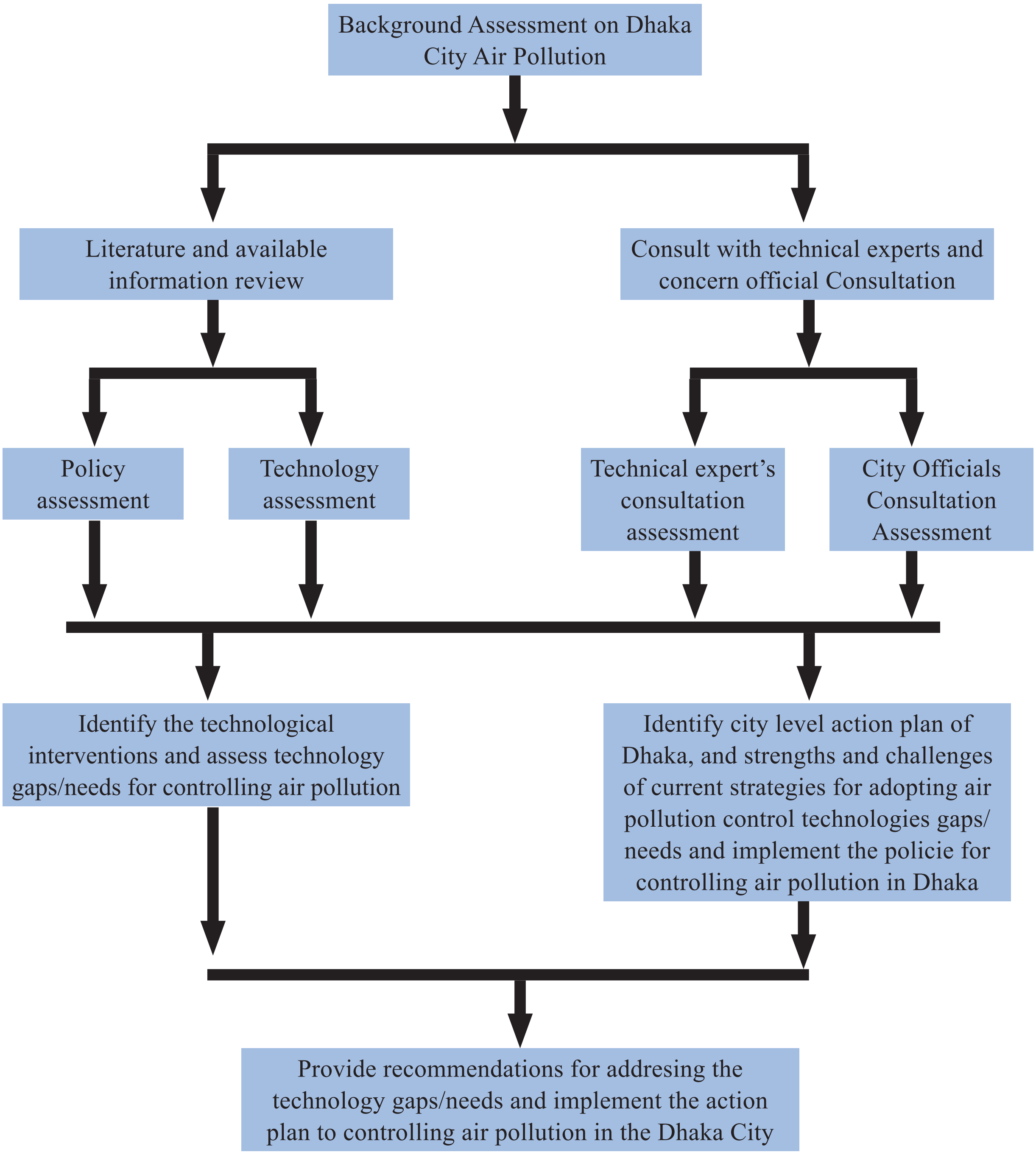
This assessment report preparation was based on the following activities:

1. Study of the technological interventions and assessment of technology gaps/needs for air pollution control in Dhaka, Bangladesh
2. Review and examination of the city level action plan of Dhaka and its alignment with national plan of Bangladesh, and assessment of the strengths and challenges of current strategies for adopting air pollution control technologies
3. Conducting the assessments in close coordination with the relevant city stakeholders and national policymakers of the country
4. Supporting in organising a multi-stakeholder consultation at the city level to discuss the outcomes of assessment report and developing draft recommendations for strengthening the city action plan for adoption of enabling mechanism for innovative technologies for air pollution

3 APPROACHES AND METHODOLOGY

The methodology is based on a review of secondary information available about the issue and previous experience of this consultant on air pollution studies. The report is also aligned to the concerned regulatory department's policies, guidelines, and practices.

3.1 Reference/Conceptual Framework



4. AIR POLLUTION PROBLEMS OF DHAKA CITY

4.1 Air Pollution Situation of Dhaka City

Dhaka (latitude 23° 45′ 39.18″N, longitude 90° 23′ 21.55″E) is the capital of Bangladesh. It ranks seventh in terms of population density and is the sixth-largest city in the world. As of census 2022, Greater Dhaka had a population of over 22.4 million people, making Dhaka a megacity with a population of 10.2 million living in the main city. It is widely considered to be the most densely populated, built-up urban area in the world. This high population density and exponential growth of the industries and economic activities like unrestrained urban development, subsequent rapid industrialization, and automobile traffic, has collectively created a huge issue of ambient air pollution in this megacity (Rahman et al.,2021).

Foy et al. (2021) recently analyzed the hourly fine particulate matter of aerodynamic diameter ≤ 2.5 µm ($PM_{2.5}$) data from two monitoring sites in Dhaka (the U.S. Embassy monitoring site and the Darus-Salam site operated by the Ministry of Environment and Forest in Bangladesh) and one monitoring site in Kolkata, India (the U.S. Consulate site in Kolkata, India) for dry months (November to March). The 24-hr averaged $PM_{2.5}$ concentrations from November to March exceeded the local ambient air quality standards on 863 out of 914 days at Darus-Salam (>65 µg/m^3), 621 out of 685 days at the Dhaka embassy (>65 µg/m^3), and 726 out of 814 days at the Kolkata consulate (>65 µg/m^3) (Figure 1.1.1). There is a very strong seasonal component to the concentration variability, with low concentrations during the monsoons, and peak concentrations during the cooler dry season. The mean concentrations of $PM_{2.5}$ from November to March are around 140 to 150 µg/m^3 at all three sites.

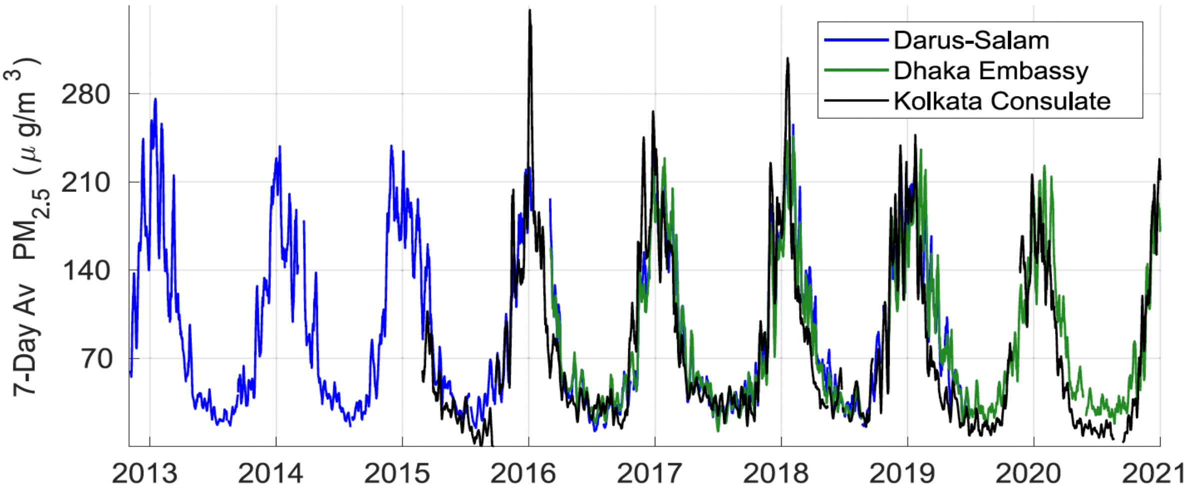


Figure 1.1.1: Time series of 7 day running average of $PM_{2.5}$ concentrations at Darus-Salam, Dhaka embassy, and Kolkata consulate.

The main sources of air pollution in Dhaka city are brick kilns, steel re-rolling mills, boilers and other industries, open biomass/waste burning, residential, construction and transport. The apportionment study performed in 2013 attributed about 58, 10.4 and 15.3 % of fine particles in Dhaka city to brick kilns, vehicles and dusts, respectively (Bangladesh Air Pollution Studies (BAPS) PO98151, DoE-S13, 2015). However, the scenarios have changed significantly due to huge construction activities for a large number of mega projects such as MRT, BRT, Elevated expressway, other developmental works and a huge increase in the number of vehicles. Therefore, the current contributions from these sectors are not available as there are no recent apportionment studies. There are seven criteria pollutants considered in determining the ambient air quality in Bangladesh namely Carbon monoxide, Lead, Nitrogen dioxide, Particulates Matters (PM), Ozone (O_3), Sulfur dioxide (SO_2) and Ammonia (NH_3). Gaseous pollutants remain within the limits most of the days of the year [AQMP report]. The primary pollutant responsible for Dhaka's poor air quality during the dry season is Particulate Matters (PM). Between 2018 and 2021, the annual mean daily average for PM_{10} and $PM_{2.5}$ concentrations was 156.40 $\mu g/m^3$ and 96.71 $\mu g/m^3$ respectively; both values were three folds more than the national yearly limit (See Table 1.1 below).

Table 1.1: National Ambient Air Quality Standards (NAAQS) [Ref. Bangladesh Air Pollution (Control) Rules 2022]

Sr No	Parameters	Concentration	Averaging Time
1	Carbon Monoxide (CO)	5 mg/Nm^3	8 hour
		20 mg/Nm^3	1 hour
2	Lead (Pb)	0.50 $\mu g/Nm^3$	24 hour
		0.25 $\mu g/Nm^3$	Annual
3	Nitrogen dioxide (NO_2)	40 $\mu g/Nm^3$	Annual
		80 $\mu g/Nm^3$	24 hour
4	Particulates Matters (PM_{10})	50 $\mu g/m^3$	Annual
		150 $\mu g/m^3$	24 hour
	Particulates Matters ($PM_{2.5}$)	35 $\mu g/m^3$	Annual
		65 $\mu g/m^3$	24 hour
5	Ozone (O_3)	100 $\mu g/Nm^3$	8 hour
		180 $\mu g/Nm^3$	1 hour
6	Sulphur dioxide (SO_2)	80 $\mu g/Nm^3$	24 hour
		250 $\mu g/Nm^3$	1 hour
7	Ammonia (NH_3)	100 $\mu g/Nm^3$	Annual
		400 $\mu g/Nm^3$	24 hour

Examining the trends and characteristics of the air quality of Bangladesh, it is found that the intensity of air pollution is highly affected by the meteorological changes happening across different seasons. Particularly the urban areas or big localities of Bangladesh have been suffering from a heightened level of PM in the air, especially during the dry season when the region experiences scarce rainfall, the wind flow is north-westerly, and the relative humidity is at the lowest. It is evident that the measured $PM_{2.5}$ and PM_{10} exceed the respective Bangladesh National Ambient Air Quality Standards (BNAAQS) during the dry season (Figure 1.1.2). As per BNAAQS, the official standards of $PM_{2.5}$ and PM_{10} daily-averages (24 hours) are 65 $\mu g/m^3$ and 150 $\mu g/m^3$ respectively. On the other hand, the rainfall in the wet season helps improve the air quality of the cities substantially. It is also to be highlighted that the concentration of other gaseous pollutants (i.e., SO_2, CO, NO_X, and O_3) are meeting the prescribed air quality standards across the city, with few exceptions.

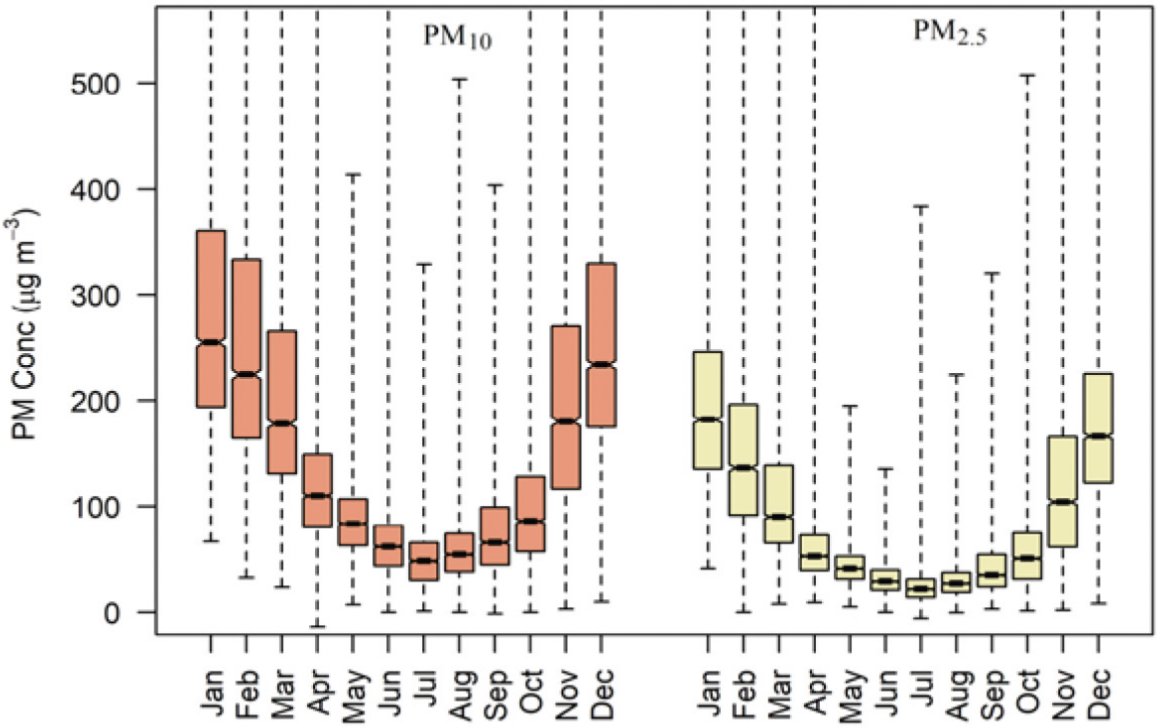


Figure 1.1.2: 24-hr Average PM_{10} and $PM_{2.5}$ pollution in Dhaka City during different months of the years 2013 to 2018 (Source: Rana, M.M. and Biswas, S.K. (2018))

With regards to the health-related impacts, air pollution is one of the biggest public health problems in Bangladesh as it is globally. Of the approximate 2 million deaths per year reported in South Asia (World Bank, 2022), 160,000 deaths per year take place in Bangladesh (McDuffie et al., 2021). Among the top 10 diseases which cause death in Bangladesh, five diseases including lung cancer (13%), lower respiratory tract infections (7%), chronic obstructive pulmonary disease (COPD) (7%), ischemic heart disease (IHD) (6%), and strokes (5%) are related to air pollution. Both ambient as well as indoor air pollution are collectively responsible for about 21% of all deaths in Bangladesh, making it the highest among all south Asian countries. The cases of short-term effects have been observed to be extensive and include irritation of the eyes, throats, and the skin; allergies; coughing; sneezing; high fever; asthma; conjunctivitis; fatigue; anxiety; nausea; and headache—all emanating from the extensive dust pollution (SOGA, 2019). Clean air can greatly improve well-being of people, reduce morbidity rate, and cause fewer premature deaths.

4.2 Sources of Air Pollution

The major sources of air pollution in Dhaka city are identified as industries including industrial emissions mainly from brick kilns; vehicular emissions; residential cooking; soil dust coming up from construction activities; road dust due to sweeping and resuspension; transboundary air pollution and open solid waste/biomass burning (BAPS, 2015). The apportionment study performed in 2013 attributed about 58%, 10.4% and 15.3 % of fine particles in Dhaka city to brick kilns, vehicles and dusts, respectively (Bangladesh Air Pollution Studies (BAPS) PO98151, DoE-S13, 2015). However, the current scenarios are completely different due to a large number of ongoing construction activities of mega projects such as MRT, BRT, Elevated expressway, other developmental works and a large increase in the number of vehicles since 2013. Therefore, the current contributions from these sectors may be different. However, there is no recent apportionment study to ascertain this.

4.2.1 Transport/vehicular emission

Vehicular emission has emerged as a major air pollution source in Dhaka. The inadequate roads network, along with the old and low-quality vehicle engines, is collectively resulting in regular and prolonged traffic congestion, further exacerbating the air pollution situation. This is evident from the fact that, as of June 2022, a total of 187,7474, registered vehicles are plying on a road area that is only 6.12% of the total city area.

In Bangladesh, of the total vehicular fleet, the percentage bifurcation between the diesel vehicles to the petrol vehicles is of the order of 19-20% to 80% respectively (ABM. S.R. Khan, 2003). The diesel vehicles mostly include buses, mini-buses, trucks, and light and medium-duty vehicles (like jeeps, pickup-vans, human haulers, light trucks, microbuses, etc.) (ABM. S.R. Khan, 2003). In Dhaka, where only about 40% of the vehicles imported into the country are registered, aspects such as old fleet, improper traffic, and parking management, overloading, lack of maintenance, non-standard adulterated fuel, etc., have enhanced the vehicle sector's contribution to air pollution in Dhaka city. A huge number of vehicles plying on an inadequate number of roads generate traffic congestion that moves at a snail's pace, resulting in excessive vehicular emissions and thus high air pollution in Dhaka city. Most of the city buses are old and run with inefficient engines, thus emitting black smoke and unburned fuels, further adding to the air pollution (Figure 1.2-1). The average speed of vehicles on Dhaka roads is no more than 6 to 7 km per hour. It causes high economic losses (3.8 billion USD per year) (Annual Report, 2022, DMRCL).

Figure 4.2.1: Black smoke emitting from old, dilapidated bus

Measuring the sustainability of Dhaka City's transport sector, it has been identified that its footprint on environment due to poor physical transportation network and vehicular emission is seventy times larger than the biocapacity of the city (Noor E Alam 2018, UNESCAP).

As per the recently promulgated Air pollution (Control) Rules 2022 by the Government of Bangladesh, the emission standards for both new and reconditioned vehicles need to be equivalent to EURO - IV standards, and that of in-use vehicles equivalent to EURO– II standards.

4.2.2 *Brick kilns and Industrial emission*

The industries located in and around the city contribute to the ever-growing air pollution level. Brick kilns that are in the vicinity (within 2 km from the periphery) of the city are contributing a significant amount to Dhaka's elevated levels of pollution. Some other small and medium type of industries such as textile, steel re-rolling mills, cement industries and tanneries are located in and around the city's periphery as well, and are therefore also contributing to the increased emissions load within the city (Report, 2022 World Bank).

Since the Dhaka division is the core industrial zone in Bangladesh, with most industries operating perennially, a surge in the critical levels of harmful emissions within the micro airshed of the city and the surrounding areas takes place, further exacerbated by the region's rapidly growing industries. The areas around the periphery of Dhaka such as Savar, Keraniganj, Dhamrai, Gazipur, Narayangang, and Munshiganj are housing many of the major industries including the brick kilns, textile mills, steel re-rolling mills, cement industries, and tanneries. These industries spill massive amounts of air pollutants into the city's micro airshed. During the dry season, the brick kilns are in operation and cause extensive air pollution in the region, which is also the time when the air pollution level increases excessively in Dhaka city as well as across the country.

4.2.3 Construction Activities

Dhaka city has recently witnessed an enormous construction work in the form of some mega-projects that include metro-rail, elevated expressway, and the third terminal of the Hajrat Shahjalal International airport. Emissions of $PM_{2.5}$ or flying dust from all the construction sites cause major environmental havoc during the construction phase. Each year, with the onset of winter, the air quality dips to its worst as $PM_{2.5}$ fills the air around the city roads, especially in areas where construction work is in progress. Unfortunately, there is hardly any safeguard in sight to protect public health in such places.

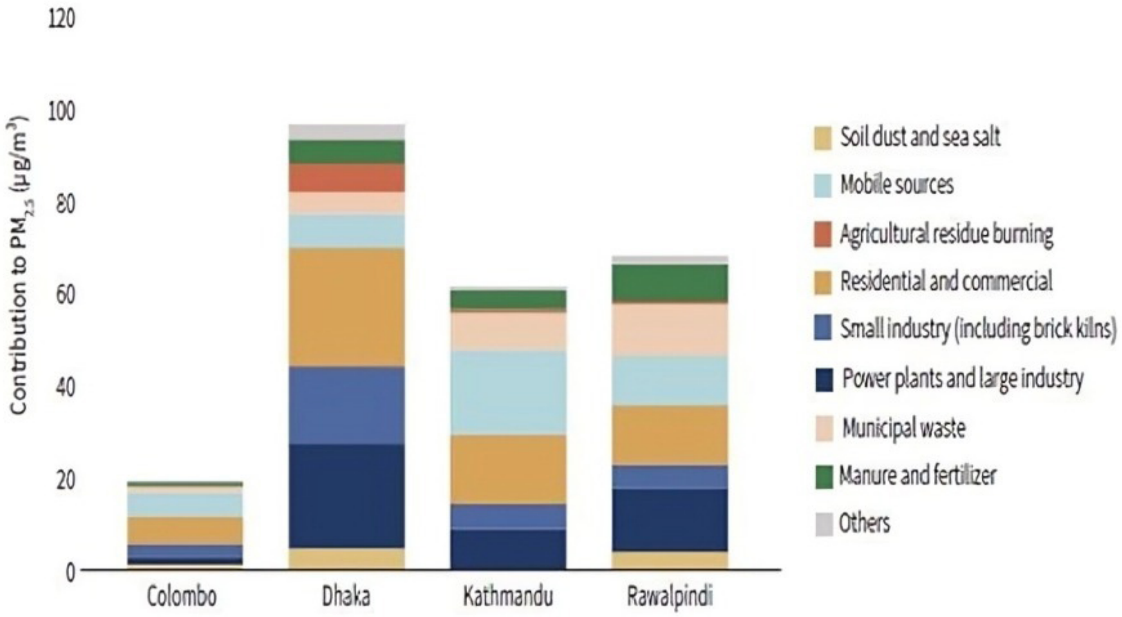
Figure 4.2.2: Severe dust pollution in construction sites

4.2.4 Waste Burning

In 2020, the daily per capita waste generation in Dhaka was 0.61 kilograms (kg)—and with a population of 10,596,475 residing in the Dhaka metropolitan area, the estimated waste generated per day is 6,464 tons. Only 73% of the waste is going to the city corporation's existing waste disposal system and the rest of the waste is either burnt in the open or finds its way into the canals, water bodies, low land filling areas, etc. (Report, 2021, World Bank). Varieties of biomass (e.g., waste, residential cooking, winter heating, crop residue, fuel wood, cow dung, etc.) burning emissions are contributing black carbon (BC) loadings. In Dhaka city, 44% of BC is produced from biomass burning (Salam et. al, 2021).

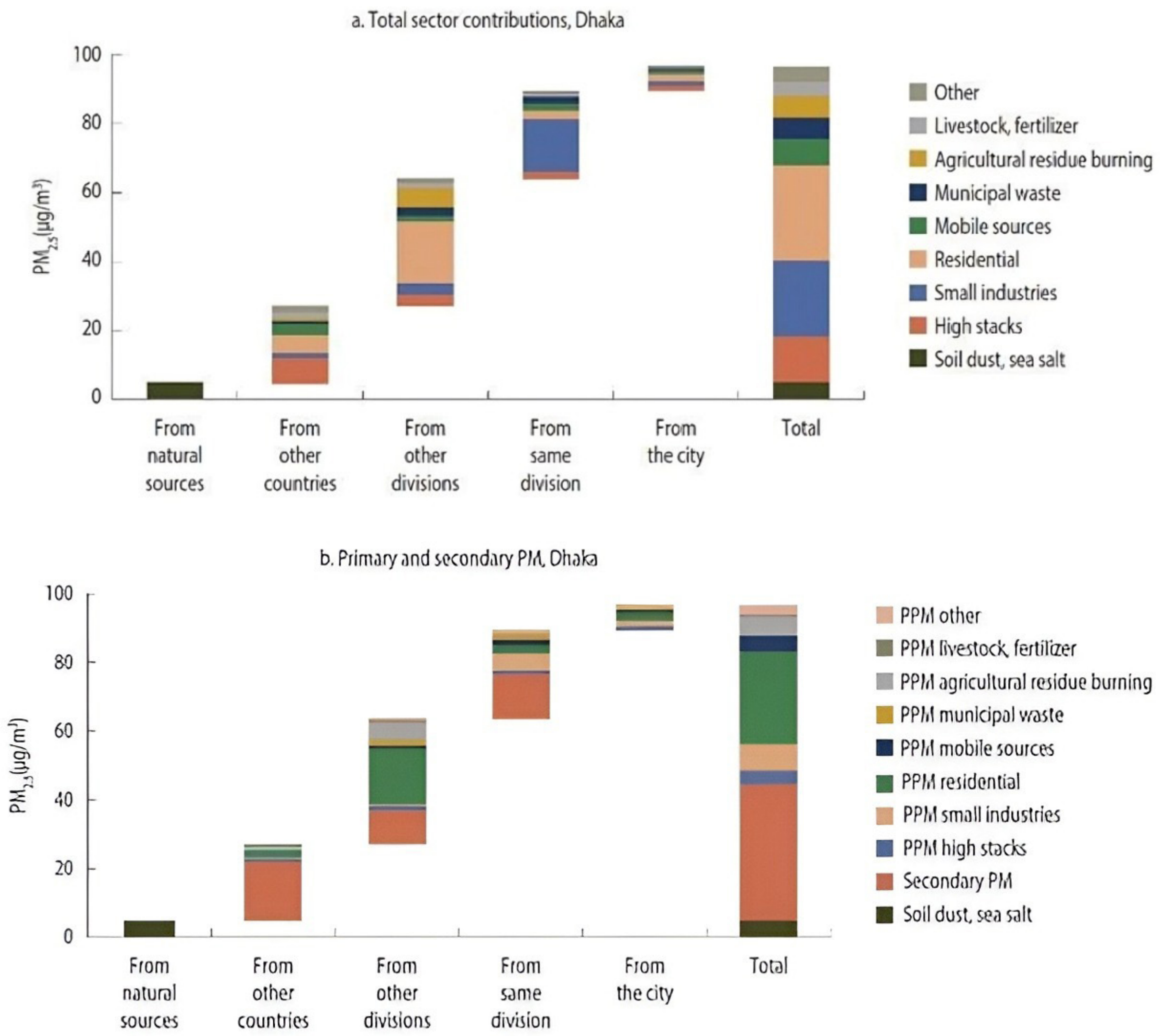
4.2.5 Transboundary pollution

The share of local sources in ambient $PM_{2.5}$ varies over South Asia, depending on the topography; meteorology; the intensity, temporal, and spatial patterns of emissions; and the size of the administrative regions. Figure-4.2.3 compares sources across the South Asian cities namely Colombo, Sri Lanka; Dhaka, Bangladesh; Kathmandu, Nepal; and Rawalpindi, Pakistan. As can be seen, the sources vary significantly within and across the major cities in South Asia. Figure -4.2.4 shows that Dhaka city itself produces only 10% of $PM_{2.5}$ pollution within the city and the rest of the pollution comes from outside of Dhaka such as from the Dhaka division, other adjoining divisions, as well as other countries in the upwind direction. The major sources of the city itself are industries, high stacks, residential, mobile sources, construction and municipality waste. The trans-boundary pollution is responsible for about 25% of the total pollution in Dhaka (Report 2022 World Bank, Dihan et. al (2020)).



Source: GAINS calculations/IIASA (2021).
Note: Fine particulate concentrations are in μg/m3.

Figure 4.2.3: Spatial origin of population-weighted fine particulate matter exposure in selected cities in South Asia (2018, Report, 2022 World Bank)



Source: Calculations using GAINS model developed by the International Institute for Applied Systems Analysis.
Note: PM = particulate matter; $PM_{2.5}$ (µg/m³) = fine particulate matter measured in micrograms per cubic meter; PPM = parts per million.

Figure 4.2.4: a) Total sectoral contributions in air pollution of Dhaka City; b) Source allocations of population exposure to total fine particulate matter in Dhaka, Bangladesh in 2018 (Report, 2022 World Bank)

5 CURRENT ACTION/TECHNOLOGY ASSESSMENT

5.1 Air Quality Monitoring

The Department of Environment (DOE) under the Ministry of Environment, Forest, and Climate Change (MOEFCC) has been continuously monitoring the ambient air quality of the country through its 16 (sixteen) regular Continuous Air Monitoring Stations (CAMS) and 15 (fifteen) Compact-CAMS installed across the country. Five criteria air pollutants namely Particulate Matters (PM_{10} and $PM_{2.5}$), Carbon Monoxide (CO), Oxides of Nitrogen (NO_X), Sulfur dioxide (SO_2), and Ozone (O_3) are continuously monitored by these stations along with meteorological parameters. The daily Air Quality Index (AQI) values are also calculated based on the available air quality data that refers to the situation of air pollution in terms of health impacts and this daily AQI is reported on the DOE's website.

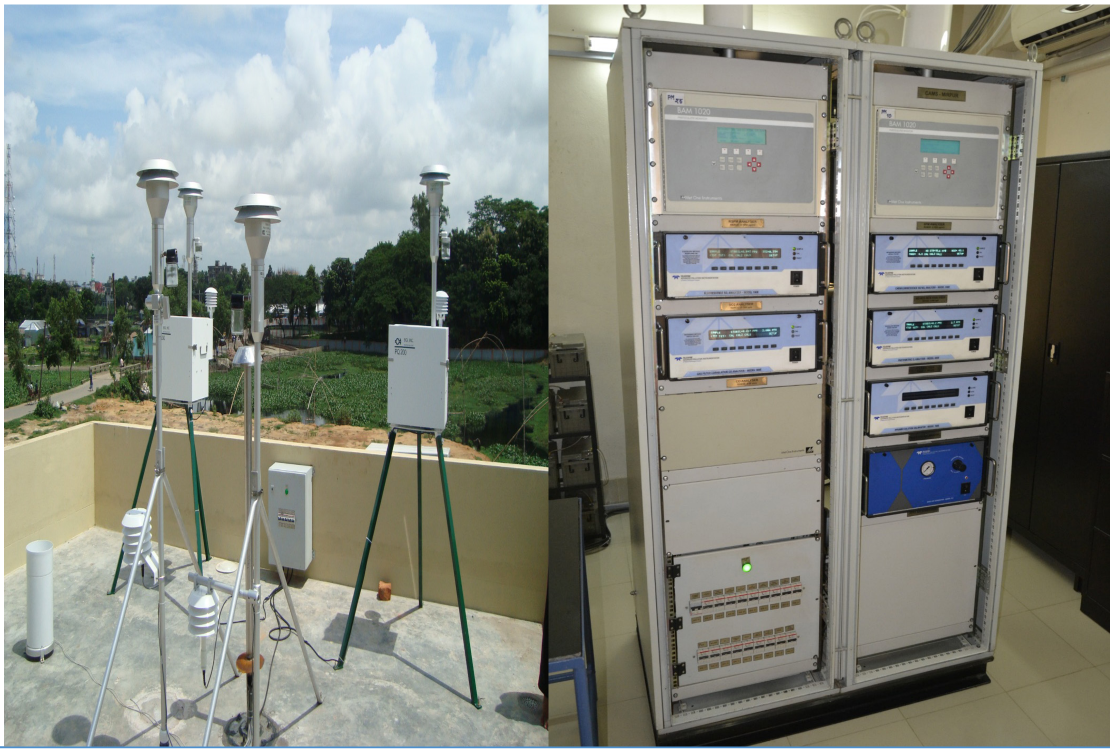


Figure 5.1: A Typical CAMS Station from CASE Project

5.2 Policies and Programmes

The government has taken action against major sources of air pollution, such as industrial emissions including brick kilns, road and soil dust that comes up from construction activities, vehicular emissions, and solid waste/biomass burning.

Various policies and programs have been implemented in Bangladesh to address the issue of air pollution. Like any other policy measure, the success and efficacy of these programs have been contingent upon collaboration and coordination across various stakeholders.

Bangladesh Environment Conservation Act 1995, (Amendment 2010) and Environment Conservation Rules, 1997 accompanying the air quality standards have been updated and a new Bangladesh Environment Conservation Rules 2023 has been promulgated. DoE accelerated the enforcement activities against pollution causing transport and construction activities.

The Government banned two-stroke 3-wheeler baby taxis from Dhaka city in 2001, resulting in 40% reduction in the PM_{10} concentrations across the city (Begum et al. 2006). Besides this, several other measures were also implemented within the transport sector, of which the introduction of cleaner fuel, compressed natural gas (CNG) and lead-free diesel to the transport sector in the early 1990s were the major ones. Such reforms in the transport sector have helped in reducing its overall emission load.

One of the most recent policies launched to tackle air pollution is the Air pollution Control Rules, 2022. The rule helps to develop city-level Clean Air Plans to implement mitigation strategies for ambient PM concentrations. Under the rule, there is an option to develop a national air pollution management plan to control air pollution sources of various sectors.

To address industrial pollution (brick kilns), the government has enacted Brick Manufacture and Brick Kiln Set-up (Control) Act, 2013 (Amendment 2019). Fixed Chimney Kilns (FCK) are banned. More than 80% FCK Brick Kilns are transformed to adopt less polluting ZigZag technology. Setting and running clay fired brick kilns are restricted. Environment friendly alternative building materials including blocks are being promoted. Government has issued a gazette notification in November 2019 putting mandatory use of blocks in all construction activities implemented by government agencies/departments by 100% in phases (from 2019-2020 to 2024-2025) except for the construction of base/sub-base of the high-ways.

Bangladesh Road Transport Act, 2018 mandated Bangladesh Road Transport Authority (BRTA) to withdraw unfit and economic life expired vehicles from the road. The Act has also given the mandate to regulate vehicle emissions to control air pollution. Local Government (City Corporation) Act, 2009 has the option to control air and waste pollution. Bangladesh Petroleum Corporation ensures compliance of its petroleum products with the government's fixed standards. The Sustainable and Renewable Energy Development Authority (SREDA) Act - 2012, Energy Efficiency and Conservation Rules - 2016, Renewable Energy Policy of Bangladesh, Country Action Plan for clean cookstoves - 2013 provided the scope to develop renewable energy and energy efficient technologies to reduce fossil fuel and increase clean fuel uses.

6. TECHNOLOGICAL INTERVENTIONS AND ASSESSMENT OF TECHNOLOGY GAPS/NEEDS:

The following Table 6.1 summarizes the current technological and policy action measures & practices, gap assessment and future interventions to improve air quality.

Table 6.1: Technological interventions and assessment of technology gaps/needs

Sector	Current Practice and Technological Gaps	Technological Intervention and Needs
Transport	Many of the existing vehicle engines are of Euro 1/2 standard	The vehicle engines are to be upgraded to Euro 5/6 level
	Old and economic life Expired Vehicle	Phase out economic life expired vehicle
	Lack of modern vehicle emission testing facilities. Absence of modernized and automated emission testing centres that can be effectively monitored	Modernized and automated emission testing centres that can effectively monitor vehicle emissions
	Lack of inspection and maintenance (I&M) systems, fleet modernization	Ensure effective inspection and maintenance (I&M) systems, fleet modernization
	Technology and capacity are not adequate for ensuring emission tests in the process of registration and annual fitness checks.	Ensure appropriate emission tests are done in the process of vehicle registration and annual fitness checks.
	Manual traffic control systems causing huge traffic congestions	Automated traffic control and management systems are to be introduced.

Table 6.1: *(Continued)*

Sector	Current Practice and Technological Gaps	Technological Intervention and Needs
Clean Fuel	Currently, Eastern Refinery Limited (ERL) can produce only more than 50 ppm sulfur diesels. EURO-4/5 engines cannot be run with this fuel.	Eastern Refinery Limited (ERL) has to be modernized with updated technology so that it can produce low-sulfur (10 ppm) Diesel and EURO-4/5 engines can run with it.
EV vehicle introduction	Lack of encouragement for aggressive introduction of EVs – both among users and manufacturers. Lack of public and private EV charging stations as part of the EV ecosystem	Waive the road tax and reduce the registration fee for EV. Target provision of public and private EV charging stations as the part of the EV promoting ecosystems Exemption of duty/tax on electricity tariff for an initial period of 10 years for EV manufacturers (vehicle and battery)
Mass Transport	Insufficient existing public transport service infrastructure for access, e.g., Bus Queue Shelters, Bus Post sign, etc. Weakness of bus system for connectivity Tendency of vehicle owners not to comply with emission standards Use of adulterated fuel, emission, and lack of vehicle servicing	Mass transportation, e.g., all metro rail services, MRT 1-6 lines, will be in operation by 2035. Improve existing public transport service infrastructure for access by installing Bus Queue Shelters, Bus Post signs, etc. Technical training on the importance of complying with emission standards, using unadulterated fuel, and servicing vehicle regularly
Municipal solid waste	Inadequate waste collection and segregation and unscientific sanitary land filling system Absence of formal Reduce, Reuse and Recycle (3R) system Inadequate Waste-to-Energy (incineration) system. Currently, two city corporations (DNCC and DSCC) are implementing two Waste-to- Energy projects (220 MW power plants).	Implement proper waste collection, segregation and scientific sanitary landfill system Execute a formal Reduce, Reuse and Recycle (3R) system nationally Further develop Waste to Energy (incineration) system.

Sector	Current Practice and Technological Gaps	Technological Intervention and Needs
Municipal solid waste	Uncontrolled open biomass (waste, stems, leaves, etc.) burning	Uncontrolled open biomass (waste, stems, leaves etc.) burning must be stopped.
	Improper drainage waste management	Implement proper drainage waste management.
Construction works and construction materials transportation management	Creating fugitive emissions from material handling, conveying and screening operations.	Undertake control measures for fugitive emissions from material handling, conveying and screening operations through water sprinkling, curtains, barriers and dust suppression units. Introduce steeper penalties for non-compliance. Needs enforcement.
	Uncovered and broken roads and footpaths	Adopt street design guidelines for paving of roads and footpaths (hard and soft paving) with vegetative barriers. Mandate restoration according to the guidelines after the completion of all infrastructure projects.
	Uncontrolled material handling, construction and demolition	For material handling, construction and demolition, it should be mandatory on part of the developers to provide evidence of debris on-site recycling and/or disposal at designated sites.
	Unmanaged truck loading and unloading or open haul trucks	Implement truck loading guidelines; use of appropriate enclosures for haul trucks; gravel paving for all haul routes.
	Unmanaged dug-up areas	Adopt dust control measures for dug-up areas.
	Inadequate dust control measures	Adopt and implement dust control measures for all types of construction–buildings and infrastructure. Adopt preventive measures as mentioned in air pollution control guidelines. Construction agencies to be made liable. Impose penalty for non-compliance.

Table 6.1: *(Continued)*

Sector	Current Practice and Technological Gaps	Technological Intervention and Needs
	Lack of a protocol for using cleaner fuels and technology for asphalt mixing and minimising the number of hot-mix plants	Establish a protocol for using cleaner fuels and technology for asphalt mixing and minimising the number of hot-mix plants.
	Lack of green cover in the region; Undertake greening of open areas, gardens, community places, schools, and housing societies	Increase green cover in the region. Undertake greening of open areas, gardens, community places, schools, and housing societies.
	Currently, roads are manually swept causing resuspension of dust. Insufficient wet/mechanized vacuum sweeping of roads	Phase in mechanical / vacuum-based street sweeping; introduce wet / mechanized vacuum sweeping of roads.
Brick kilns and other industries emission	Polluting brick kilns in the areas surrounding Dhaka, mainly FCKs and traditional zigzag kilns	Phase out most of the polluting brick kilns in the areas surrounding Dhaka.
	There is uncertainty to achieve the government alternative building materials (non-fired Block) use as targeted.	Achieve the government alternative building materials (non-fired Block) use target by 2025 and gradually increase it to the private sectors. Replace fired brick with non-fired (Block) cleaner and efficient production technologies.
	Non-compliance of the brick kilns, cement, steel re-rolling mills and other factories.	Ensure compliance of cement, steel re-rolling mills, and other factories with the emission standards.
	Inadequate cleaner and efficient production technologies	Ensure developing a continuous emission monitoring system (CEMS) and reporting by major polluting industries.
Clean technologies (Solar)	Although it is mandatory for all housing societies having installed solar rooftop systems to meet a certain amount of electrical load, most of the solar systems do not sustain for a long time.	Installed solar rooftop systems have to be monitored for ensuring their continuation. Ensure this system is linked with transition from diesel generator set to solar power.
		Electric public transport can also be linked with solar power plans to shift to a zero-emission target. Identify and target institutional/industrial and residential consumers for faster adoption. Identify open areas in the city where solar power generation is possible.

Sector	Current Practice and Technological Gaps	Technological Intervention and Needs
Clean technologies (Solar)	Insufficient Solar Command Centre (SCC) within the SREDA that provides guidance, facilitates redressals, and acts as a watchdog for solar rooftop adoption. Inadequate monitoring facilities in the Solar Command Centre (SCC) Lack of available and affordable technology and incentive and other tax waiver facilities	Set up a Solar Command Centre (SCC) within the SREDA that provides guidance, facilitates redressals, and acts as a watchdog for solar rooftop adoption, especially tracking progress under schemes and mandates (including renewable purchase obligation). Make the affordable technology available and ensure the incentive and other tax waiver facilities.
Provide cleaner fuels (LPG, Electricity)	Solid fuel is cheaper and more easily available than clean fuel (LPG/Electricity). Access is limited to clean fuels (such as LPG; electricity) due to market price. Lack of purchasing capacity Lack of available resources	There is an urgent need to rapidly expand the accessibility to clean fuels (such as LPG and Electricity) for households that are reliant on solid fuels. The LPG subsidy with direct transfer schemes should be made available to all customers, with an additional subsidy made available to the lowest expenditure classes in rural areas. For those who cannot afford LPG in the near term, market access should be increased to biomass/ biogas stoves that are compliant with emission rates recommended by the World Health Organisation (WHO). Advanced gasification and improved cook stoves (50% efficiency) should be made available as an intermediate solution. Induction stoves (powered by solar or gas) should be made available at a subsidized price, particularly in slum areas of Dhaka.

Table 6.1: *(Continued)*

Sector	Current Practice and Technological Gaps	Technological Intervention and Needs
Launching a National Clean Air Mission of Dhaka for multi-scale and cross-sectoral coordination	Insufficient integrated efforts to take targeted actions recommended by the regional scale air quality management plans.	Focus on developing regional scale plans for air quality improvement with annual targets. To achieve the target, the authorities should look for ways to integrate efforts to take targeted actions recommended by the regional scale air quality management plans.
	Insufficient investments for mitigation actions: It should be addressed through subsidy reallocations and Corporate Social Responsibility (CSR).	Investments for mitigation actions should be addressed through subsidy reallocations, marginal increase in fuel prices, and Corporate Social Responsibility (CSR) activities.
Institutional strengthening, capacity and technology development	Institutional limitation and lack of technical capacity	Develop institutional strengthening and enhance the manpower and their technical capacity.
	Lack of skilled manpower and infrastructure	Training and skill development will be required of public and private sector officials and other public and private functionaries for planning, management, and execution of the plan. This will also require extensive capacity building in all sectors and infrastructure planning.
Source apportionment study and emission inventory	No national database of high-resolution source emission inventories and source apportionment study Limited research on air pollution done at academic institutions and government Insufficient use of quality modeling tools to predict current and future air quality to enable informed policy decisions Lack of Emergency Response Plan (ERP)	Emission inventories are important tools to drive legal actions in different sectors. They are also essential for developing trading schemes and are immensely important for air quality modeling required for prioritizing actions. The current and future projections of emission inventories need to be developed in consultation with academic institutions. Need to develop a national database of high-resolution source emission inventories with lower uncertainties

Sector	Current Practice and Technological Gaps	Technological Intervention and Needs
		It is necessary to conduct a source apportionment study and emission inventory in Dhaka city. Air pollution research done at academic institutions and government and laboratories needs to be well coordinated. Air quality modeling tools should be used to predict current and future air quality to enable informed policy decisions. An Emergency Response Plan (ERP) needs to be developed to reduce emissions during episodes and avoid the exposure of the public to high pollutant concentrations.
Monitoring	Web-enabled real time air quality monitoring and forecasting system is not yet enabled. Lack of alarm and sms system for public awareness to take precautionary measures in the case of extreme air pollution	Need to develop web-enabled real time air quality monitoring and forecasting system to make people aware of taking precautionary measures in the case of extreme pollution.
	Lack of installation of Continuous Emission Monitoring System (CEMS) by major industries	Self Continuous Emission Monitoring System (CEMS) and reporting of pollution must be made mandatory for highly polluting industries.
	All industries including brick kilns are yet to send the quarterly emission monitoring report.	All industries including brick kilns are to be brought under regulatory framework so that they send the quarterly emission monitoring report regularly.
	Emission sources are not under monitoring by the concerned authority.	Every emission source is to be brought under monitoring by the concerned authority.

Table 6.1: *(Continued)*

Sector	Current Practice and Technological Gaps	Technological Intervention and Needs
	Lack of public sharing of information on air quality and involving the public in the formulation of management plan	In the entire process, public participation needs to be ensured to share information on air quality, and the public should be involved in the formulation of management plan.
	The air quality indices and spatial air quality map are not yet publicly available.	Public awareness needs to be enhanced through display of air quality indices and spatial air quality maps using print and electronic media.
Enforcement	Inadequate enforcement of programs to control air pollution	Need for concerned ministry, department and agency to enhance their enforcement program to control air pollution.
	All emission sources are not under surveillance by the concerned authority.	Every emission source has to be under surveillance by the concerned authority.
	Penalty/punishment is not strictly implemented in the case of violating the rules and regulation.	Penalty/punishment should be strictly implemented in case of violation.
Awareness	Inadequate awareness among the concerned ministry, department and agency to control air pollution	Public awareness needs to be enhanced through display of air quality indices and spatial air quality maps using print and electronic media.

7. LIST OF THE TECHNOLOGIES THAT CAN BE USED TO REDUCE EMISSIONS IN DHAKA

7.1 Low Cost Sensor (LCS) for ambient air quality monitoring

Currently, no Low-Cost Sensor (LCS) is being used by the Department of Environment (DOE), Bangladesh. As mentioned earlier, DOE operates 16 CAMS and 15 compact CAMS devices for monitoring $PM_{2.5}$ and PM_{10}. These devices are certified by USEPA. However, due to the high capital costs as well as the operation and maintenance (O&M) of these monitoring devices, they cannot be expanded to cover all the areas. This is where the LCS system can be helpful in expanding the existing monitoring network. Figure 7.1 shows a typical low-cost sensor network, which can be used for air pollution monitoring.

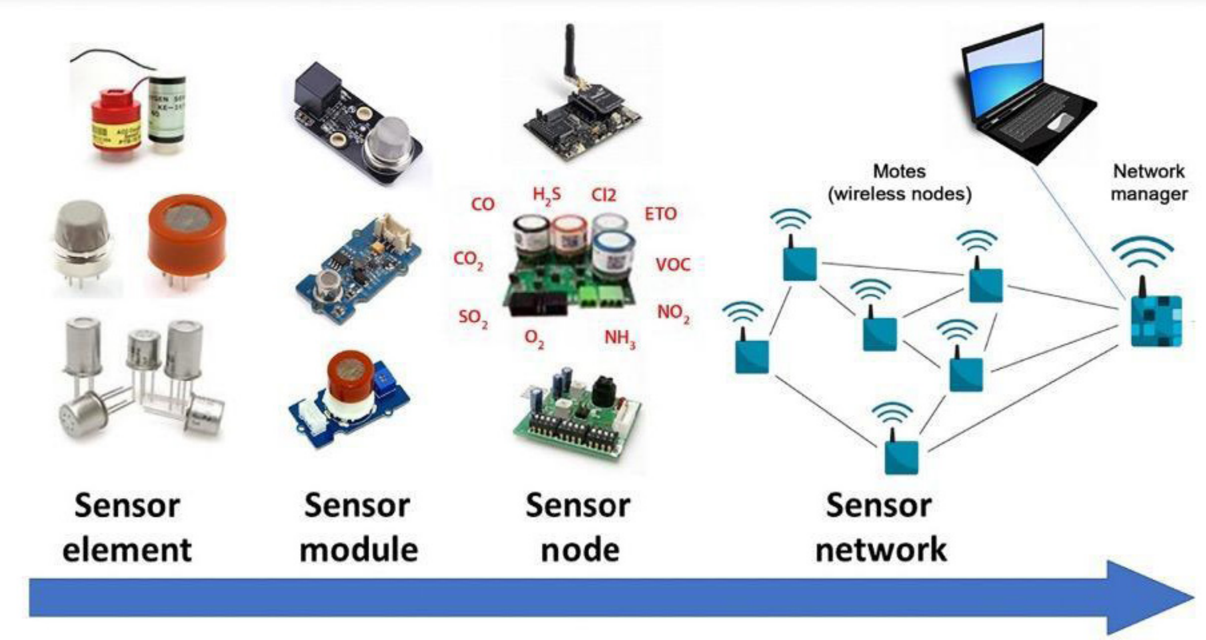


Figure 7.1: Typical Low-Cost Sensors for Pollutants Monitoring [Penza, M. (2020)]

7.2 Filters and Dust Collectors

Filters and dust collectors (baghouses) can be set up across all major intersections to collect dust from ambient air by passing the ambient air through a fabric that acts as a filter. The most used is the bag filter, or baghouse. Various types of filter media that can be used include woven fabric, plastic, ceramic, and metal-based media. The dust/ particulates can be collected in a bag or in a chamber and subsequently removed on a periodic basis. Fabric filters are efficient (99.9% removal efficiency) for both high and low concentrations of particles but are suitable only for dry and free-flowing particles.

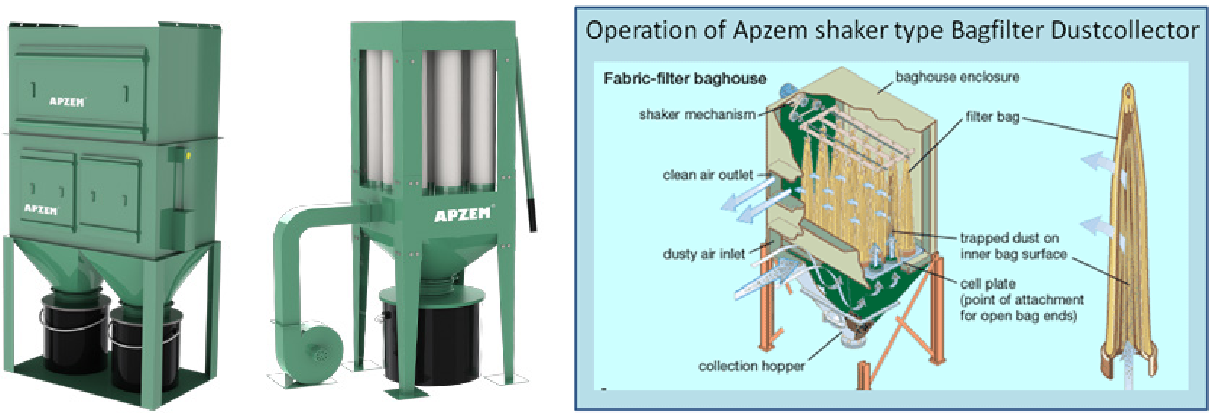


Figure 7.2: Bag Filter [ref: https://apzem.com/]

7.3 Diesel Particulate Filter (DPF) for diesel vehicle emission control

A DPF (Figure 7.3) is a device that reduces the diesel PM or soot from the exhaust gas of the diesel engine. They can be fitted to both new and in-use vehicles (retrofitted). DPF filters the exhaust emission, and the PM is trapped within the filter. There are two main types of filters.

1. A 'full' DPF, which can reduce PM emissions between 85% and 99%. It is also very effective at reducing emissions of small particles, which are of great concern to health. It is available for new vehicles from the factory or for retrofitting in in-use vehicles.
2. A 'partial' filter can reduce PM emissions between 30% and 50%. It may not be able to reduce small particles as efficiently as it does for the larger particles but is available for use in the in-use vehicles with moderate level of emission reduction.

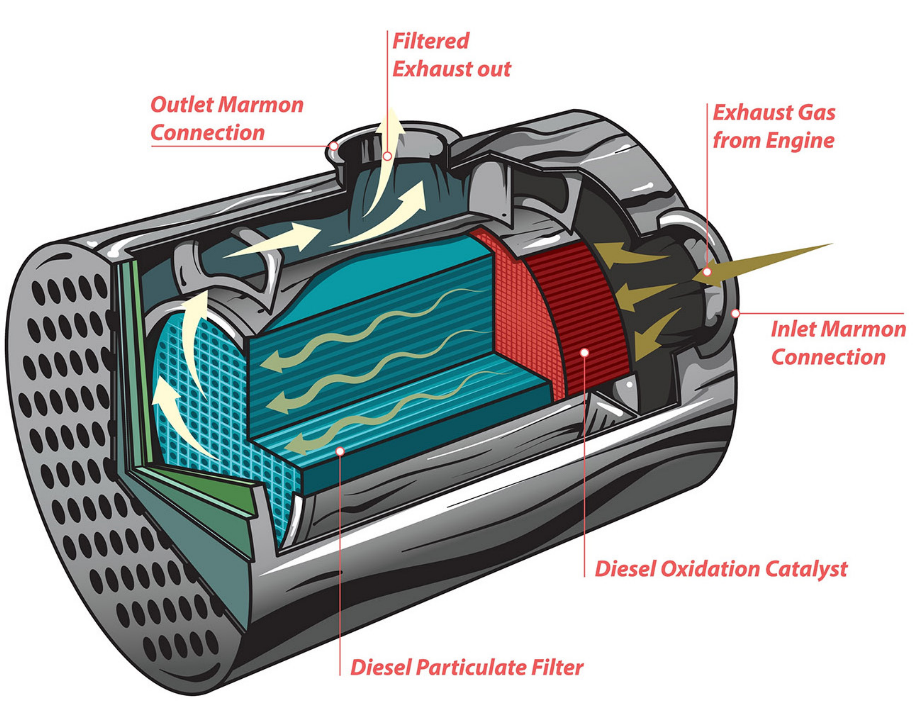


Figure 7.3: Diesel Particulate Filter for diesel vehicle emission control (DPF)

7.4 Electric Vehicles (EVs)

Transport sector is a major source of air pollution. EVs can be used to curb localised air pollution. There are three main types of electric vehicles—Plug-In Hybrid Electric Vehicles (PHEVs), Hybrid Electric Vehicles (HEVs), and full Electric Vehicles (EVs) as shown in Figure 7.4.

For Plug-In Hybrid Electric Vehicles (PHEVs) and Hybrid Electric Vehicles (HEVs), IC engines are used; therefore, fossil fuels are utilized along with electricity for running the vehicle. In the case of all-electric vehicles or 100% EVs, there is no IC engine and, therefore, they do not need fossil fuel in the car for generating energy to make it run. EVs are further classified into two types: The Battery-based Electric Vehicles (BEVs) (Figure 7.4) in which a large traction battery pack is used for powering the electric motor; this requires plugging into a wall charging outlet or equipment, also called Electric Vehicle Supply Equipment (EVSE), for its charging. Because it runs on electricity, the vehicle emits no exhaust from its tailpipe and therefore the typical liquid fuel components, such as a fuel pump, fuel line, or fuel tank are absent in the vehicle. The second type of EVs is Fuel Cell Electric Vehicle (FCEV), in which hydrogen and oxygen are combined to produce electricity, which runs the motor of the vehicle. Emissions from this type of EV simply include water vapor and warm air.

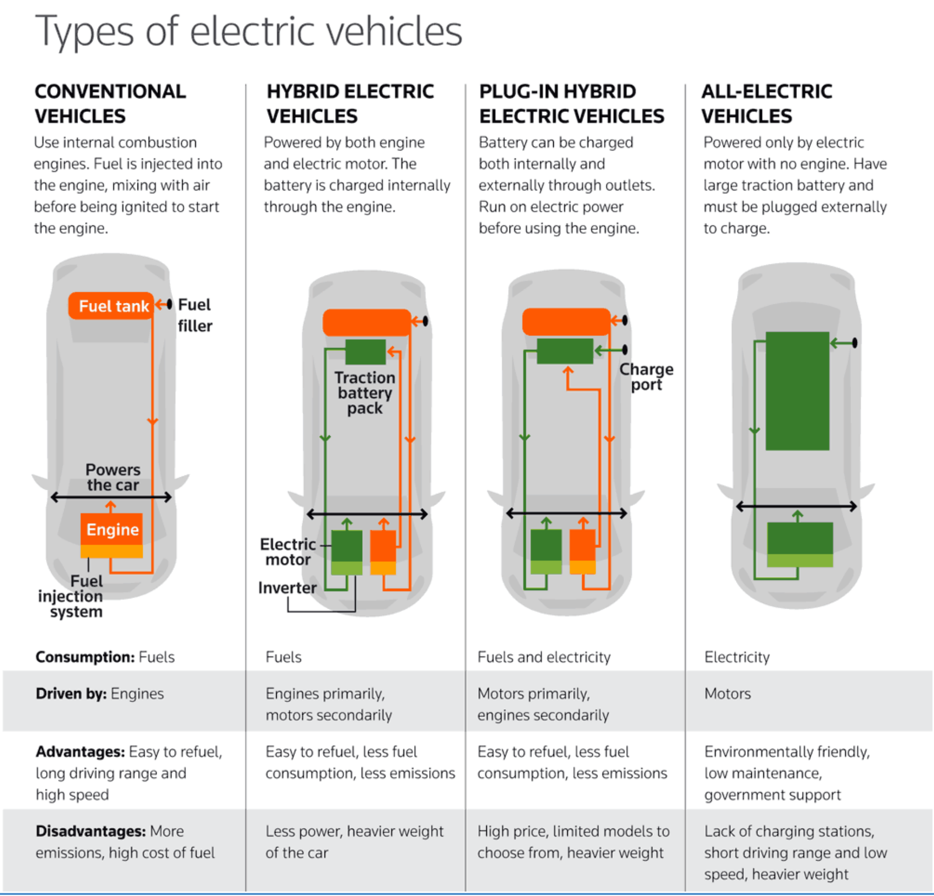


Figure 7.4: Type of electric vehicles (Source: Reuters Graphics and U.S. Department of Energy)

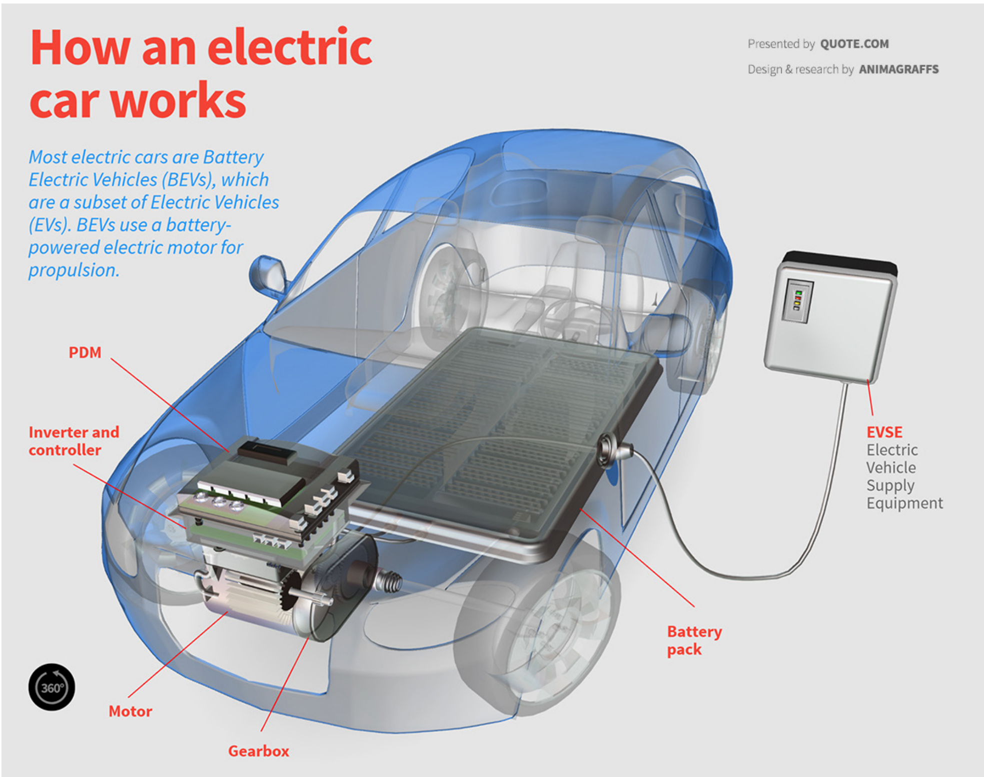


Figure 7.5: Battery electric vehicles (BEVs) [source: Animagraffs]

7.5 Dust Control Measures

Dhaka city roads are mainly swept manually which causes a huge resuspension of road dust. Currently, Dhaka South City Corporation has 3 automatic road sweeping trucks and 8 water spray trucks while Dhaka South City Corporation has 4 automatic road sweeping trucks, 10 water browsers, and 2 mist blowers. Their numbers are largely inadequate for the huge magnitude of road sweeping work of Dhaka city. Also, it is difficult to keep them in operating conditions with the limited number of skilled manpower of both city corporations. Both the number of equipment and the number of skilled manpower should be adequately increased. It will greatly reduce the resuspension of dust from roads (Figure 7.6). To curb dust, vehicle mounted anti-smog guns, as shown in Figure 7.7, can also be used. This is very effective for tackling smog-related problems.

Figure 7.6: Road sweeping truck with vacuum sucker for road dust

Figure 7.7: Truck mounted anti-smog gun to spray water droplets to curb air pollution

7.6 Stop Open Biomass Burning

Burning of solid fuels such as dung, coal, wood, leaves and agricultural residues for cooking and other purposes causes significant air pollution (Figure 7.8). In Bangladesh, instead of these fuels, LPG is getting popular day by day. Moreover, the Bangladesh Government has implemented Improved Cook Stove (ICS) project to improve the biomass fuel burning efficiency in cooking stoves. They can be used in rural areas. However, biomass burning cook stoves should not be allowed in Dhaka city and its neighborhood. LPG or natural gas or electric ovens should be encouraged instead of solid fuels. Government is implementing two waste-to-energy projects in Dhaka through its two city corporations. More such projects can be implemented wherever deemed appropriate. In Dhaka city, cooking by burning biomass is not that common. However, biomass burning, which should be banned, is commonly used to produce asphalt mix for road carpeting purposes.

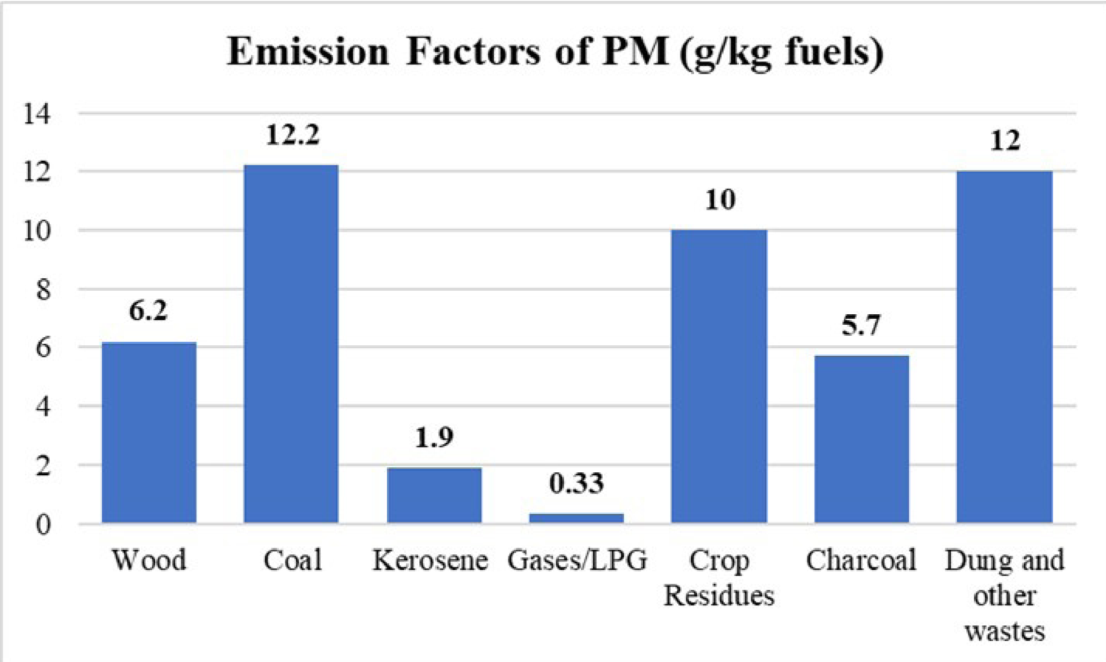


Figure 7.8: Emission Factors of PM from various materials in the residential sector (Shrestha et al., 2013)

7.7 Remote sensing for vehicle exhaust emissions

Remote Sensing Device (RSD) is a technology to inspect and monitor exhaust emissions from the transportation sector as the vehicles are driven past the remote sensing device on streets and highways. The emissions are measured spectroscopically by casting a narrow infrared (IR) and ultraviolet (UV) beam of light across the road and through the trailing exhaust of passing motor vehicles. A mirror then reflects the IR/UV light back to a series of detectors that measure the amount of transmitted light at characteristic wavelengths absorbed by the pollutants of interest. Remote sensing can measure pollutants such as hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen monoxide and dioxide (NO and NO_2 separately, combined as NO_x), ammonia (NH_3), and particulate matter as proxy from opacity. By taking the ratios of the various pollutants to CO_2 and applying stoichiometric rules and other conversion factors, the emission values can be estimated in units as grams per kilogram of fuel burned (g/kg fuel burned), which can then be converted to distance emissions (g/km) with appropriate assumptions. The processing of remote sensing inspection is presented in Figure 7.9 and 7.10.

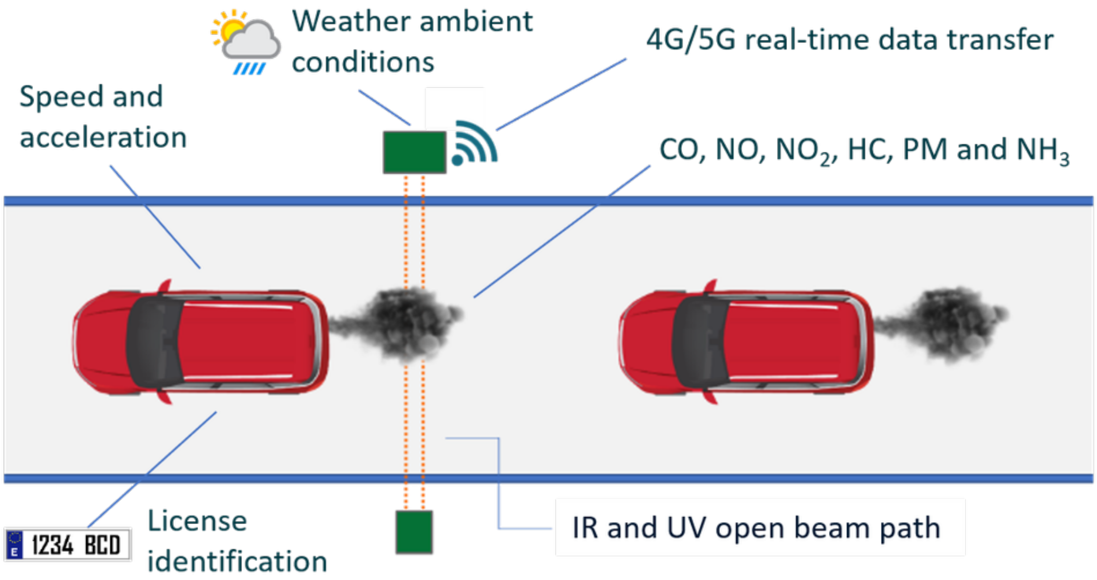


Figure 7.9: Remote sensing for vehicle inspection (OPUS, 2023)

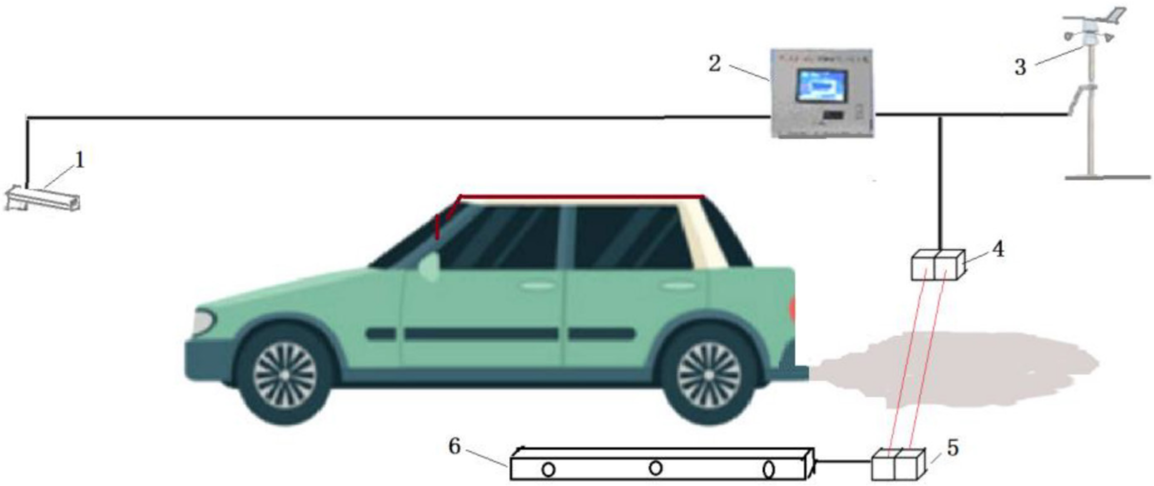


Figure 7.10: Schematic of vehicle emission remote sensing system. 1. License plate camera; 2. main control computer; 3. weather station; 4. light source and detector; 5. reflector; 6. Speedometer (Ren X. et al., 2022)

Remote sensing can measure the instantaneous emissions of a large number of vehicles under real driving conditions at a relatively low cost, making it an ideal tool for identifying both high-emitting and clean vehicles. The former application is aimed to detect dirty vehicles for the inspection and maintenance (I/M) programs, while the later one is to exempt clean vehicles from the mandatory periodic inspections, reducing inconvenience and cost for both vehicle owners and governmental regulators (Huang et al., 2018).

7.8 Continuous Emission Monitoring Systems (CEMS) for industrial air pollution control

A continuous emission monitoring system (CEMS) is the set of equipment necessary for the measurement of gas or particulate matter concentration or emission rate. It uses pollutant analyzer measurements and a conversion equation, graph, or computer program to produce results in units of the applicable emission limitation or standard (USEPA, 2023).

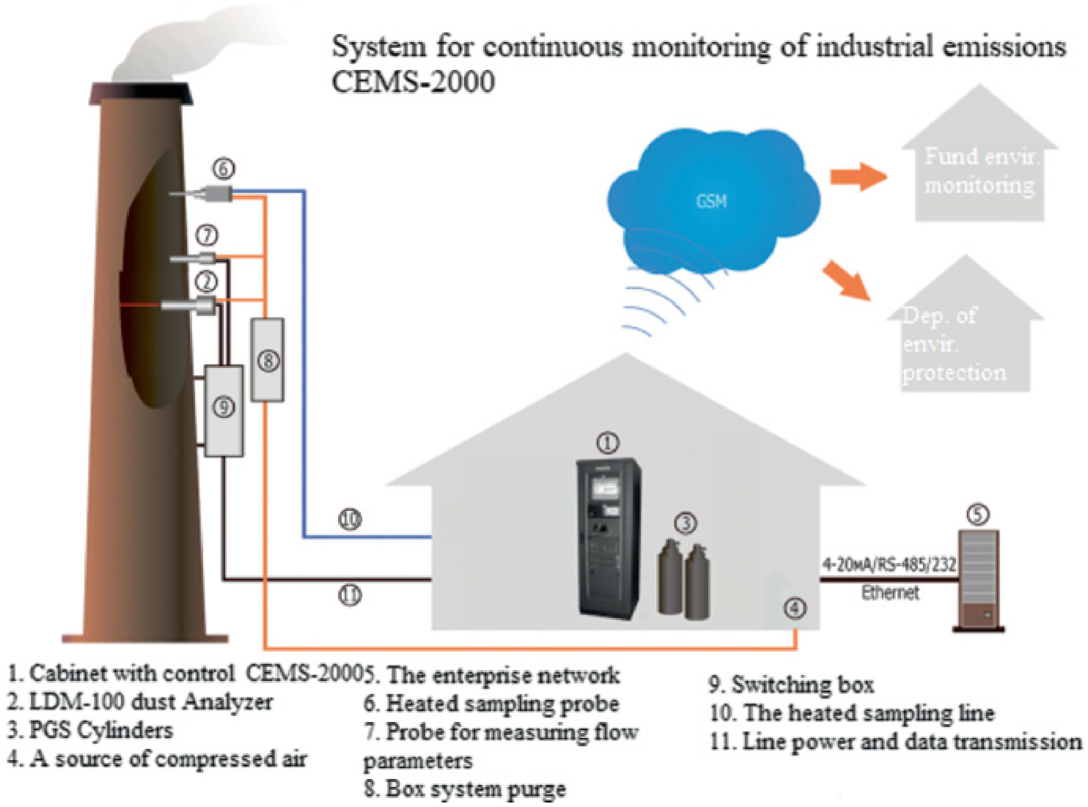


Figure 7.11: Component of CEMs (Tsymbalov, S.D., et. al (2022))

CEMs must be installed in large scale polluting industries. The Department of Environment (DOE) should establish a data centre and mandate large scale polluting factories to transmit their CEMS data to this central facility. DOE should ensure that all large scale industries install CEMS and submit their data to DOE. They should inspect factories with high potential to emit pollutants in the Dhaka area. If their emissions exceed the standard, they will be given a specified time to rectify the situation. If the emission remains above the standard after the required improvements, the factories can either be fined or ordered to cease operations.

8. CONCLUSIONS

8.1 Overview

Particulate matter, namely PM2.5 and PM10, are the major cause of Dhaka's unbearable air pollution. Curbing Dhaka PM pollution requires emission mitigation in several sectors, with the most critical being transportation, residential cooking by biomass, industry and construction activities, and biomass burning.

8.2 Transport

The old economic life expired vehicles must not be allowed to ply on Dhaka city roads. Automated modern vehicle emission testing centres must be installed, and vehicles should be tested before being issued fitness certificates. Remote sensing vehicle pollution monitoring centres can be established. Euro 5/6 level diesel engines vehicles cannot be introduced with high sulfur diesels. Refining capacity and technology must be upgraded to produce high quality fuels compatible with Euro 5/6 engines. High-capacity, energy efficient clean fuel transportation systems should be introduced in urban areas. Introduction of metro rail services, electric vehicles (cars and buses), expressways, automated traffic signal systems, and high-volume mass transport facilities can significantly reduce air pollution in this sector.

8.3 Solid Waste Management

There is ample scope to improve solid waste management, reduce and stop open biomass burning, and segregate solid waste at source. The existing waste management system is not scientifically updated. Proper collection, segregation, and sanitary landfill management system, adoption of the Reduce, Reuse, and Recycle (3R) policy, introduction of waste-to-energy (incineration) projects, and control of open waste burning are required to reduce the contribution of existing waste to air pollution. Increased penetration of LPG and electric stoves for cooking can greatly reduce air pollution caused in the residential sector. An LPG subsidy with direct transfer schemes could be made available to all customers.

8.4 Construction Sector

Construction dust, resuspension of road dust and soil dust contribute significantly to Dhaka's unbearable air pollution. Construction-related good practices such as proper debris handling, transporting construction materials in covered condition, keeping the construction area wet, minimising dust generation, etc. must be followed to reduce pollution in this sector. Current practices do not maintain the standards for proper debris management, recycling, and debris disposal at designated sites. There is also no established protocol for using cleaner fuels and technology for asphalt mixing and minimising the number of hot-mix plants. For power/hit generation, they usually use an open solid-fuel stove for the hot mix plant.

8.5 Road Dust

This assessment identified a lack of mechanical/vacuum street sweeping trucks and wet/mechanized vacuum sweeping trucks for road cleaning. Green areas or open spaces, gardens, and community places need to be increased. Additionally, there is a need for wall-to-wall paving, repair of broken roads and pavements, and the installation and maintenance of water fountains.

8.6 Industrial Pollution

Continuous Emission Monitoring System must be installed on a large scale in highly polluting industries. The Department of Environment (DOE) should establish a data centre and mandate those industries to transmit their CEMS data to this central facility. DOE should take proper action to ensure the emissions are within the limits specified in Air Pollution Control Rules (2022).

8.7 Others

The current and future projections of emission inventories need to be developed in consultation with academic institutions specializing in air pollution science. There is an absence of accurate source identification study. Therefore, it is necessary to conduct a detailed source apportionment study and emission inventory in the Dhaka city.

Air quality modelling tools should be used to predict current and future air quality to enable informed policy decisions. Currently, there is no web-enabled real-time air quality monitoring system, alarm and messaging systems for public awareness so that they can take precautionary measures in the case of extreme air pollution. Public awareness needs to be enhanced by sharing air quality indices and spatial air quality maps using electronic media and message boards.

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