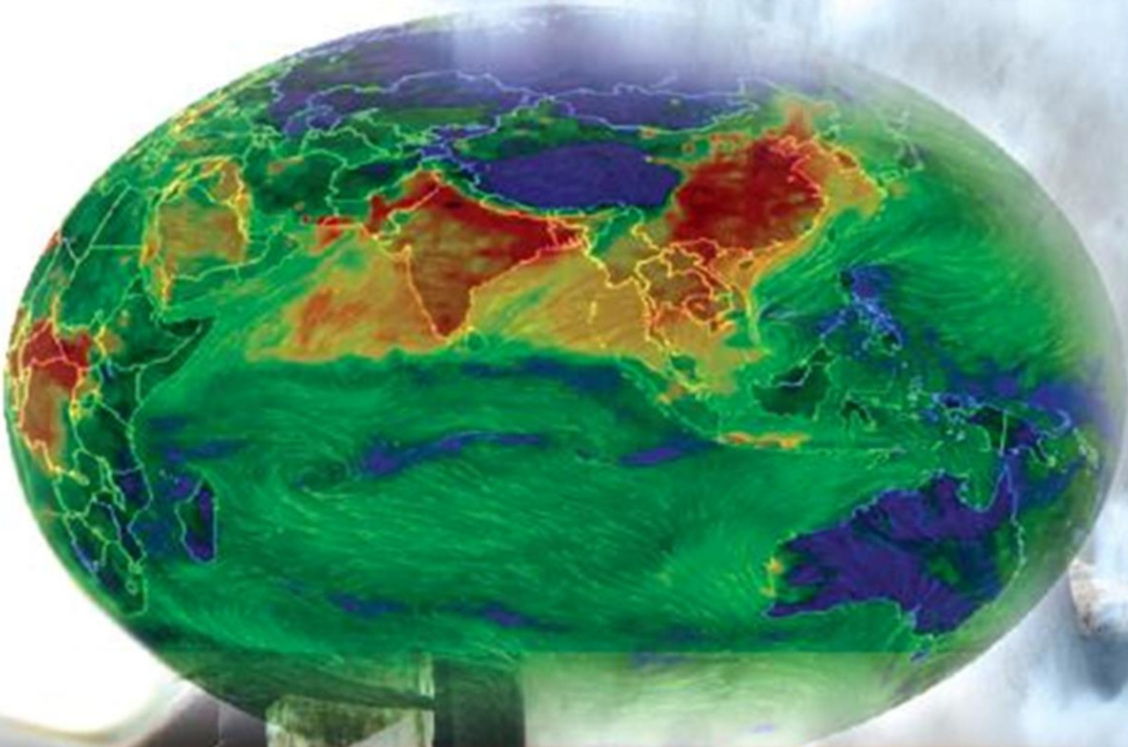

Air pollution in Bangladesh

Outdoor vs. Indoor: Sources and Penalties

LIVE AQI CITY RANKING
World major city air quality ranking

#	CITY	US AQI
1	Delhi, India	451
2	Sarajevo, Bosnia Herzeg....	346
3	Lahore, Pakistan	325
4	Dhaka, Bangladesh	293
5	Kolkata, India	257
6	Karachi, Pakistan	237
7	Bishkek, Kyrgyzstan	206
8	Kabul, Afghanistan	193
9	Kathmandu, Nepal	178
10	Wuhan, China	174

ESDO

Environment and Social Development Organization

Air Pollution in Bangladesh

Outdoor vs. Indoor: Sources and Penalties

ENVIRONMENT AND SOCIAL DEVELOPMENT ORGANIZATION-ESDO

Air Pollution in Bangladesh

Outdoor vs. Indoor: Sources and Penalties

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This report is published for current information and represents the existing - Air Pollution scenario in Bangladesh along with the major sources of pollutants in Dhaka city. Environment and Social Development Organization- ESDO holds the copyright of the report “Air Pollution in Bangladesh: Outdoor vs. Indoor: Construction Materials are the top Most pollutants: Bangladesh Ranks-1 & Capital Dhaka Ranks-2”.

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June, 2020,
Dhaka, Bangladesh.

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Executive Summary

Air pollution is a major environmental concern in Bangladesh, particularly in Dhaka, Sylhet, Narayanganj, Gazipur, Rangpur and Chittagong are six *of the* major and *densely* populated cities *of Bangladesh*. It is a persistent issue and made Bangladesh ranked 179th (out of 180 countries) at the Environmental Performance. Index for Air Quality in 2018 and in 2019 Bangladesh was the top most polluted country in the world. According to WHO study, at least 123,000 people died in Bangladesh in 2017 due to indoor and outdoor air pollution and the figure was estimated to rise to about 0.2 million by the year 2019. Considering the seriousness of the situation, Environment and Social Development Organization- ESDO initiated a study on both indoor and outdoor air pollution in Bangladesh with specific focus on major urban and rural centers of the country. The aim was to identify major pollution sources, assess current conditions and ambient air quality, dynamics along with associated health and environmental impacts and subsequently recommend potential prevention measures. The study integrated both qualitative and quantitative assessment methods, including – air quality measurement using standard equipment and a questionnaire survey. Major sources of air pollution. As per the study findings, the air quality of Dhaka city has degraded abruptly over last year, as about 50% of the days (February 2019 -March 2020) remained unhealthy or below the recommended level. However, due to prolonged lockdown condition for COVID-19 outbreak, Dhaka's air quality has substantially improved in the past months (15-March to 31 May), but has not reached a satisfactory level, perhaps the less strict implementation of the lockdown.

Construction work is the integral part of development activities, which have been, identified the major source of outdoor air pollution in urban areas the country try in recent times. In the last 5 years, in Dhaka city construction work has increased at a rate of 300 times. Large-scale construction projects from the Government and privet sectors have increased in last 10 years. Mismanagement in all the stages of piling, transporting and processing the construction materials is causing the particles to mix up in and pollute the air in the surrounding areas of the construction process. Sands contain silicon, and cement consists essentially of compounds of lime (calcium oxide, CaO) mixed with silica (silicon dioxide, SiO2) and alumina (aluminum oxide, Al2O3) which is highly toxic when these enter into human body through breathing. Other import air pollution contributors are the use of lead and sulfur content of fuel of urban traffic, toxic industrial emissions, exhausts from brick kilns, cement kilns, incineration of wastes etc. these toxic substances are travel and pollute outdoor air.

Although our concern mostly on outdoor air pollution. Nevertheless, indoor air pollution is also quite severe in Bangladesh. This particular study has focused on the indoor air pollution scenario in urban and rural areas of the country. In case of indoor pollutions, most of the pollutants come from three major sources- biomass burning for cooking, indoor smoking and gaseous substances emerged from sewerage emission process. In rural areas, the use of gas as fuel in very low (nearly 8%) and 66% of the respondents use coal/firewood and another 17% use dung cake. As stove fuel, majority of the urban respondents use natural

gas (42%) or L.P (27%) contained in cylinders. As a result indoor air pollution owing to biomass burning stove is more severe in rural areas compared to urban areas of Bangladesh.

On the other hand, in urban areas as stove fuel, majority of the urban respondents use natural gas (42%) or L.P (27%) contained in cylinders. As per the perceived response, nearly half (44%) of the surveyed households in urban areas reportedly suffers from insufficient air circulation. As well as in case of possession of heat resistant mechanism within the houses, 49% of the urban households reportedly do not have access to any.

According to the perceived response, nearly half (44%) of the surveyed households in urban areas reportedly suffers from insufficient air circulation, whereas this percentage is very low for the household placed in rural settlements (13%).

Standard Air Quality Index (AQI) measurement of Dhaka city reveals that, during last one year (1st February '19 to 1st March '20) the air quality of the capital city has degraded to the very unhealthy condition. About 50% of the days during this time remained unhealthy. The current study has also inspected movement dynamics such as the seasonal variation in air pollution and transboundary movement of pollutants. The findings suggest that, pollutant concentration in air increases in the pre-monsoon and winter seasons. To the contrary, in monsoon and post-monsoon period, the air quality remains in relatively good condition. This may be attributed to the construction activities, mostly taking place during the pre-monsoon and winter season in Bangladesh.

Another important dynamic associated with air pollution is the transboundary movement of airborne particles from the neighboring countries like India, Nepal, Pakistan, Myanmar and China. In this study, transboundary movement or exchange of pollutant particles has been considered for four major south Asian cities- Dhaka, New Delhi, Kolkata and Kathmandu. The findings suggest that, seasonal variation of air pollution in Dhaka may be limitedly explained by transboundary movement from neighboring countries as the wind movement and seasonal variation carry pollutants a long distance which ultimately get deposited in the local air during passing out the countries.

Exposure to outdoor and indoor air pollution is associated with a broad range of acute and chronic health effects, ranging from minor physiologic perturbations to death from respiratory or cardiovascular disease. In Bangladesh, the health impact on humans is becoming a common case as the air quality in recent 10 years have decreased significantly. The impact has both short term and long-term effects on human health. In recent years, urban areas in Bangladesh are affected by the short-term high intensity air pollutions. Short- term effects of pollution include eye, nose and throat irritation, bronchitis, asthma and pneumonia and emphysema and allergic reactions. On the other hand, long-term effects are just results of regular exposure to constant polluted air like in ceramic and cement factory, construction activities, plastic burning and recindustries, etc.es etc. The World Health Organization estimates that indoor air pollution from solid fuel leads to approximately 1.6 million deaths per year[1].

Air pollution can cause a variety of environmental effects as well like acid rain, eutrophication, smog, etc. The main problem associated with air pollution to environmental impact is that the airborne chemicals like PFAS, Lead, Mercury, etc. are deposited in the open water bodies and ultimately go to the groundwater aquifers. The unwanted chemicals mixed with water ultimately go in direct contact with domestic animals, fishes, and eventually enters into the food chain.

Countrywide lockdown of COVID-19 pandemic outbreak and subsequent reduction in transport and industrial activities has created significant impact upon the air quality of Dhaka city. According to the measurement of the standard equipment set up by ESDO, air quality in of Dhaka has steadily improved over the last 11 weeks of 15 March to 31 May 2020. Dhaka's air quality has progressively improved. At the end of May '20 Dhaka ranked 27th globally, which in earlier ranked as the worst air quality city on earth. Apparently imposed restriction on movement, air quality in Dhaka also improved compared to the usual, but yet, the quality did not rise up to the expected level. This may be attributed to the disobeying of lockdown regulations by the city dwellers and subsequent unauthorized use of motor vehicles neglecting the imposed movement restriction. Bangladesh, as a nation was also ranked the 2nd most polluted nation among the south Asian nations as per AQI value measured over past 11 weeks. It is a clear reflection of the fact that, although officially declared, lockdown restrictions were not strictly followed or implemented in most parts of Bangladesh.

[1] https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

1.1 INTRODUCTION

1.1.1 Background

Air pollution is a major environmental danger in Bangladesh, particularly in the capital city Dhaka and other five major cities. In developed and developing countries, the effect of poor ambient air quality on human health, agricultural production, and material damage has been well reported. Governments in all developed countries have been very involved in regulating air pollution to ensure their people have a decent quality of life. Developing countries such as Bangladesh often took note of air pollution issues and often led by international agencies such as the World Bank (WB), the Asian Development Bank (ADB), the United Nations Environment Program (UNEP), took action, or intended to mitigate and monitor air pollution.

Air pollution is a pressing issue in our country as Bangladesh ranks 179th (out of 180 countries) at the Environmental Performance Index for Air Quality[2]. The main sources of air pollution include emission from faulty vehicles, especially diesel run vehicles, brick kilns and dust from roads and construction sites and toxic fumes from industries. The main pollutants from gasoline powered internal combustion engines are carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulates of lead compound and unburned carbon particles. Emissions from diesel engines are smoke, CO, unburned carbon, NO_x and SO_2. According to the Department of Environment (DoE), the density of airborne particulate matter (PM) reaches 463 micrograms per cubic meter (μgm^{-3}) in the city during the dry season (December-March) - the highest level in the world[3]. World Health Organization (WHO) air quality guidelines (2005) recommend a maximum acceptable PM level of 20μgm^{-3}, cities with 70μgm^{-3} are considered highly polluted. A study conducted by the scientists of Bangladesh Atomic Energy Commission (BAEC) revealed that about 50 tons of leads are emitted into Dhaka city's air annually and the emission reaches its highest level in dry season (November-January).

Poor ambient air quality is causing damage to human health, agricultural production and materials. It is high time to create awareness and motivation about air pollution across the country. At different times air pollution issues have been considered, and often guided by the multinational agencies like the World Bank (WB), Asian Development Bank (ADB), United Nations Environment Programme (UNEP), have taken measures or have made plans to reduce and control air pollution. The Department of Environment (DoE), the Government Agency entrusted with safeguarding the environment in Bangladesh, sought proposals to develop an 'Air Pollution Reduction Policy for Bangladesh' under the framework of the Malé Declaration on Control and Prevention of Air Pollution and Its Likely Trans-boundary Effects for South Asia[4].

[2] https://epi.envirocenter.yale.edu/epi-country-report/BGD
[3] Air Pollution Reduction Strategy for Bangladesh, Final Report, 2012.
[4] Monthly, A.Q.S. and Annual, A.Q.S., 2012. Air Pollution Reduction Strategy for Bangladesh.

Ambient air quality standards were first introduced in Bangladesh in 1997 under the environmental conservation rules (ECR) 1997. The Air Quality Management Project (AQMP) implemented by the DoE during 2000-2007 with support from the World Bank was the first major project aimed at air quality management in Bangladesh. The objectives of the AQMP included reducing vehicular emissions in the metropolitan areas, setting standards, enforcing pilot programs towards cleaner technologies, as well as implementing air quality monitoring and evaluation. This led to the revision of the ambient air quality standards of Bangladesh in July 2005. Other notable projects aimed at air quality management include certain components of the Clean and Sustainable Environment (CASE) Project supported by the World Bank, the Bangladesh Air Pollution Management (BAPMAN) Project, and the Implementation of Malé Declaration[5].

In recent times, Bangladesh air quality has degraded sharply due to different identified and unidentified sources of pollutants. Major projects of Government and other organizations were mainly focusing on brickfield and vehicle emissions and no other sources were recognized as an air quality-degrading agent. Keeping that in mind, Environment and Social Development Organization- ESDO has initiated a research study on air quality monitoring and finding the major reasons of air pollution in and around Dhaka city. The study was initiated in February 2019 up to March 2020. However, the impact of COVID-19 pandemic on ambient air quality of Bangladesh has also been addressed in this report. The aim of the study is to identify the major source of air pollution, transboundary movement of pollutant from industrial areas near Bangladesh border and seasonal impact on air quality.

1.1.2 Air Pollution in Bangladesh

Air pollution is a serious environmental health hazard affecting the populations of Bangladesh. Indoor and outdoor air pollution in Bangladesh is caused due to increasing population, associated motorization, industrial emissions, and use of biomass fuels during cooking with poor ventilation. Industries are mainly concentrated in major urban metropolitan areas such as Dhaka (The capital of Bangladesh), Rajshahi, the seaport cities such as Chittagong and Khulna, the inland port city Narayanganj, and other divisional towns.

Obviously, the air pollution problem is more severe in all of the major cities in Bangladesh. Apart from unplanned industrial development in these areas, the severity of the pollution is increased mainly due to exhausts from illegal use of two-stroke engine and diesel-run vehicles. In the rural areas of Bangladesh, the danger of air pollution not yet turns into a point of concern. This is due to less motorized vehicles and industries in rural areas. The following Table 1 shows the ambient air quality standards in Bangladesh and their comparison with WHO and United States (US) standards (ADB, 2006). The government for 15 years has not changed these standards, but the air pollution condition has sharply changed towards extreme conditions.

[5] Haque, H.A., Huda, N., Tanu, F.Z., Sultana, N., Hossain, M.S.A. and Rahman, M.H., 2017. Ambient air quality scenario in and around Dhaka city of Bangladesh. Barishal University Journal, Part-1, 4(1), pp.203-218.

Table 1: *Ambient air quality standards in Bangladesh from July 2005 and their comparison with WHO and US standards*[6]**.*

Pollutant	Pollutant (observation realized)	Bangladesh Standard (μgm^{-3})	WHO guideline (μgm^{-3})	US standard (μgm^{-3})
Carbon Monoxide (CO)	8 hr. 1 hr.	10000 40000	10000 30000	10000 40000
Lead (Pb)	Annual	0.5	0.5	0.15
NO_x	Annual	100	-	-
SPM	8 hr.	200	-	-
PM10	Annual 24 hr.	50 150	20 50	- 150
PM2.5	Annual 24 hr.	15 65	10 25	15 35
Ozone O_3	1 hr. 8 hr.	235 157	- 100	235 157
Sulphur dioxide	24 hr.	80	-	78

*PM = Particulate matter in micron; Suspended particulate matter.

In recent past, agro based industries like sugar, pulp, paper, tanneries and value added industries like textile, garments, pharmaceutics, oil refineries, and fertilizer and chemical industries had contributed for air pollution. The air pollution percentage of most five industrial sectors of Bangladesh in the year 2001 is shown in Table 2 (Faisal, 2001). Other than industrial emissions, there are many brick-making kilns operated seasonally, mainly in dry season all over Bangladesh. More or less all of these kilns use coal and wood as their prime sources of energy, resulting in the emission of particulate matter, oxides of sulfur, and volatile organic compounds.

Table 2: *Air pollution percentage of most five industrial sectors of Bangladesh in the year 2001*[7]*.*

Industry	Emission (ton y-1)	Pollution (%)
Food Industry	146,356.06	38.7
Cement/Clay	62,725.88	16.6
Pulp and Paper	51,963.92	13.7
Textile	39,831.01	10.5

Additionally to these usual sources of fuel, used rubber wheels of vehicles are also burnt, which produce black carbon and toxic gases. These are harmful for health (UNEP, 2001). Occurrence of choking smells and irritating eyes are common (Shakeel, 2011). The tremendous force of population has made it almost unfeasible to maintain a clean environment in the capital city of Dhaka (UNEP, 2001). Dhaka has been identified as the second worst city to live for the second consecutive time, according to a survey of

[6] Haque, H.A., Huda, N., Tanu, F.Z., Sultana, N., Hossain, M.S.A. and Rahman, M.H., 2017. Ambient air quality scenario in and around Dhaka city of Bangladesh. Barishal University Journal, Part-1, 4(1), pp.203-218.
[7] Haque, H.A., Huda, N., Tanu, F.Z., Sultana, N., Hossain, M.S.A. and Rahman, M.H., 2017. Ambient air quality scenario in and around Dhaka city of Bangladesh. Barishal University Journal, Part-1, 4(1), pp.203-218.

Economist Intelligence Unit (EIU) affiliated with the UK-based weekly Economist. The listing was based on 30 factors across five broad categories: stability, healthcare, culture and environment, education and infrastructure. The survey factor was rated as accepted, tolerable, uncomfortable, undesirable or intolerable in a system that "allows for direct comparison between locations," according to the report (Daily Star, 2011).

1.1.3 Statement of the Problem

In the last 10 years the air quality Bangladesh, especially of Bangladesh especially in Dhaka city has degraded quite sharply. For the last two decades, Bangla has experienced rapid urban population growth, most of which is in and around Dhaka – the country's capital. The concentration of the key air pollutant of concern (particulate matter [PM]) in Dhaka and other major cities has been steadily increasing, with an annual average much higher than the World Health Organization (WHO) standard. Up until 2018, two of the primary sources of urban air pollution in Dhaka were identified as vehicles (43.0%) followed by small brick kiln industries (37.5%). However, - development and construction activities including construction of high- rise buildings and infrastructures have also increased -2 fold since 2010. Massive scale government projects (Flyover, Metrorail Project etc.) within the urban regions of the country in recent times have included reasons for deterioration of air quality in urban landscape. Rapid urban population growth also has far outstripped the capacity of urban infrastructure, leading to a low level of efficiency and shortages. In recent years especially since 2013, the transport conditions in Dhaka are mainly characterized by chronic traffic congestion and delays, low quality of public transport service, lack of comfort and safety for general people, and uncontrolled growth of air pollution in the road. The tremendous force of population has made it almost unfeasible to maintain a clean environment in the major urban centers, particularly in the capital city of Dhaka.

Air pollution is a serious environmental health hazard adversely affecting the populations of Bangladesh. Indoor and outdoor air pollution in Bangladesh is caused due to increasing population, associated motorization, industrial emissions, and use of biomass fuels during cooking without poor ventilation arrangement. Air pollution condition is more severe in all of the major cities in Bangladesh. Industries are mainly concentrated in major urban metropolitan areas such as Dhaka (The capital of Bangladesh), Rajshahi, the seaport cities such as Chittagong and Khulna, the inland port city Narayanganj, and other divisional towns. Apart from rapid and unplanned industrial development in these areas, the severity of the pollution is high due to other factors such as long-term construction activities, exhausts from illegal use of two-stroke engine and diesel-run vehicles etc. Additionally, to these usual sources, used rubber wheels of vehicles are also burnt, which produce black carbon and toxic gases, which are harmful for health and environment. In the rural areas of the country, the risk of air pollution is comparatively less severe and has not yet turned into a point of concern. This is due to fewer motorized vehicles and industries in rural areas.

1.1.4 Purpose and Need of the Study

In recent times, air quality in Bangladesh has degraded sharply due to different identified and unidentified sources of pollutants. Major projects of Government and other organizations were mainly focusing on Brickfield and vehicle emissions as no other sources were recognized as air quality degrading agent. However, other sources are rising, especially ongoing and future construction activities and building unplanned industries around Dhaka city and other major cities of Bangladesh. The death rate and affected person rate due to air pollutant is increasing as well. Keeping these in mind, Environment and Social Development Organization- ESDO has initiated a research study on air quality monitoring and finding the major reasons for air pollution in Bangladesh with a specific focus on the capital city of Dhaka. The study was initiated in February 2019 and lasted up to March 2020.

The primary objective of the study is to identify and manifest major sources, dynamics and perceived intensity of air pollution condition (both outdoor and indoor) in Bangladesh along with their associated health and environmental impacts. The research aims to learn more comprehensively about the local sources of air pollution, transboundary movement of pollutants from cross border nations, impacts of harmful airborne pollutants upon health and environment and the potential remedies required to improve the existing situation. However, the impact of COVID-19 pandemic on ambient air quality of Bangladesh has also been studied under the provision of this research. This review is focused on the status of air pollution in Bangladesh and Dhaka, negative consequences of degraded air quality, pollution control strategies, policies, laws, standards, and regulations etc. ESDO hopes that this study report will serve as a comprehensive document delineating multifaceted aspects of air pollution in Bangladesh and will form the basis for more detailed and scientific studies in future in this respective field.

1.1.5 Methodology of the Study

ESDO conducted an extensive study on air pollution condition in Bangladesh with specific focus on the capital city Dhaka. This comprehensive study integrated both qualitative and quantitative measurements of air pollution in the country. The Major data collection method applied to collect qualitative information includes structured questionnaire survey conducted both in urban and rural areas of the country. Quantitative data were collected employing two prominent methods – literature review and instrumental monitoring of ambient air quality. As well as FGD, and Key Informative Interviews…

1.1.5.1 Qualitative Data Collection Method: Questionnaire Survey

The principal method adopted for qualitative data collection in this study includes questionnaire survey (questionnaire added in ANNEX-A). The survey has been conducted in two successive phases – Indoor air quality assessment survey and outdoor air quality assessment survey. The indoor air quality assessment survey was conducted from Feb 2010 – December 2013 and the outdoor air pollution survey was conducted from December 2019 -March 2020. Indoor air pollution survey was conducted in 29 major areas of Dhaka

City, five divisional towns Chittagong, Sylhet, Rajshahi, Khulna, Barisal, and some other major towns- Bogra, Rangpur, Dinajpur, Munshinganj, Mymenshing, Cox's Bazar, Jassor, Pabna, Comilla, Jamalpur, Gazipur, Tangail, Faridpur, Feni, Noakhali, Jaipurhat, Naogaon, Thakurgaon, and as well as in 49 villages of the above districts. The outdoor pollution survey was conducted in five most densely populated and potentially polluted areas of Dhaka city – Mohammadpur, Rayer Bazar, Old Dhaka, Shahbagh Area (University of Dhaka Campus) and Farmgate and in Gazipur. However, in the second phase, 4 most prominent ceramic factories in Bangladesh have also been visited and surveyed with a view to deriving insights regarding industrial air pollution sources.

Survey Locations and Sample size:

❖ Indoor Air Pollution Survey Locations:

	Inside Dhaka	Outside Dhaka
Urban	Uttara, Pollibi, Mirpur, Cantonment, Aminbazar, Gulshan, Banani,Tejgaon, Mohammadpur, Kallanpur, Shymoli, Dhanmondi, Rayerbazar, Lalbagh, Azimpur, Sutrapur, Sadarghat, Islampur, Wari, Damra, Bashabo, Kamlapur, Sajhanpur, Shabujbagh, Khilgaon, Chowdhurypara, Rampura, Badda, Kafrul	Chittagong, Sylhet, Rajshahi, Khulna, Barisal, Bogra, Rangpur, Dinajpur, Munshinganj, Mymenshing, Cox's Bazar, Jassor, Pabna, Comilla, Jamalpur, Gazipur, Tangail, Faridpur, Feni, Noakhali, Jaipurhat, Naogaon, Thakurgaon
	*Survey Respondent-150*29=4,350	*Survey Respondent-300*23=6,900
Rural	49 villages from the above-mentioned districts *Survey Respondent-150*49=7,350	
Total Respondent	18,600	

❖ Outdoor Air pollution Survey Locations: (In Dhaka)

Survey Location in Dhaka	Survey Area
Town Hall	Mohammadpur
BRTC Bus Counter	
Beribadh	Rayer Bazar
Islambag	Puran Dhaka
Chalkbazar	
TSC	University of Dhaka
Shahbag	
Indira Road	Farmgate

❖ Name and locations of the ceramic manufacturing industries surveyed during the outdoor air pollution survey:

Name of the Ceramic Industry	Location
X Ceramics Ltd.	Ansar road, Mawna, Sreepur, Gazipur
Greatwall Ceramic Ind. Ltd.	Gilarchala Sreepur, Gazipur, Bangladesh
Shinepukur Ceramics ltd.	BXIMCO Industrial park, Chakrobarti, Joydebpur
Mir Ceramics Ltd.	Mawna, Sreepur, Gazipur, Bangladesh.

1.1.5.2 Quantitative Data Collection Method (AQI Monitoring)

Under the provision of this study, PM2.5 pollutant concentration in the air of Dhaka was measured by standard Air quality Monitoring Device. Dr. Greg Howard, Research Fellow at ESDO, has designed the Air device. The device was set up in different locations in Dhaka city, including Lalmatia, Banani, Dhaka University Campus, and Old Dhaka The monitoring device was set up and air quality data were recorded from 1st February 2019 onwards. The data was derived in the form of PM concentration and later transformed into Air Quality Index (AQI) Value to get a standardized measurement on ambient air quality around Dhaka city.

AQI Calculation: The daily $PM_{2.5}$ AQI is calculated by taking the 24-hour concentration average (from midnight to midnight in Local Standard Time) and converting the value into AQI as per the formula defined in following table. 75%, or 18/24 hours of data are needed for a valid daily AQI calculation and the average is computed according to US EPA Scale convertor as shown in the table below.

Category	AQI (no units)	24-hours average $PM_{2.5}$ concentration (ug/m^3)
Good	0-50	0-12
Moderate	51-100	12-35.5
Unhealthy for Sensitive Groups	101-150	35.5-55.5
Unhealthy	151-200	55.5-150.5
Very Unhealthy	201-300	150.5-250.5
Hazardous	300-500	250.5-500.5

SECTION II

2.1 DEVELOPMENT, URBANIZATION AND AIR POLLUTION

Since the beginning of the industrial revolution, people have increasingly congregated in urban areas so that as of 2005, more than half of us lived in cities. Development and urbanization has changed the structure of the cities and most people moved to major cities from rural areas. This situation has also changed the environment including the ambient air quality of the cities.

2.1.1 Broad Trends in Development

Several conceptual frameworks have been developed to describe broad trends in development over time. These include the demographic transition, the epidemiologic transition, and the environmental risk transition (see Figure 1).

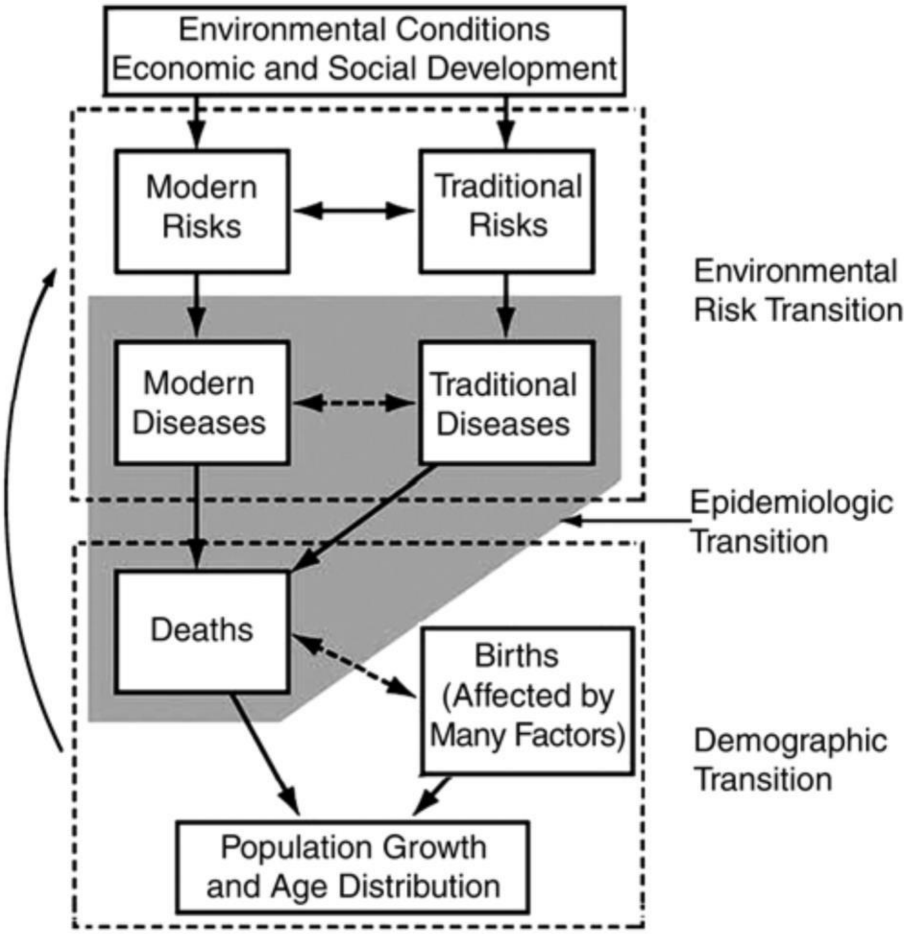

Figure 1 : Integrated frameworks describing broad trends in development*. The gray area designates the three main factors driving development. Solid arrows represent known relations; dashed arrows represent possible relations. [Adapted from the Annual Review of Environment and the Resources, Smith and Ezzati 2005.]*

The demographic transition is a conceptual framework that describes how changes in the rates of birth and death affect population size. In brief, increased development is expected to lead to decreased death rates, followed eventually by gradual declines in birth rates. The lag time between the two declines initial results in a large population increase. The lag time can be partially explained by the fact that fertility tends to be higher in regions of low development and poverty, where there tends to be a lack of access to education and birth control methods; therefore, only after development has affected daily life do the measures limiting fertility take effect. Over time, continued decreases in the birth and death rates result in a gradual fall in the rate of population increase; the population may shrink and become increasingly older overall.

Similarly, the environmental risk transition focuses on changes in underlying environmental risk factors for disease and therefore may be a major trigger of current and future trends in disease patterns. Development often involves several processes—including urbanization, industrialization, agricultural modernization, and vehicularization. These tend to produce community exposures or potential environmental hazards or risk factors such as outdoor air pollution, solid and hazardous waste, lead exposure, and pesticide use[8]. It is worth noting, however, that exposure increase, but ease but the associated population-level risk may decrease if disease cofactors such as health care reduce the potential effect or the size of the susceptible subpopulations. As countries modernize further and environmental controls are tightened, community-level exposures tend to decline. This decline leads to the third stage of the environmental risk transition, in which the developed countries contribute most to global risks that are due to greenhouse gas (GHG) emissions and other causes of global environmental change.

Overall, exposures leading to potential environmental health risks generally seem to decline with economic development, both in absolute and relative terms. Household exposures are considerable in poor areas and decline with increasing development; community exposures first rise, as modern industrial economic development begins, and then decline (Smith and Ezzati 2005). Residents of urban areas living in poverty, who are particularly numerous in Asia, experience considerable risk from both community and household exposures (Smith 1990). Such populations are likely to have a larger environmental burden of disease, and a larger portion of their entire disease burden due to environmental risk factors, than do populations living in the more developed regions (Smith et al. 1999).

Figure 1 illustrates the integrated nature of the demographic transition, the epidemiologic transition, and the environmental risk transition. Although these frameworks can be used to aid the understanding and management of environmental risks, there can be significant local departures from the overall trends predicted, because the processes driving these trends are dynamic and interrelated.

2.1.2 Urbanization Trends

Urbanization is closely related to the three dimensions of sustainable development: economic, societal and environmental (see Box I.1). Well-managed urbanization (among other factors), informed by an understanding of population trends over the long run, can help to maximize the benefits of agglomeration

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[8] Occupational risks seem to increase because of these hazards or risk factors as well, although the occupational hazards of farming in traditional, poor communities in rural areas are not well documented. Occupational risks in the informal unregulated sector of the urban economy are not well described either, although they are probably considerable.

while minimizing environmental degradation and other potential adverse impacts of a growing number of city dwellers, especially in low-income and lower-middle-income countries where the most rapid urbanization is expected between now and 2050.

As countries develop, there is a tendency for increased urbanization. Several years ago, it was projected that by 2020, more than half of the world's 7.8 billion people would be living in cities (United Nations Economic and Social Affairs 2018). This population shift is especially pronounced in Asia, where the urban population is expected to double in the next 22 years, from 1.36 billion to 2.64 billion. The global urban population is projected to grow by 2.5 billion urban dwellers between 2018 and 2050, with nearly 90 per cent of the increase concentrated in Asia and Africa[9]. It is projected that by 2030, Asia's urban population will make up over half the world's urban population.

Patterns of urban growth differ around the world. However, urban growth is most often attributed to migration from rural to urban areas, natural increases in the urban population and reclassification of city boundaries also contribute to the increase in city populations. For example, in India, natural increase is the primary factor driving urban growth. In contrast, migration is the main factor driving urbanization in many Chinese cities, where population growth is tightly regulated.

Expanding City Size: Megacities are cities with a population over 10 million. As of 2000, over half the 20 megacities in the world were in Asia: Tokyo, Mumbai, Delhi, Shanghai, Kolkata, Jakarta, Dhaka, Osaka–Kobe, Karachi, Beijing, and Manila (United Nations Economic and Social Affairs 2004). Six of these megacities are among the top 10 largest cities in the world. Although Tokyo is currently the only city in Asia with more than 20 million residents (i.e., a megacity), it is projected that Asia will have five megacities by 2020.

Despite the large size of megacities, they are home to only about 4% of the world's urbanites. Smaller towns and cities have rapidly increasing populations and account for the bulk of the trend in urban growth. The majority of people undergoing the shift from rural to urban areas come from the smaller cities and towns in the poorer developing world. About 53% of the worldwide urban population lives in cities with < 500,000 residents and another 22% live in cities with 1–5 million residents. Moreover, despite the rapid growth in urban populations, Asia continues to have a substantial rural population. As of 2018, 41% of all rural dwellers lived in Asia.

Urban Land Use Change: Urban sprawl can be categorized as residential suburbanization or peri-urbanization. Residential suburbanization refers to planned growth consisting mostly of housing for single families in the middle to upper classes built at low density away from the city center. This suburbanization can lead to increased commuting and associated increases in energy use and vehicular pollution. Peri-urbanization refers to the unplanned expansion of economic activities into the areas surrounding an urban

[9] World Urbanization Prospects: The 2018 Revision

center; this occurs mostly in the transitional zones between urban and rural boundaries. In Asia, peri-urbanization is often characterized by the incorporation of adjacent rural areas or small towns into larger urban settlements. Peri-urbanization is often associated with disorderly growth and lack of regulation, followed by environmental degradation.

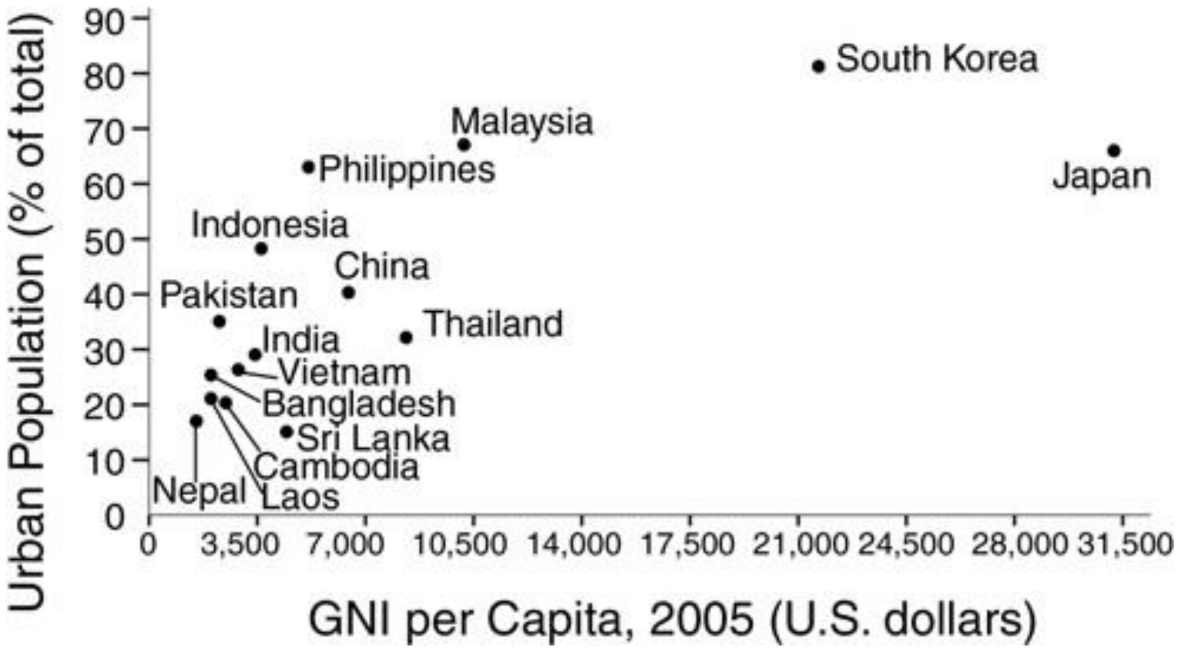


Figure 2: Degree of urbanization according to gross national income (GNI) per capita in various Asian countries in 2005. *[Data compiled from WHO 2007]*

A cross-sectional sampling of Asian countries shows that increases in income are associated with a larger proportion of the population living in urban areas (Figure 3). This is particularly true at the lower end of income and urbanization scales. Once approximately half the population in a given Asian country lives in urban areas, the degree of wealth in that country ranges widely.

Between 1950 and 2018, the urban population of the world grew more than fourfold, from an estimated 0.8 billion to an estimated 4.2 billion. The average annual rate of change of the urban population during this period, estimated at 2.54 per cent, was more than 50 per cent higher than that of the world's population as a whole (1.62 per cent). Thus, between 1950 and 2018 the world's population was urbanizing rapidly, with the proportion urban rising from 30 per cent in 1950 to 55 per cent in 2018 (see box I.1 for definitions of urbanization). The rate of urbanization between 1950 and 2018, defined as the average annual rate of change of the percentage urban was 0.92 per cent per year on average. As a result of this rapid urbanization, in 2007 the population of the world became more urban than rural for the first time. The urbanization process is expected to continue for decades and an ever-increasing majority of humankind will likely be living in urban areas.

2.1.3 Poverty and Air Pollution: The Interlinkage

There is emerging evidence, largely from studies in Europe and North America, that economic deprivation increases the magnitude of air pollution–related morbidity and mortality (Krewski et al. 2000). There are two major reasons why this may be true (O'Neill et al. 2003): First, economically disadvantaged communities are exposed to higher concentrations of air pollution; and second, because of poorer nutrition, less access to medical care, and other factors, people in these communities experience more health impact per unit of pollution exposure (i.e., are more vulnerable to health effects). In addition, air pollution could exacerbate the conditions of poverty. The relative impact of air pollution has been observed to be modified by group or neighborhood characteristics, such as living in slums (Gouveia et al. 2004) or living in highly polluted areas (Jerrett et al. 2004). At the same time, because of the challenges of explaining the observed group-level effects, individual estimates of exposure and socioeconomic position continue to be used in analyses.

Previous studies using characteristics of individuals to assess changes in the magnitude of the air pollution effect estimate (i.e., effect modification) by socioeconomic position suggest that a low level of education (Gouveia et al. 2004; Jerrett et al. 2004) and low family income (Gouveia et al. 2004) are associated with increased health effects that are related to air pollution. Evidence also suggests that group-level indicators, such as residence in a poor neighborhood, could be risk factors beyond the socioeconomic position of an individual (Malmström et al. 1999). This finding underscores the importance of using analyses that include hierarchical models that integrate individual and group-level indicators of socioeconomic position.

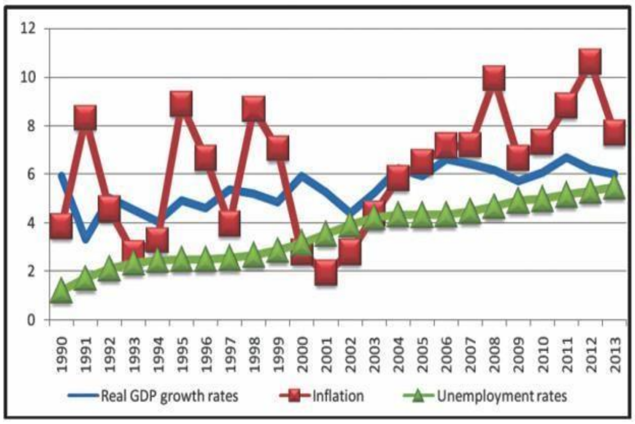
Poverty: Growth Nexus in Bangladesh

During the decades since the 1990s, faster growth rate has been identified as one of the causes in reducing poverty. Graph 1 shows that the real GDP growth rate in 1990 was 5.94% and gradually increased to 6.12% in 2014. During the past two decades, the growth rate in some years was around 4%, but the overall trend was above 5% on the average[10].

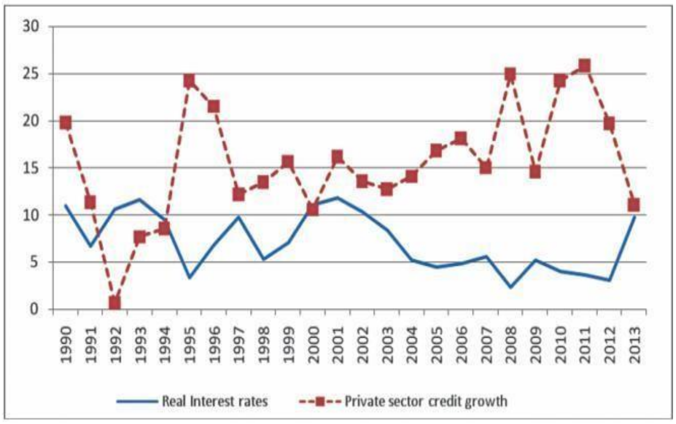
Bangladesh experienced two devastating natural disasters (flood and cyclone) in 2007 and a subsequent food price shock in 2008. However, the country's real GDP growth was greater in the 2005-2010 period relative to previous periods. Poverty estimation based on the 2016 HIES - poverty is still high in Bangladesh but she has continued to make impressive progress in reducing poverty. Measured against the international extreme poverty line, poverty fell from 18.5% in 2010 to 13.8% in 2016, and the country is on track to reach the first Sustainable Development Goal of eradicating extreme poverty by 2030. Progress on reducing poverty measured by the national upper poverty line has been equally strong. In 2010, almost one third of the

[10] https://www.thedailystar.net/supplements/25th-anniversary-special-part-2/development-trends-and-the-tasks-ahead-210835

country's population lived in poverty; by 2016, this had fallen to less than one-fourth. Since 2010, 8 million Bangladeshis moved out of poverty[11].



Graph 1



Graph 2

During this period, growths in income and consumption expenditure were the main drivers of poverty reduction. In fact, growth during the first part of the decade (2000-2010) was more significant than redistribution in reducing poverty. In the first half of the decade, the faster reduction of poverty due to growth only has been accompanied by a worsening of income distribution.

Air pollution is strongly linked to poverty. Nearly 92% of pollution-related deaths occur in low- and middle-income countries[12]. In Bangladesh, children face the highest risks and are the most vulnerable victims of pollution because small exposures to chemicals in utero and early childhood can result in lifelong disease, disability, premature death, as well as reduced learning and earning potential. The health impact of air pollution is likely to be much larger than can accurately be quantified today because of insufficient data collection and scientific research from many pollutants. The public health and social policy implications of the relations among health, air pollution, and poverty are likely to be important, especially in areas such as Asia, where air pollution concentrations are high and many live in poverty. However, the interaction between poverty and the health effects of air pollution has been studied little in developing countries in general and in Asia in particular.

[11] https://www.worldbank.org/en/news/feature/2017/10/24/bangladesh-continues-to-reduce-poverty-but-at-slower-pace
[12] https://www.heart-resources.org/reading_pack/pollution-and-poverty/

2.2 AIR POLLUTION: TYPE, COMPONENTS, AND SPECIFIC SOURCES

Air pollution can be classified in different types. Mainly it can be divided by indoor and outdoor air pollution. On the other hand, it can be categorized according to the pollutants in the air. In some case, similar types of pollutant cause both indoor and outdoor air pollution like carbon monoxide, carbon di- oxide, but they are produced from different sources. In Bangladesh, pollutant category is generally used to identify and define the air quality.

2.2.1 The different categories of air pollutants in Bangladesh

The Earth's atmosphere is composed mainly of dinitrogen (N_2: 78% by volume) and dioxygen (O_2: 21% by volume). Gaseous, liquid and solid pollutants either from natural sources or discharged into the atmosphere by human activities can pollute it. Natural sources include emissions from plants, from the biomass of the ocean, volcanic gas and the re-suspension of dust in arid areas such as deserts. Anthropogenic sources include combustion engines (both diesel and petrol), household and industry solid fuel combustion for energy production (coal, lignite, heavy oil and biomass), other industrial activities (building, mining, manufacture of cement, smelting), agriculture, with the use of entrants, and the erosion of roads by vehicles and abrasion of brakes and tyres.

Man-made and natural discharge in the atmosphere can lead to both primary and secondary pollutants. Primary pollutants are directly released in the air, and include the following components:

- Particulate matter (PM_{10} and $PM_{2.5}$);
- Carbon oxides (e.g. carbon monoxide);
- Oxides of sulphur;
- Ammonia;
- Light hydrocarbons;
- Volatile organic compounds;
- Metals (lead, mercury, cadmium).

By contrast, secondary pollutants are formed in the atmosphere as a result of a chemical reaction between gaseous precursors such as sulphur dioxide, oxides of nitrogen, ammonia and non-methane volatile organic compounds. They include the following elements:

- Oxides of nitrogen[13],
- Ozone.

a. Particulate matter (PM)

PM, or coarse particles[14], consist of invisible solid and liquid particles with diameters of either less than 10µm (PM_{10}), or 2.5µm ($PM_{2.5}$). They affect more people than any other pollutant[15], and can penetrate into

[13]Amount of the loss divided by the value of the insured property

the respiratory tract. $PM_{2.5}$, being even smaller, can reach the deepest areas of the breathing apparatus, such as the pulmonary alveoli[16]. They include ultrafine particles having a diameter of less than 0.1µm. The chemical compounds of PM include sulfates, nitrates, ammonium and other inorganic ions such as sodium, potassium, calcium or magnesium, metals such as cadmium, copper, nickel and zinc and biological components such as allergens or microbes[17].

PM can be generated by industry, transport and agriculture, and due to their lightweight, can also be carried on air currents from one country to another. As an example, two-thirds of the PM10 recorded in the Netherlands is estimated to have originated in foreign countries[18].

The WHO 2005 Air Quality Guidelines recommend maintaining PM concentrations below the following levels:

- $PM_{2.5}$: 10 $\mu g.m^{-3}$ annual mean; 25 $\mu g.m^{-3}$ 24-hour mean;
- PM_{10}: 20 $\mu g.m^{-3}$ annual mean; 50 $\mu g.m^{-3}$ 24-hour mean.

According to the WHO, in 2016, 91% of the world population was living in places where the air quality guidelines levels were not met.

It is widely accepted that particulate matter is the major pollutant of concern internationally and in Bangladesh (ADB, 2006; UNEP, 2012). In recent times, the adverse effects of black carbon (BC), a major component of soot, has attracted much attention (WHO, 2012; UNEP, 2011). Black carbon and other particulates are emitted from many common sources, such as diesel cars and trucks, residential stoves, forest fires, agricultural open burning and some industrial facilities. Although Bangladesh was one of the first few countries in Asia to enact a $PM_{2.5}$ standard for ambient air, the achievements on the compliance of this and other particulate related standards are poor. Consistent and coherent source for time series information on SPM or PM concentrations in ambient air are also not available, since the Continuous Air Monitoring Station (CAMS) of the Department of the Environment (DoE) at Shangshad Bhaban in Dhaka started operating in 2002 (partially operative during 2007-2010); the other CAMS in Dhaka (BARC) has been operating since 2008.

b. Nitric oxides (NO_x)

Nitric oxides include nitric oxide (NO) and nitrogen dioxide (NO_2), the result of the oxidation of nitric oxide by ozone. Nitrogen dioxide is a by-product of combustion reactions, and typically appears during the

[14] WHO, regional office Europe, Health effects of Particulate Matter, 2013
[15] WHO | Air pollution http://www.who.int/topics/air_pollution/en/
[16] Deng, X., Rui, W., Zhang, F. et al., "PM2. 5 induces Nrf2-mediated defense mechanisms against oxidative stress by activating PIK3/AKT signaling pathway in human lung alveolar epithelial A549 cells", Cell biology and toxicology, (2013) 29: 143 https://dx.doi.org/10.1007/s10565-013-9242-5
[17] WHO, regional office Europe, Health effects of Particulate Matter, 2013
[18] Hendriks et al., "The origin of ambient particulate matter concentrations in the Netherlands", Atmospheric environment (2013) 69: 289.

burning of fossil fuels in power plants. In cities, where it contributes to the formation of smog events[19], most of the nitrogen dioxide comes from motor vehicle exhaust.

Nitric oxide is an important molecule in human cells, but has a limited toxicity in the concentrations at which it is found in the atmosphere. However, exposure to nitrogen dioxide can decrease lung function and increase the risk of respiratory symptoms[20].

Nitrogen Dioxide (NO_2) has some health impacts and is a well-known precursor to acid rain, which can reduce agricultural production and damage the environment (UNEP, 2012). NO_2 is also a precursor for the formation of particulates and O_3 in the atmosphere.

c. Ammonia (NH_3)

Ammonia is the most abundant alkaline gas in the atmosphere and the most commonly produced chemicals. It is a precursor for the nitrogen reaction chain and is produced naturally from decomposition of organic matter, including plants, animals and wastes. The largest source of NH_3 emissions is agriculture, with both animal husbandry and the use of fertilizers.

Being lighter than air, this gas usually rises and does not typically lead to immediate impact on health. At high concentrations however, or in moist areas, ammonia leads to throat and respiratory tract irritation.

d. Ozone

Ozone is known as the high altitude shield of the Earth, where it protects the atmosphere against the harmful ultraviolet radiation emitted by the sun. However, at lower altitudes ozone is a secondary pollutant resulting from a reaction between nitric oxides and organic volatile compounds (as hydrocarbons present in petrol). This photochemical process can only occur under the radiation of the sun, which explains the summer-seasonality of ozone pollution events.

Ozone (O_3) in high concentrations at the ground level can be a significant health hazard, resulting in premature mortality. Ozone can also reduce agricultural productivity significantly by hindering plant growth (GEO5, 2012). Unlike particulates, NO_x or SO_2, O_3 is not directly emitted by any source, but is produced in the atmosphere when emissions of volatile organic compounds and NO_x from different sources react in the presence of sunlight.

e. Sulphur dioxide

Sulphur dioxide (SO_2) is a corrosive gas produced by the consumption of fuel containing sulphur, such as coal and oil. It can also be discharged into the atmosphere through natural processes, such as organic decomposition or volcanic eruptions. Sulphur dioxide irritates the skin and mucous membranes (eyes, nose, throat and lungs), and can affect the respiratory system.

[19] Wang et al., 2016, "Persistent sulfate formation from London fog to Chinese haze", PNAS.
[20] WHO, "Health Aspect of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide", 2003 (cf 7)

Sulphur dioxide (SO_2) has health impacts as a gas and acts as a precursor to the formation of particulates and acid rain in the atmosphere. SO_2 emissions occur primarily from combustion of sulphur containing fuel (coal, diesel). In Bangladesh, diesel vehicles and brick kilns are the most important sources because of the presence of sulphur in commercially available diesel and coal.

f. Lead (Pb)

Lead was identified as a major health hazard in Bangladesh as early as the 1980s, when an average blood Pb concentration of 55±18 μgdL^{-1} was observed in a group of 100 adults in Dhaka[21]. In early 1990s, tests confirmed the presence of Pb in ambient air in Dhaka, and petrol additives were identified as a major source. At present, air quality standard in Bangladesh for Pb concentration in ambient air is 0.5 μgm^{-3}. Recent test results show that Pb concentration in ambient air in Dhaka comfortably achieves the standard (Begum and Biswas, 2008). In fact, these results show that the current ambient Pb concentration nearly meets the U.S. EPA standard (0.15 μgm-3), however, caution must be exercised in interpreting the numbers since these tests considered the Pb contained within the fine PM ($PM_{2.5}$) only. Comparison of these results with earlier ones shows that the total ambient Pb concentration can be approximately 57% more when Pb in coarse PM ($PM_{2.5-10}$)[22].

g. Carbon monoxide (CO)

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

h. Indoor pollutants

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

[21] Haque, H.A., Huda, N., Tanu, F.Z., Sultana, N., Hossain, M.S.A. and Rahman, M.H., 2017. Ambient air quality scenario in and around Dhaka city of Bangladesh. Barishal University Journal, Part-1, 4(1), pp.203-218.

[22] Haque, H.A., Huda, N., Tanu, F.Z., Sultana, N., Hossain, M.S.A. and Rahman, M.H., 2017. Ambient air quality scenario in and around Dhaka city of Bangladesh. Barishal University Journal, Part-1, 4(1), pp.203-218.

available on indoor air quality (Dasgupta et al., 2009; Khaliquzzaman et al., 2007). Dana (2002) found that concentration of SPM in a kitchen environment in Gazipur and Dhaka slum areas ranged from 4,040 to 39,192 mgm-3. Alauddin and Bhattacharjee (2002) found concentration of SPM in a poorly ventilated rural kitchen (5,032 mgm^{-3}) in Dhamrai, Manikganj to be much higher than that in a well-ventilated rural kitchen (3,670 mgm^{-3}). Under average conditions, Bangladeshi households using “dirty” fuels can experience 24- hour average PM_{10} concentrations as high as 800 mgm^{-3} (Dasgupta et al., 2006b), against an acceptable level of 150 mgm^{-3} (U.S. EPA, 2006).

2.2.2 Pollutant Specific Sources

Globally, the major sources of the individual air pollutants are briefly listed in Table 3. Considering the different structure of the economy and meteorology, not all of these sources are important for Bangladesh, and the major sources in Bangladesh are described in the next section.

Table 3: *Major sources of criteria air pollutants (Source: USEPA, with minor modifications).*

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

2.2.3 Dynamics and trends of air pollution

Air pollution is considered an emerging risk, and its dynamics depend on a broad range of factors. A WHO global comparative analysis of air pollution[23] concluded that ambient air pollution increased by 8% between 2008 and 2013. In the absence of more stringent policies, or disruptive technological changes, increasing economic activity and energy demand will lead to a significant increase in global emissions of air pollutants in the coming decades. This is because air pollution mirrors the underlying baseline assumptions of economic growth, but at a slower pace. The OECD has developed projections of emissions of pollutants over time based on environmental-economic models (ENV Linkage models) where some pollutants, in particular nitrous oxides, are expected to almost double by 2060. The figure below summarizes the projected

[23] http://www.who.int/mediacentre/news/releases/2016/air-pollution-rising/en/

trends in emissions of the most common pollutants, in particular black carbon (a component of fine particulate matter – PM2.5), carbon monoxide, nitric oxides (NO_x) and sulphur dioxide (SO_2).

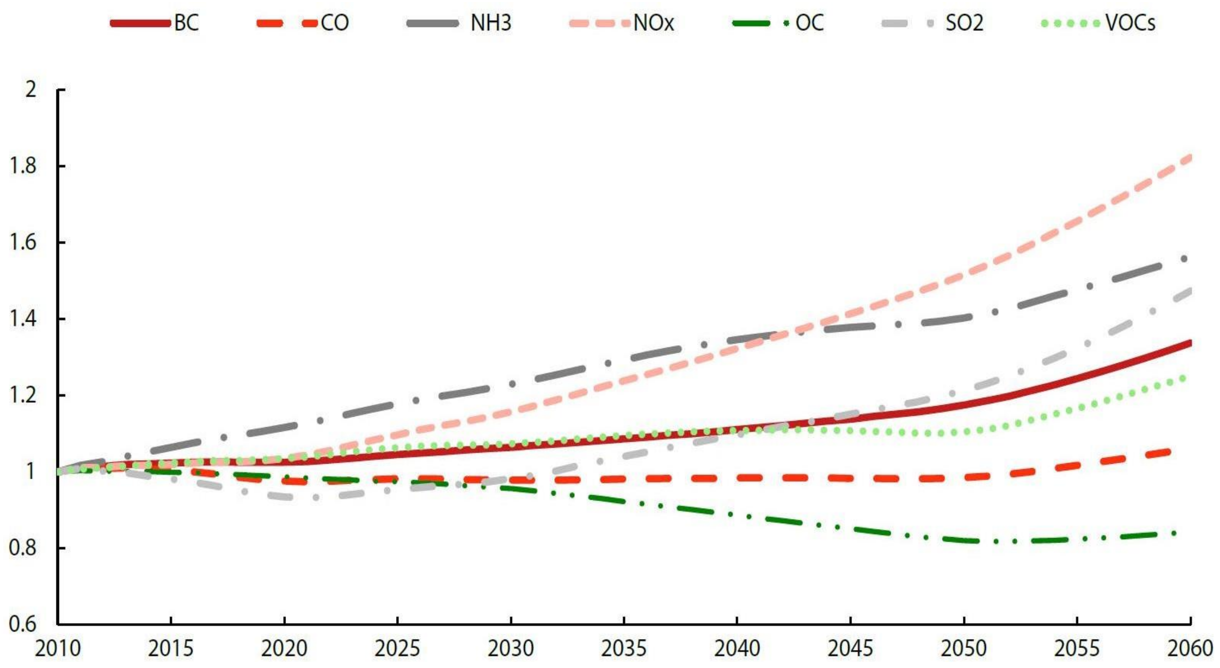


Figure 3. Emission projections over time indexed with respect to 2010[24].

Finally, there are geographical discrepancies in both levels and trends of air pollution, due to the uneven level of development and population concentration around the globe. The concentration of pollutants, and in particular of PM, was already above the levels recommended by the WHO Air quality guidelines in a number of regions, such as in South and East Asia. Several studies have demonstrated that air pollution negatively correlates with the level of income of countries, as Europe, the Americas and the Western Pacific Region face low levels of pollution, while urban air pollution averages in the Eastern Mediterranean and South East Asia can exceed WHO limits by up to 5-10 times[25].

[24] OECD, "The economic consequences of outdoor air pollution", 2016
[25] Beelen et al., "Long-Term Exposure to Traffic-Related Air Pollution and Lung Cancer Risk", Epidemiology: September 2008 - Volume 19 - Issue 5 - p 702-710.

SECTION III

3.1 TRANSBOUNDARY MOVEMENT OF AIRBORNE POLLUTANTS IN BANGLADESH

Transboundary pollution is the pollution that originates in one country but can cause damage in another country's environment, by crossing borders through pathways like water or air. Pollution can be transported across hundreds and even thousands of kilometers. Transboundary air pollution (generated in one country and influencing others) makes a major contribution to acidification and summer smog (caused by tropospheric ozone), and to eutrophication of soil and water and dispersion of hazardous substances. As most of the South-Asian, countries have highly polluted air, especially in China and India, which affects other neighboring countries and changes its ambient air quality unwantedly. In the case of Bangladesh, the effects of bordering countries like India, Nepal, Pakistan, and Myanmar contribute and add unwanted pollutants when wind passes through our country. These transboundary movements of pollutants are remained unnoticed in our country, not enough research also done on it.

3.1.1 South-Asian Countries Comparison on Air Quality Index (AQI)

In previous reports (HEI ISOC 2004; WHO 2006), air quality levels in Asian cities remain well above the maximum levels set by national and international standards and pose a great challenge to Asian megacities as their economies continue to grow at a record pace. Figure 10 shows summary 5-year average concentrations (from 2013–2017) of PM_{10}, SO_2, and NO_2 in 20 Asian cities. PM_{10} is the routinely monitored air pollutant of greatest concern in all these cities, with Beijing, Dhaka, Hanoi, Kathmandu, Kolkata, New Delhi, and Shanghai reports, annual averages > 5 times the WHO guidelines' limit on PM_{10} of 20 µg/m3. Although PM2.5 is not yet part of most regulatory ambient air quality monitoring network in Asia, several studies have conducted systematic monitoring of $PM_{2.5}$ and PM_{10} in Asian cities (Oanh et al. 2006; Hopke et al. 2008). These reports suggest that annual average $PM_{2.5}$ concentrations are generally above 25 $\mu g/m^3$ and as high as 150 $\mu g/m^3$, with $PM_{2.5}$:PM_{10} ratios ranging from roughly 0.4 to 0.7 in urban areas of rapidly developing countries in Asia.

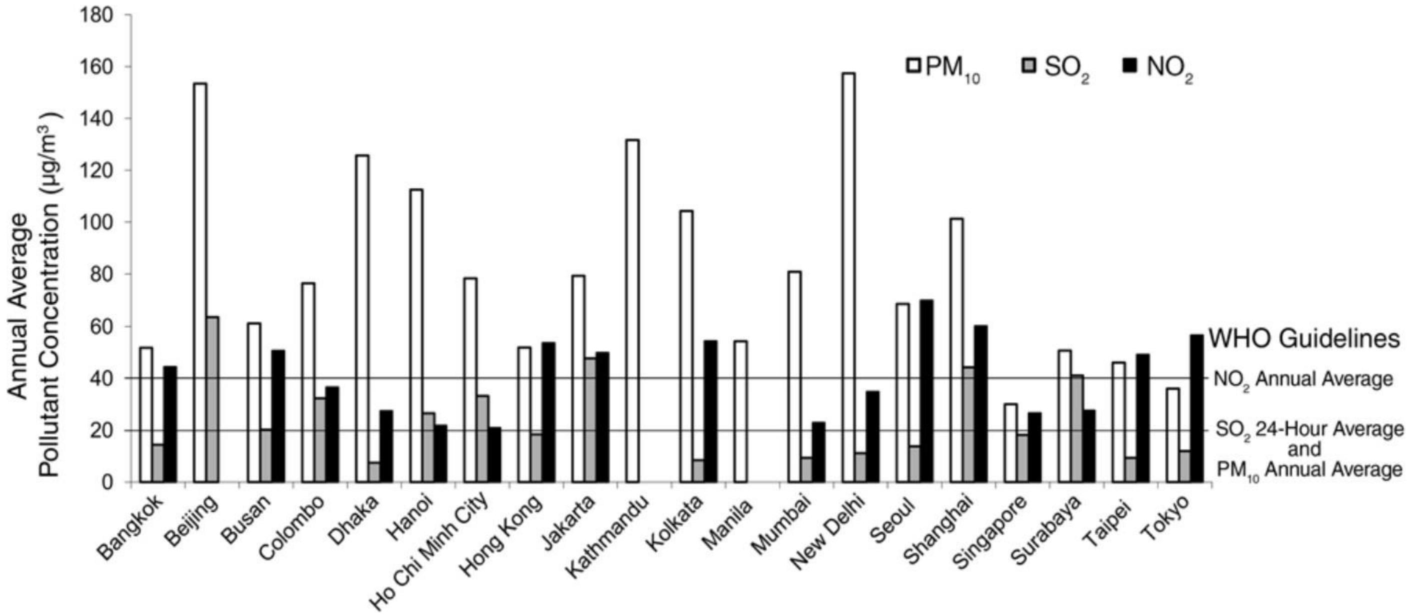


Figure 4 Five-year (2013–2017) average PM_{10}, SO_2, and NO_2 concentrations in selected Asian cities[26].

Based on these studies, long-term concentrations well above the WHO guidelines' $PM_{2.5}$ limit of 10 μg/m^3 would appear to be the norm in urban areas throughout much of Asia. Short-term concentrations and concentrations measured at high-impact locations (e.g., in traffic) indicate that concentrations of PM much higher than the estimated annual average are also present intermittently or in specific geographic areas.

Annual trends in air quality across major Asian cities suggest a significant downward trend in annual average SO_2 concentrations in urban areas in contrast to the increase in overall country-level emissions with the exception of an average increase in SO_2 concentration 2019. These SO_2 reductions occurred in spite of increasing fuel consumption. Regulations requiring the use of low-sulfur fuels and relocation of major coal-fired power plants and industrial facilities to outside of cities were responsible for these decreases. Overall, the trends in urban air quality measurements of SO_2 broadly follow the emission estimates described earlier in this section. However, the emission estimates suggest a substantial increase in SO_2 emissions at the country level in Asia that has been driven by increases in industrial emissions in China since 2002 — a trend confirmed by the Chinese State Environmental Protection Administration.

To better understand these trends and the air quality challenge Asian cities face in light of increasing populations, energy consumption, and vehicle numbers and vehicle-miles traveled. In Tokyo, Japanese emission controls have resulted in reduced oxidant-precursor concentrations over several decades, with subsequent reductions in oxidant concentrations, but in recent years oxidant concentrations have begun to increase while precursor concentrations continue to fall. This shift may be explained by continually increasing concentrations of oxidants (corresponding to increased emissions) in the region and increasing concentrations of transported oxidants from neighboring countries upwind.

[26] Standards from WHO air quality guideline, 2005 Global Update (WHO 2006): PM10 annual average, 20 μg/m3; SO2 24-hr average, 20 μg/m3; and NO2 annual average, 40 μg/m3. [Reprinted with permission from CAI-Asia (www.cleanairnet.org/caiasia; accessed January 2008).]

3.1.2 Meteorological and seasonal influences in ambient air quality parameters of Dhaka city

3.1.2.1 Monsoon as a factor

In Bangladesh, the climate is subtropical monsoon (summer monsoon), which is characterized by seasonal increases in rainfall, high temperatures, and humidity. Monsoon plays important role in differentiating one season from another in many ways, including with respect to air pollution exposures. Meteorologically, there are four seasons in Bangladesh: pre-monsoon (March–May), monsoon (June–September), post monsoon (October–November), and winter (December–February) (Salam et al. 2003). The winter in Bangladesh is defined as the dry season because of the dry soil conditions, low rainfall, and low relative humidity. During the winter season, there are weak northwesterly prevailing winds in Bangladesh. During the premonsoon season, the rainfall, relative humidity, and wind speed start increasing when the prevailing wind becomes southwesterly. The rainfall, relative humidity, and wind speed decrease in the post monsoon season, and the wind direction starts to shift back to northeasterly (Begum, Biswas, and Hopke 201). In Dhaka, the rain associated with the monsoon season is a major meteorological influence on the air pollution levels. Weather conditions are known to be one of the major driving forces of varying the concentration of air pollution (Jacob and Winnerb 2009). The emissions, dilution, transport, chemical transformation, and the deposition of atmospheric air pollutants are all influenced by meteorological variables, including temperature, humidity, precipitation, wind speed and direction, and mixing height (Kinney 2008). For example, rain-washes out water-soluble air pollutants and airborne particulate matter. Moreover, temperature also has an impact on forming and dissipating secondary air pollutants in the atmosphere, such as when higher temperatures expedite chemical reactions in the air. It is very well known that the temperature varies with locations and season. The concentration of PM also varies with region and season. Often, seasonal variations of PM_{10} and $PM_{2.5}$ have been observed to reach maximums during winter months, though the seasonal variations vary across the regions, depending on variation weather patterns. For example, the variation of PM_{10} concentration has been found to have a strong seasonal pattern (with peak in summer) in 100 U.S. cities (Peng et al. 2005), whereas the PM concentration has been found to be 1.5- to 5- fold increased during winter in Asian countries such as China, India, Bangladesh, and Nepal (Pant, Guttikunda, and Peltier 2016). These variations in seasonal patterns are likely largely due to differences in the extent to which particulate matter is formed by primary (largely winter) or secondary (largely summer) processes.

3.1.2.2 Average pollution concentrations, seasonal variation, and exceeds of National Ambient Air Quality Standards (NAAQS) in Dhaka Metropolitan area

A. Particulate matter ($PM_{2.5}$ and PM_{10})

Except during monsoon, the average concentrations of particulate matter ($PM_{2.5}$ and PM_{10}) in the three monitoring sites exceeded the relatively lax Bangladesh National Ambient Air Quality Standards

(BNAAQS) (150 µg/m^3 for PM_{10} and 65 µg/m^3 for $PM_{2.5}$) in all seasons. The highest numbers of exceedances of $PM_{2.5}$ NAAQS limit were found at the Darus-Salam neighborhood (72% of total observations), followed by Gazipur District (67% of total observations) and Narayanganj District (63% of total observations). The highest number of exceedances for $PM_{2.5}$ in Darus-Salam (Dhaka City) could result from local traffic emissions in all seasons in Dhaka City. The maximum exceedances of PM_{10} NAAQS limit were observed at Narayanganj (50% of total observations), followed by Darus-Salam District (40.3% of total observations) and Gazipur District (40.2% of total observations)[27]. In every day during winter season, particulate matter ($PM_{2.5}$ and PM_{10}) exceeded both the BNAAQS and NAAQS limits. The road dust, sand dust, and textile industrial dust could be accounted for highest exceedances for PM_{10} in Narayanganj. The results from the preceding analysis reveals that $PM_{2.5}$ is the most major concern among pollutants in Darus- Salam, whereas PM_{10} is the pollutant of concern in Narayanganj.

During winter, the lower mixing layer height, including thermal inversions, and the high emissions from brick kiln industries are thought to contribute to the increased PM concentrations. Winter in Bangladesh is considered a dry season with low relative humidity, low wind speed, low temperature, and scant rainfall. Thus, the resuspended road dust and soil dust also amplify the PM concentration during winter.

B. Sulfur dioxide (SO_2)

The major source of SO_2 in the atmosphere is the burning of fossil fuels, especially at local brick kilns, where coal burning is the main contributor to high SO_2 emissions (Randall et al. 2015). The diesel fuel used in mobile sources in Bangladesh contains about 3000 ppm sulfur (Begum et al. 2014). Thus, the other significant anthropogenic source is the burning of high-sulfur content diesel fuels in vehicles and power plants. SO_2 concentration was not as significant as PM. During the study period, most of the year SO_2 concentration was complaint with BNAAQS (140 ppb 24-hr average for SO_2).

[27] Md Mostafijur Rahman, Shakil Mahamud & George D. Thurston (2019) Recent spatial gradients and time trends in Dhaka, Bangladesh, air pollution and their human health implications, Journal of the Air & Waste Management Association, 69:4, 478-501.

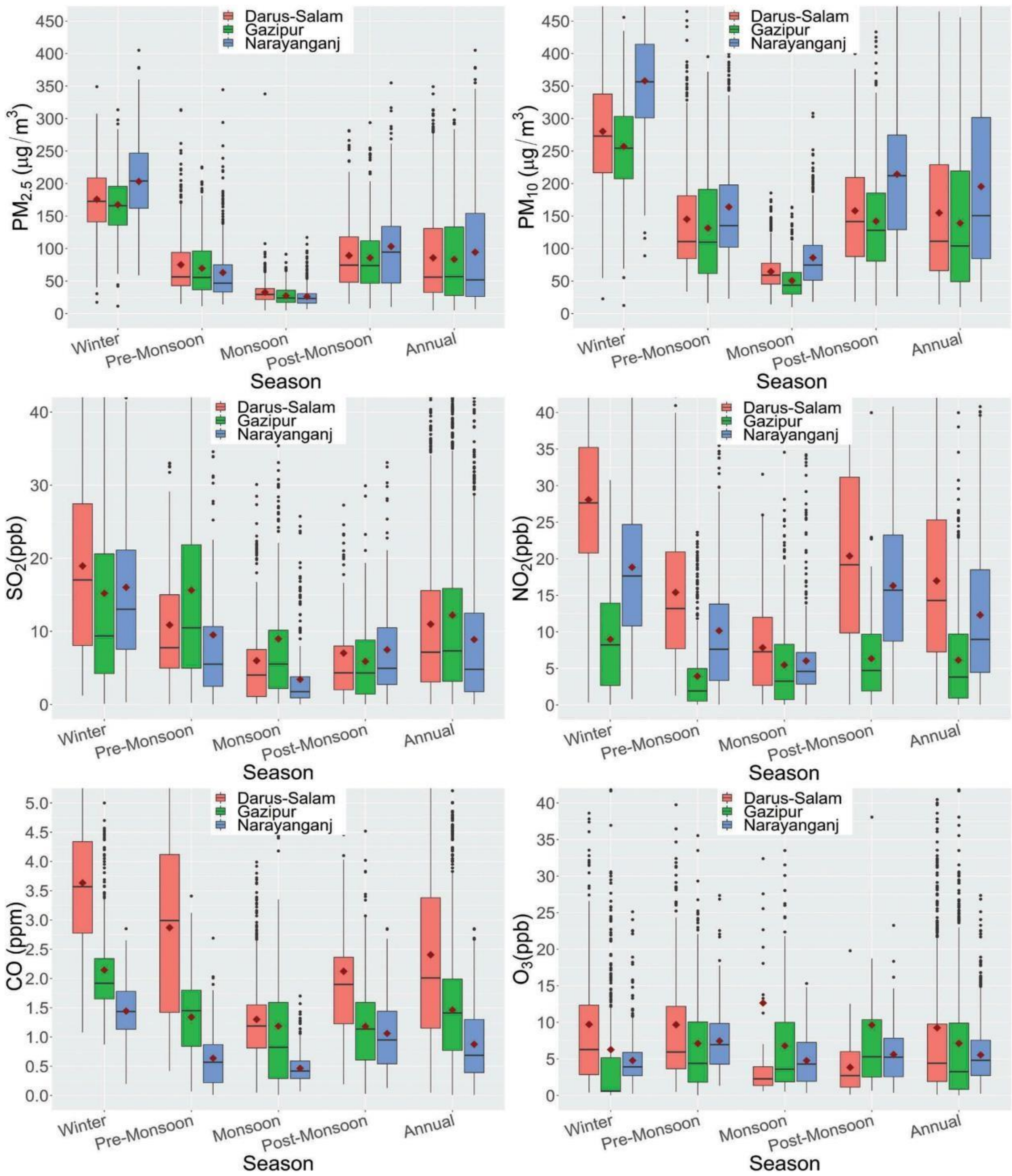


Figure 5: Average annual and seasonal concentrations of pollutants in three sites. ***(****The ends of each box are the first and third quartiles. The horizontal line inside the box denotes the median. The diamond red point denotes the mean.)*

However, like particulate matter, SO_2 concentration showed significant seasonal variation in all three sites, with the highest levels in winter. The brick kilns are one of the seasonal industries in Bangladesh, running their brick production only in the dry season, as rain interrupts the brick making, brick drying, and brick firing processes, so the brick making operation is carried out primarily during November to June, and not during monsoon season (Sajan et al. 2017). Thousands of textile industries also surround Dhaka City. As a result, there is a regular movement of heavy-diesel-fuel lorry trucks for the shipment of garment products

((ICA 2011), and most of the heavy vehicles use high-sulfur diesel fuel, which makes a significant contribution to SO_2 emissions in the Dhaka metro area.

C. Nitrogen dioxide (NO_2)

The major source of NO_2 pollution in urban cities such as Dhaka is often motor vehicle exhaust. Other sources may include coal and oil burning in power plants, metal refining industries, and other manufacturing and food processing industries (Department of the Environment and Heritage 2005)[28]. A high temperature is required for the reaction between nitrogen and oxygen to form NO, and this condition is found in the combustion of coal and oil at electric power plants, and during the combustion of fuel oils in automobiles.

During the study period, significant seasonal patterns were detected with highest concentration during wintertime and lowest concentration during monsoon time (28.1 ppb vs. 7.8 ppb). In the other two seasons, non-significant variation in NO_2 concentrations was observed (15.4 ppb during pre-monsoon vs. 20.3 ppb during post monsoon). The distinct difference in NO_2 concentrations between winter and monsoon season reveals that along with traffic, brick operation during the wintertime is also a major contributor to NO_2 pollution in Dhaka[29].

There is no 24-hr average BNAAQS level for NO2. As shown in Figure 11, the annual NO_2 concentrations in all three stations during 2013–2017 did not exceed the U.S. NAAQS level (24-hr average 100 ppb for NO_2), which provides a clear message that the NO_2 pollution in Dhaka is not as significant as particulate matter pollution.

D. Carbon monoxide (CO)

The greatest source of ambient CO emissions in Dhaka is the burning of fossil fuels, derived mainly from automobiles, trucks and other vehicles, and oil or coal fired plants (Randall et al. 2015). Significant seasonal variation in concentrations was detected between winter versus monsoon, with peaks in the winter season. CO was found insignificant during the study period. With only four exceeds at Darus-Salam sites, the 8-hr average CO concentration was almost compliant with the BNAAQS value (8-hr average 9 ppm for CO) at all three stations throughout the study time (Figure 11). Lack of emission control regulations, and allowing old and unfit vehicles on road, using solid fuels in household cooking, and using coal in brick kilns industries is responsible for increasing CO emissions in Dhaka City. In the case of older vehicles, poor engine conditioning inhibits proper combustion inside the engine cylinder, which emits a high concentration of CO.

E. Ozone (O_3)

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[28] http://www.environment.gov.au/protection/publications/factsheetnitrogen-dioxide-no2

[29] Md Mostafijur Rahman, Shakil Mahamud & George D. Thurston (2019) Recent spatial gradients and time trends in Dhaka, Bangladesh, air pollution and their human health implications, Journal of the Air & Waste Management Association, 69:4, 478-501.

Ozone is one of the secondary pollutants, and it is formed when NOx and volatile organic compounds (VOC) emitted by the vehicles, power plants, refineries, boilers, and other sources react chemically in presence of sunlight (Guo 2012). The annual mean ± SE ozone concentrations during the study period at Darus-Salam, Narayanganj, and Gazipur CAMS locations were generally very low (9.2 ± 0.34 ppb, 5.5 ± 0.09 ppb, and 7.1 ± 0.26 ppb, respectively). In Bangladesh, the national air quality standard for O_3 is 80 ppb (8-hr average). The highest number of exceedances of O_3 NAAQS limit was observed at the Darus-Salam site.

At Darus-Salam, 12 exceedances of the O3 BNAAQS limit and 22 exceedances of the O_3 NAAQS limit were found during this study period. The Narayanganj site was compliant with both BNAAQS and NAAQS limits. Three exceedances of O_3 BNAAQS limit and nine exceedances of O3 NAAQS limit were found at the Gazipur site. In recent study period, the O_3 pollution in the Dhaka metropolitan area was not therefore indicated to represent as much of a health threat as other pollutants[30].

Seasonal variation, day-of-week analysis, spatial gradients, and trends of $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, and O_3 were investigated for the Dhaka metropolitan area for the period of 2013 to 2017. The diurnal cycles investigation was limited to only 2017 due to lack of availability of hourly data from 2013–2016. Ozone in Dhaka showed seasonal patterns different from those of other pollutants, which all showed distinct seasonal variation with a maximum during winter and a minimum during monsoon. The pollution concentration of $PM_{2.5}$ and PM_{10} was increased about five- to six fold during winter versus monsoon, while SO_2, NO_2, and CO concentrations were roughly two- to threefold increased during winter versus monsoon. Particulate matter ($PM_{2.5}$ and PM_{10}) showed nonattainment of BNAAQS during the non-monsoon time of the year, whereas gaseous pollutants experienced a minimal number of BNAAQS exceedances throughout the study period, suggesting that gaseous pollutants in Dhaka are not as significant a health threat as PM. In the three Dhaka metropolitan area stations considered, fine particles dominated variations in the total PM mass during the winter season, while coarse particles dominated variations in the total PM mass during monsoons, likely due to reductions in the kiln emissions of fine $PM_{2.5}$ during the monsoon. Unlike many other major cities in the world, day-of week pollution patterns were not significant in Dhaka. The results of diurnal cycle analysis indicated that maximum pollution concentrations were observed at night, between 10 p.m. and 9 a.m., which is governed by long route bus and heavy-duty truck flow during that time, as well as the reduced dispersive capabilities of the atmosphere at night (due to generally lower wind speeds and mixing heights at night). Homogeneous spatial distributions of PM were found across the Dhaka metropolitan area, while other pollutants showed nonhomogeneous patterns. Spatiotemporal variability of pollution concentrations was apparently a result of spatial and time variations in the major local anthropogenic sources of pollutions (i.e., brick kilns, industries, traffic) and their operating times.

[30] Rahman, M.M., Mahamud, S. and Thurston, G.D., 2019. Recent spatial gradients and time trends in Dhaka, Bangladesh, air pollution and their human health implications. Journal of the Air & Waste Management Association, 69(4), pp.478-501.

3.1.3 Incursion of Transboundary Pollution into the Atmosphere of Dhaka

The city of Dhaka, Bangladesh, and its vicinity severely suffers high levels from high level of particulate matter (PM) concentrations in the atmosphere, especially during dry season (November–April). The region experiences several air pollution episodes in winter (November–January) when the atmosphere is polluted with $PM_{2.5}$ concentrations 10–14 times greater than the World Health Organization guideline value[31]. Most of this pollution originates from the local sources like brick manufacturing kilns, vehicles, and resuspended dusts. According to an estimation made through receptor modeling approach[32], an average contribution of 22% and 36% of fine particles in Dhaka during the year of 2007 to 2009 originated from the brick kilns and motor vehicles, respectively. Not only do the Gangetic Delta regions suffer from this severe pollution, but also many other countries in Asia, including India, Pakistan, Nepal, and China also report heavy pollution scenarios in this season[33]. Transboundary transport of PM is crucial in such a continental pollution scenario as fine particles (PM2.5: particulate matters with aerodynamic diameter less than 2.5 micrometers) having days to weeks of lifetime in the atmosphere can travel hundreds or thousands of kilometers and can pollute transboundary regions. PM outflow from the South Asian countries studied by revealed that the pollution from this region in winter season transports towards the northeastern direction[34] (to which Bangladesh is located). Biofuel and biomass burning in this region are the major source of carbonaceous aerosols that form a thick haze layer in the lower troposphere spreading out over millions of square kilometers. Scientists studied PM inflow into the Indo-Gangetic Plain from the western regions like Arabia, Thar Desert, and Afghanistan in dry season[35].

Recent studies identified hotspots of PM pollution in South Asia throughout the dry season and investigated probabilities of transboundary PM transport towards Dhaka city through different routes. For this purpose, 96-hour backward trajectories equated on Gazipur, Dhaka, throughout the dry season (November 2013 to April 2014) and their associations with respective hourly PM_{10} concentrations and $PM_{2.5}$ to PM_{10} ratio were exhaustively examined. Such long-term associations and their analyses against local source profiles are important to understand the features of transboundary pollution into a region.

Table 4: Trajectory paths and ranks in their association with high pollution at Gazipur station[36].

[31] M. M. Rana, N. Sulaiman, B. Sivertsen, M. F. Khan, and S. Nasreen, "Trends in atmospheric particulate matter in Dhaka, Bangladesh, and the vicinity," Environmental Science and Pollution Research, 2016.
[32] B. A. Begum, P. K. Hopke, and A. Markwitz, "Air pollution by fine particulate matter in Bangladesh," *Atmospheric Pollution Research*, vol. 4, no. 1, pp. 75–86, 2013.
[33] S. Dey, S. N. Tripathi, R. P. Singh, and B. N. Holben, "Seasonal variability of the aerosol parameters over Kanpur, an urban site in Indo-Gangetic basin," *Advances in Space Research*, vol. 36,no.5, pp. 778–782, 2005.
[34] M. G. Lawrence and J. Lelieveld, "Atmospheric pollutant outflow from southern Asia: a review," Atmospheric Chemistry and Physics, vol. 10, no. 22, pp. 11017–11096, 2010.
[35] H. Pawar, S. Garg, V. Kumar et al., "Quantifying the contribution of long-range transport to particulate matter (PM) mass loadings at a suburban site in the north-western Indo-Gangetic Plain (NW-IGP)," Atmospheric Chemistry and Physics, vol. 15, no. 16, pp. 9501–9520, 2015.
[36] Rana, M., Mahmud, M., Khan, M.H., Sivertsen, B. and Sulaiman, N., 2016. Investigating incursion of transboundary pollution into the atmosphere of Dhaka, Bangladesh. Advances in Meteorology, 2016.

Cluster	96-hour trajectory path and direction of entering the station	Pollution association (rank)		Contribution from long range sources
		PM_{10} conc.	$PM_{2.5}$ fraction	
C1	Most of them started from the middle of India and entered the station from the west.	Very high (1)	Moderate(5)	Low
C2	Most of them started from Iran and the Middle East, several from north-Europe, travelled with good height, over Nepal, and entered the station from the north.	Moderate (3)	Very high (1)	High
C3	East, some from India; some had long flight; some had shorter paths and entered the station from the north-west.	High (2)	Moderate (4)	Moderate
C4	Starting point somewhere in Afghanistan or Tajikistan; took a zigzag and entered the station from the north.	Low∗ (6)	Moderate (3)	Moderate
C5	Started from the east and entered the station from the east. Shorter length.	Low∗ (5)	High (2)	Moderate
C6	Marine air; started from the south and entered the station from the south.	Low∗ (4)	Low (6)	Low

* Compared to C1, C2, and C3, but the pollution level is still very high.

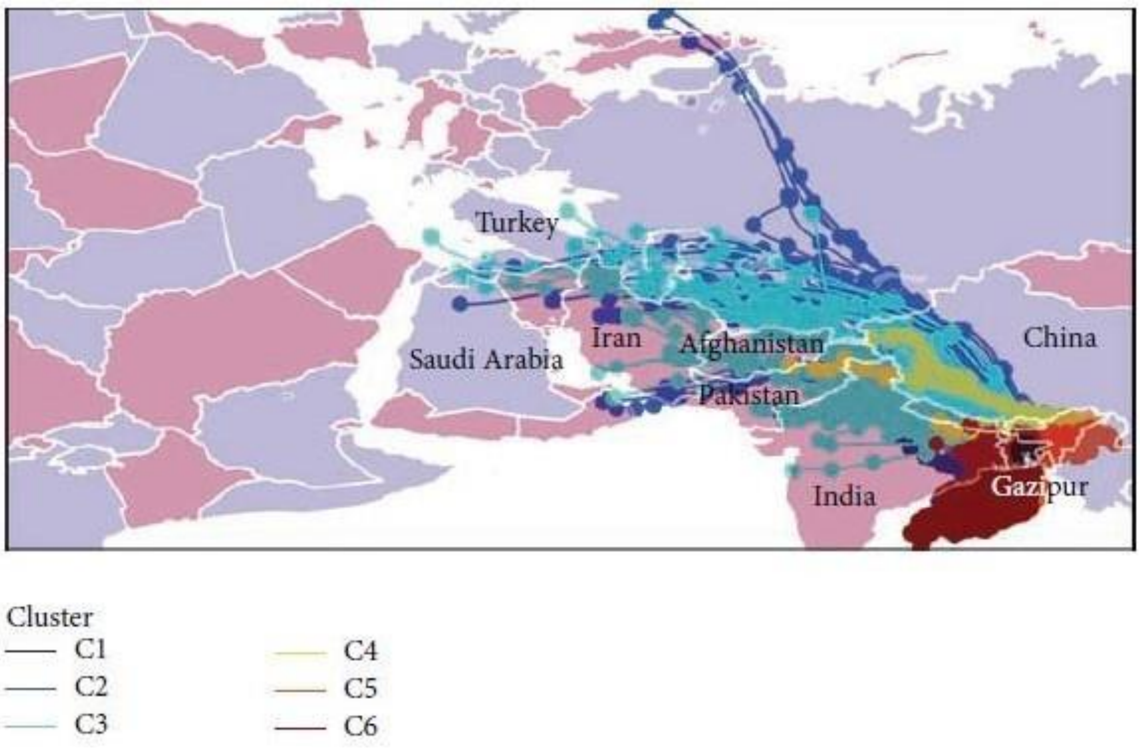


Figure 6: Trajectories centered on Gazipur station during the dry season dry from different routes of air pollutants travelings into Bangladesh.

Such differences, perhaps laid lied in their grouping patterns and entering directions. Most of the C2 trajectories had flown as a group over the Middle East and Himalayan valley and gained about the same pollution before entering the station (Figure 12). In contrast, C3 trajectories originated from various regions; some were long and some were short. Moreover, C3 trajectories encountered brick kilns on their way and gained coarse particles, as was the case for C1 trajectories. Overall, trajectory count under C5 cluster was very low, but its association with higher $PM_{2.5}$ to PM_{10} ratio in the long range PM or local sources from the eastern side. Long-range pollution from the south is denied as fine fraction of particles associated with C6 trajectories coming from that direction was poor.

December and January were the months when C2 trajectories dominated in contributing to PM2.5 concentrations at the station. On the other hand, C3 trajectories dominated in January and March (Figure 12). It is obvious that the station started getting southerly wind (i.e., air trajectories under C6 cluster) dominantly from the last week of March. Before that, the wind was mainly northerly, westerly, and northwesterly. C5 trajectories, which came mostly from the east, did not have any specific time zone in Figure 12. C1, C2, C3, and C4 trajectories were the prime air masses responsible for higher concentrations at the station during November to March. As found in Table 5, C2, C3, and C4 trajectories were associated with comparatively higher $PM_{2.5}$ to PM_{10} ratio at the station. Pollution roses and bivariate polar plots (Figure 12) express similar findings as were found from the analyses of trajectory-concentration association on the advent of pollution at the station. The directions of entrance of trajectories and the wind directions at the station should be the same. Northwesterly winds dominated in contributing to the PM pollution during winter (November–January), whereas mixed wind directions were observed in summer (February–April). Depending on the frequency of wind direction in dry season, the station was experiencing higher pollution from all the directions; however, higher contributions of fine particles were observed from the north-west, north, and the northeast directions. It is remarkable that the 50th percentile of $PM_{2.5}$ to PM_{10} ratio in winter (0.71) equals the 90th percentile of that in summer—meaning that PM pollution in winter was characterized by fine particles whereas that in summer was characterized by coarse particles. Thus, it may be assumed that long-range fine particulate matters from the directions of north and northwest might have joined with those from local sources during winter season.

SECTION IV

4.1 ESDO STUDY: QUALITATIVE AND QUANTITATIVE ASSESSMENT OF DHAKA CITY AIR QUALITY

Bangladesh 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 general people without any gender bias should be able to influence the policy making and be accountable for the results.

Keeping this in mind, ESDO researched on ambient air quality in and around Bangladesh and Dhaka. PM2.5 concentration has been measured monitoring device monitoring device from 1st February 2019 to 1st March 2020 which was further converted to Air Quality Index (AQI). As the threat of air pollution is very grave, ESDO further conducted a comprehensive study to assess the outdoor and indoor air pollution sources and conditions, both in urban and rural areas of the nation in two phases (in 2010-2013 and 2019-20). Respondents from major areas of Dhaka city and some other divisional towns were surveyed to derive information on urban air pollution sources. To gather information from rural context, mostly the population living along the sub-urban areas to the surveyed cities were considered. The findings have generated some important insights regarding the prevalent air pollution condition in Bangladesh.

4.1.1 Major Air Pollution Sources in Bangladesh:

<u>Outdoor Air Pollution Sources:</u>

- **Construction Activities:**

Construction activities has been identified as currently, the major source of outdoor air pollution in the urban areas of the country. Construction of roads and buildings generates massive amount of sand and dust particles that are released in the air adjacent to the construction site massively decreasing the air quality. Massive development activities including the construction of roads, bridges and modern transportation facilities like Metro Rail along the major cities (Particularly in Dhaka and Chittagong) of the country has greatly contributed to the deterioration of the air quality.

Figure 1: Dust from construction activities in Capital City Dhaka.

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

Roads are also responsible for emissions during its construction and maintenance phases through open processing of asphalts. In the next 5 years (2020-2025), some very large transportation projects such as elevated express highway, Metro Rail in Malibagh-Badda-Kurilbisho road area etc. will take place in Dhaka, which would be responsible for additional dust emissions and increase short-term acute exposure to air pollution.

- **Combustion of fossil fuels for Road Transport and Power Generation:**

Combustion of fossil fuels like coal and oil for electricity generation or in motor vehicles, produces air pollutants like nitrogen and sulfur dioxide. Vehicular emission had previously been the largest source of outdoor air pollution in Bangladesh. However, after the banning of use of two stroke engines for motor vehicles in Bangladesh, pollution from this particular source has declined to some extent.

Figure 2: Vehicular Emission in Dhaka.

Combustion of fuels in motor vehicles is, undoubtedly, one of the important sources of air pollution in the largest of the urban centers, i.e. in Dhaka and Chittagong. Fuel combustion not only produces fine particulates directly, which have severe health effects, but also emits NO_x and SO_x, which are important precursors to producing further particulates in the atmosphere[37]. NOx and HC emitted from vehicles can also undergo transformation in the atmosphere to produce ozone (as well as a range of other secondary pollutants), another pollutant with direct adverse health impacts. In addition, vehicles emit closer to the human population and thus have a direct effect on human health in urban areas.

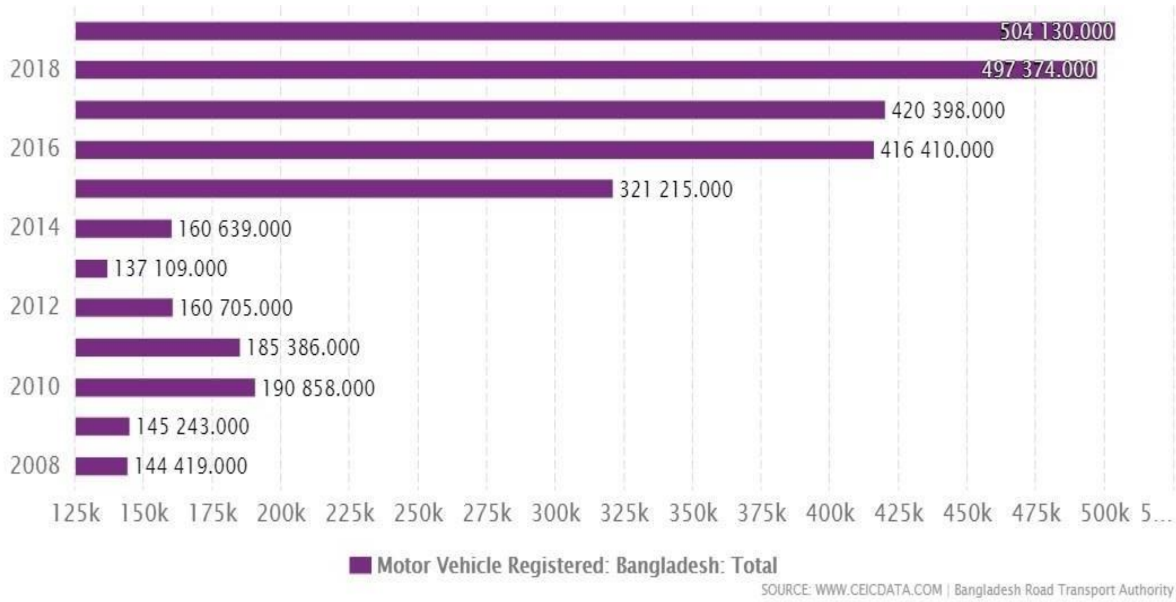


Figure 3: Vehicle growth in Bangladesh during 2008-2019.

It is clear that natural gas is the major primary source of electricity generation in Bangladesh with more than three-fourths of all electricity generated from natural gas. Most of its electricity is produced from natural gas, which is much cleaner than coal, both in terms of local air pollution and global air pollution (i.e. GHG emissions). However, a major air pollution concern in the power sector is the small, particularly because of the prevalence of natural gas power plants, but numerous small to medium diesel generators currently supplementing the infrequent grid electricity supply in the residential, industrial and commercial sectors. These small diesel generators currently do not have to meet any emissions standards and their total emissions may be significant (no reliable data available), and they also emit much closer to the people in comparison to large scale power plants, with potentially large health impacts.

[37] NO_x and SO_x react with NH_3, which is in abundant supply in Bangladesh because of its vast agriculture sector, to produce fine particles of NH_4NO_3 and NH_4SO_4.

Figure 4: Coal Based power plant in Patuakhali, Bangladesh[38].

Diesel generators can also be a large growth sector in the future, if reliable electricity supply cannot be ensured. While the power industry (apart from the diesel generators mentioned above) is not a major air- polluting source at present, there is a potential for it to become a large one in the near future.

- **Brick Kilns**

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

Bangladesh has only limited natural sources of stones and construction of infrastructure and buildings often depends on the supply of locally produced bricks. The construction sector has been growing at a rate of 8.1% to 8.9% a year during the last decade, with concomitant growth in demand for bricks. It is estimated that around 15 billion bricks are produced annually in Bangladesh from around 5,000 brick kilns, although some recent estimates put the number at 8,000.

Figure 5: Brick kilns in Bangladesh are a major source of air pollution and GHG emissions.

38 https://thefinancialexpress.com.bd/views/opting-for-cluster-development-of-power-plants-1524060546

Among the brick kilns, 75% are Fixed Chimney Kilns (FCK), while around 16% are still Bulls Trench Kilns (BTK), which are highly polluting. The rest (only 9%) is Zigzag and Hoffman Kilns (ZK and HK), which are better in their emissions performance. Almost all the brick kilns use coal as the primary fuel, although unofficial estimates mention that around 25% of the fuel used in 2007 were still wood.

- **Industrial Processes:**

Manufacturing industries and factories release large amount of carbon monoxide, hydrocarbon, chemicals and organic compounds into the air causing severe forms of outdoor air pollution. Pollutants released from industrial facilities are often toxic and are responsible for creating severe respiratory diseases. Contribution from industrial sources are not negligible. The major polluting industries in this regard include the cement, steel, parboiling rice mills, and glass plants. All these are directly linked to building and infrastructure construction (as is a brick), which is a natural consequence of the state of growth in Bangladesh. Since such growth is expected in the future, it is important to control emissions from these sources in order to keep the air quality at a reasonable level. There are currently gaseous emissions standards governing emissions from these industries, but enforcement is so lax that only a few people are aware of their existence.


Figure 6: Industrial emission in and around Dhaka.

ESDO's current study has focused upon one of the major industrial sectors that serves as prominent outdoors air pollution sources in Bangladesh – ceramic factories. Ceramic manufacturing processes result in the emission of gaseous effluents containing various quantities of pollutants into the atmosphere, mainly dust particles, lead and fluorine, in addition to other substances (oxides of sulphur, nitrogen, and carbon; boron, zinc, calcium compounds etc.) in minor or negligible quantities. Emissions of glaze constituents other than lead (such as boron, zinc, calcium compounds, etc.) are a minor environmental problem, as both the quantity (these compounds represent only a small percentage of the glaze) and the toxicity are lower compared to lead.

- **Agricultural Processes and Biomass burning:**

Agricultural processes also generate significant amount of air pollutants arising from the use of pesticides, insecticides, and fertilizers that emit harmful chemicals. Other than that, biomass burning in agricultural sector accounts for the generation of a large amount air pollutants. Outdoor biomass burning generally takes place during the winter after a crop harvest. This adds to the winter fogs to create dense smog in rural areas of Bangladesh. While immediate health impact may not be of serious concern, smog can be a driving hazard and has been blamed for a quite a few road accidents and fatalities in the highways of Bangladesh. It is also a common practice to burn refuse, which can be potentially harmful, especially if there are other harmful elements in the refuse (e.g. PVC, heavy metal, batteries etc.). Burning of accumulated dry leaves is also fairly common in cities and rural areas during the winter (as a means of disposal of these "solidwastes").

Figure 7: Biomass burning in agricultural fields

- **Open Landfill Incineration of Plastic Wastes**

Incineration of plastic waste in an open field is a major source of outdoor air pollution in Bangladesh. Most of the times, the Municipal Solid Waste containing about 12% of plastics is burnt, releasing toxic gases like Dioxins, Furans, Mercury and Polychlorinated Biphenyls into the atmosphere. Further, burning of Poly Vinyl Chloride liberates hazardous halogens and pollutes air, the impact of which is climate change. In Dhaka city, current disposal methods of waste into landfills implies an irreversible loss of valuable raw materials and energy. The incomplete combustion of Polyethylene (PE), Polypropylene (PP) and Polystyrene (PS) during thermal utilization can cause high concentrations of carbon monoxide (CO) and noxious emissions, while PVC generates dioxins, carbon black and aromatics like pyrene and chrysene in the surrounding air of dumping area. Hazardous emissions can include bromide and color pigments that contain heavy metals like chromium, copper, cobalt, selenium, lead and cadmium which remains in the ambient air and travels with the wind for a long distance. Open burning of municipal solid wastes and landfill fires to emit 10,000 grams of dioxins/furans into lower atmosphere every year[39]. Despite waste management efforts to manage wastes, more than 91% of municipal solid wastes collected is still landfilled or dumped on open lands. Besides methane is also generated in landfills.

[39] Verma, R., Vinoda, K.S., Papireddy, M. and Gowda, A.N.S., 2016. Toxic pollutants from plastic waste-a review. Procedia Environmental Sciences, 35, pp.701-708.

Figure 8: Smoke emission from waste incineration around Dhaka City (Matuail Landfill and Puran Dhaka area). (Photos taken during ESDO study survey)

According to the studies, the by-products of plastic combustion in Dhaka city are airborne particulate emission (soot) and solid residue ash (black carbonaceous colour). Several studies have demonstrated that soot and solid residue ash possess a high potential of causing health and environmental concerns, especially Volatile organic compounds (VOCs), semi- VOCs, smoke (particulate matter), particulate bound heavy metals, polycyclic aromatic hydrocarbons (PAH's), polychlorinated dibenzofurans (PCDF's) and dioxins[40]. This can travel thousands of kilometers, depending on prevailing atmospheric conditions and enter our food chain. A significant amount of pollutants of environmental and health concern, including Nitro-carcinogens such as PAH's, nitro-PAH's and dioxins have been identified in the airborne particulate emission.

Indoor Air Pollution Sources:

- **Smoke emitted from cooking stove/burning of biomass:**

Cooking of any kind produces some pollutants that are potentially harmful. Smoke emitted from stove while cooking due to burning of natural gas or other fuel causes pollution of the surrounding air. Applying heat to food produces particles — tiny particles (PM10, or particulate matter 10 micrometers in diameter), tinier particles (PM2.5, or 2.5 micrometers in diameter), and even tinier "ultrafine" particles (100 nanometers in

[40] Valavanidid, A., Iliopoulos, N, Gotsis, G. and Fiotakis, K. 2008. "Persistent free radicals, heavy metals and PAHs generated in particulate soot emissions and residual ash from controlled combustion of common type of plastics". Journal of Hazardous Materials, 156 : 277-284.

diameter) — that can exacerbate respiratory problems. It also produces nitrogen oxides (NOx), including nitrogen oxide (NO) and nitrogen dioxide (NO2), carbon monoxide (CO), and formaldehyde (CH2O or HCHO). All of these pollutants create health risks if not properly managed. All cooking should be done in a properly ventilated space. Exposure to this particular source is quite common both in urban and rural areas of Bangladesh.

Figure 9: Smoke Emitted from kitchen stoves due to biomass burning.

The World Health Organization (WHO) estimates that 2.4 billion people worldwide rely on burning biomass fuels (e.g., fuelwood, animal dung, crop residues) for cooking and heating their homes. Biomass is extensively used in rural areas of Bangladesh, primarily for cooking. Biomass contribute to more than half of the total primary energy needs in Bangladesh. Biomass burning, especially in traditional cooking stoves, results in significant air pollution, which is harmful, especially to the women and young children who often spend most of their time in the kitchen premises with a high level of particulates concentration. In rural Bangladesh, majority of people rely on solid biomass fuel; and firewood, crop residue dung, and tree leaves accounts for about 97% of total household energy use (Asaduzzaman et al., 2007).

- **Smoke emitted from cigarette smoking**

Tobacco smoke produces fine particulate matter, which is the most dangerous element of indoor air pollution. These fine particles are a risk factor for chronic lung disease, which can be debilitating and sometimes fatal. They can lead to conditions such as asthma, bronchitis, and emphysema, and are a risk for lung cancer, write the researchers.

- **Gaseous substances emitted from toilet/sewerage arrangements**

Sewer gas is a byproduct of the breakdown of natural human waste. It comprises a mixture of gases, including hydrogen sulfide, ammonia, and more. Chronic exposure, or higher levels of exposure, can cause symptoms of sewer gas poisoning. Exposure to low levels of hydrogen sulphate can irritate the eyes, cause a cough or sore throat, shortness of breath, and fluid accumulation in the lungs. Prolonged low-level exposure may cause fatigue, pneumonia, and loss of appetite, headaches, irritability, poor memory, and dizziness. High concentrations of hydrogen sulfide (>150 ppm) can produce olfactory fatigue, whereby the scent becomes undetectable. At higher concentrations (>300 ppm), hydrogen sulfide can cause loss of consciousness and death.

4.1.2 Air Pollution Condition in Bangladesh and Dhaka: Survey Findings

4.1.2.1 Outdoor Air pollution Condition in and Around Dhaka

ESDO extensively studied outdoor air pollution condition in and around Dhaka surveying over 200 respondents from major areas of Dhaka city and Gazipur. In the survey questionnaire, there were about 25 questions regarding outdoor air pollution in the context of the respondents' types of work, types of waste generation, waste dumping procedure and types of industries existent in that area.

Locally identified major pollution sources: As for the question of the local air pollution source, about 33% of the respondents identified industrial activities to be the major source while about 28% identified dust particles generated from construction works to be the major outdoor pollution source. About 17% also blamed biomass burning and 22% vehicular emission.

Pollution from waste generation and dumping: The respondents were also asked about waste generation and dumping mechanism as waste management may create profound impact upon air pollution condition. As for the question of types of waste generated, about 41% replied of generating household waste on regular basis and 36% reportedly generated industrial wastes. About 27% of the respondents reported of putting their wastes into municipal dustbins, 23% adopted incineration, 19% went for land filling and rest of the 31% reportedly throws their waste in undefined places without following any proper waste dumping procedure-reflecting gaps in mass awareness level.

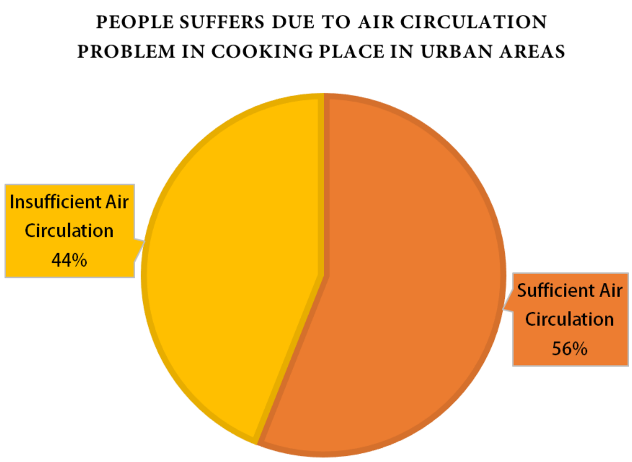
Findings from ceramic factory visit: To derive insights on industrial source of air pollution in the sub- urban areas, four ceramic factories were visited and the population located in nearby areas were surveyed. According to the perception of the surveyed population, construction activities and ceramic industries are one of the major source of outdoor air pollution in their areas. Especially in Gazipur area, the pollution due to series of industries the air pollution is always high. Although the vapor coming out of the long and short chimneys from the ceramic industries not considered high rated pollutants high rated pollutant, these vapors are constantly increasing the ambient temperature. On the other hand, unwanted water vapor is also considered as a greenhouse gas, which contributes to the climate change. Indoor air pollution is also highly visible inside the industries, as clay materials and other vaporized elements like paints are causing serious pollution. The workers inside are working directly under this condition for years and slowly they are eating poisons through breathing.

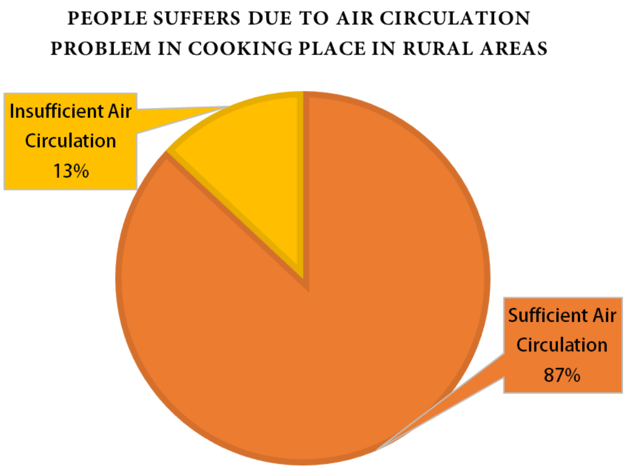
The perception of common people out there suggests that road cleaning and management with improvement in indoor ventilation is the most important measure to control the ambient air pollution.

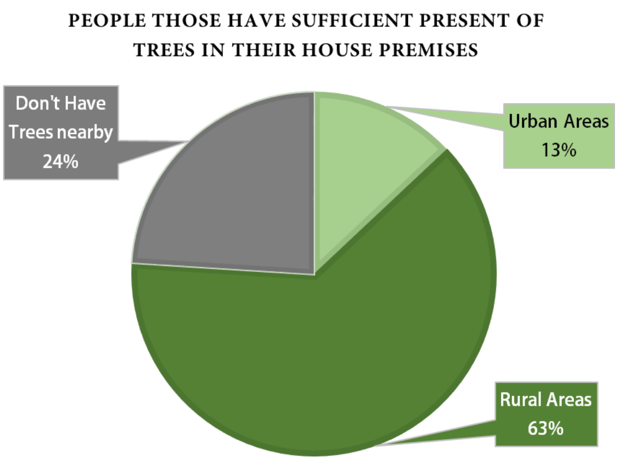
4.1.2.2 Indoor Air Pollution Condition in Bangladesh

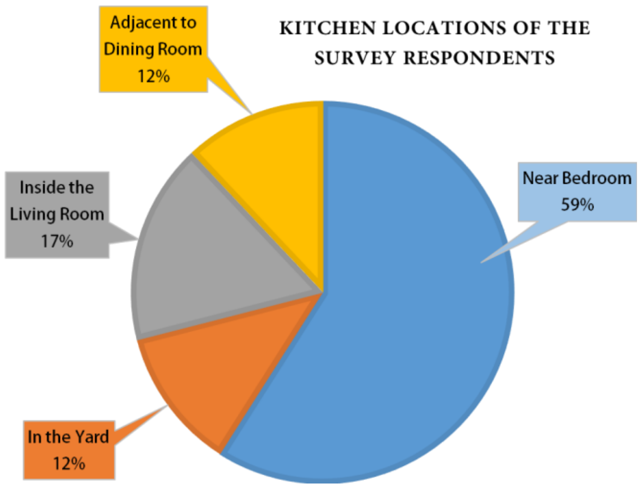
Indoor air pollution survey conducted under the provision of this study assessed average air circulation condition in the households in both urban and rural areas of Bangladesh. There were about 31 questions regarding indoor air pollution in the context of the respondents' households, kitchens, toilets, and pollution caused due to smoking. The respondents were surveyed with regard the predominant sources of indoor air pollution:

Air circulation and ventilation: As per the perceived response, nearly half (44%) of the surveyed households in urban areas reportedly suffers from insufficient air circulation, whereas this percentage is very low for the household placed in rural settlements (13%). In case of possession of heat resistant mechanism within the houses, 49% of the urban households reportedly do not have access to any. Similar is the case in rural areas in this aspect. Nearly 41% of the population do not have any heat resistant mechanism in their households. While asking about the presence of trees nearby, about 13% of the respondents in urban areas said that they have sufficient trees at their home premises, while around 77% do not have any. In rural areas, this percentage has much higher at around 63 % of the surveyed respondent's sufficient trees at their home premises.



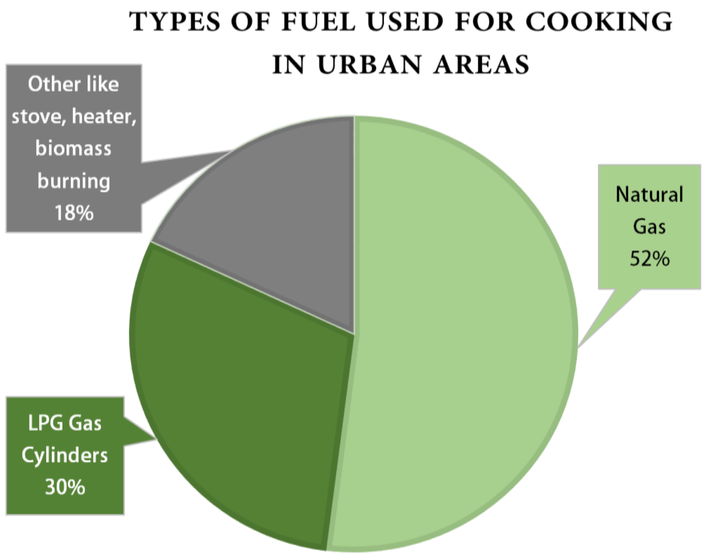


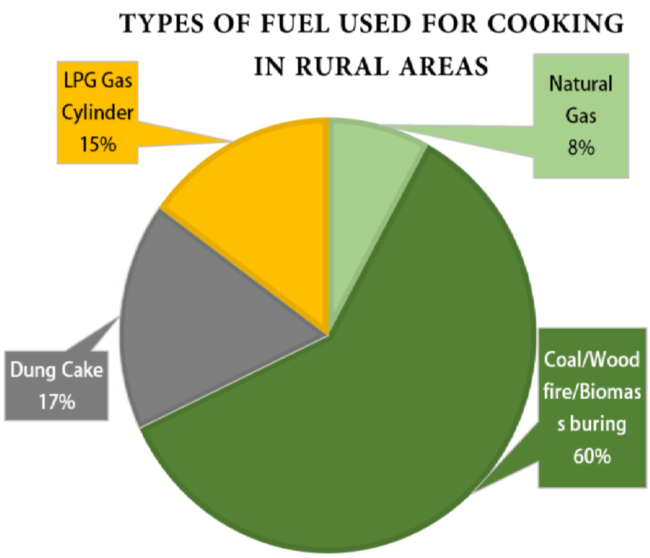




Proximity of kitchen to living areas greatly influences the movement of air pollutants emerged from the burning of fuels in the kitchen. As per our survey findings, 59% of the respondents have kitchens near their bedrooms, only a few percentage (12%) have the kitchen in their yard, another 17% have it inside the living room and the rest of the 12% have it adjacent to the dining room. In the urban context, household sizes are small and as a result, the rooms are located very close to each other gain increasing risk creasing risk of inhaling air pollutants coming out of the kitchen. The size of the kitchen is also an influencing factor for the circulation of indoor air pollutants. In urban areas only about 17% of the respondents said that they have enough passage in their kitchen to pass out the smoke that cooking generates while around 39% have insufficient passage and the rest 44% do not have any passage at all resulting in the accumulation or concentration of the emitted gas within the house.

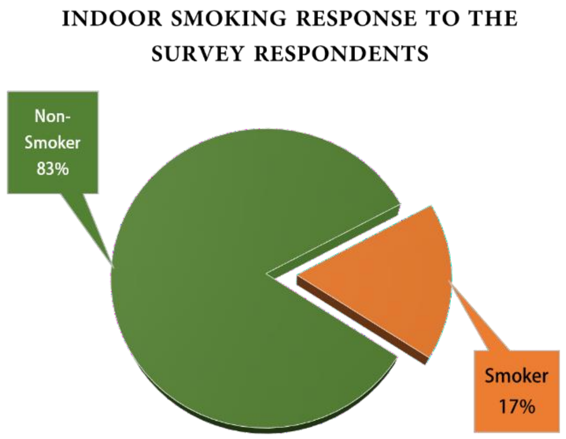
Indoor Fuel Combustion for cooking:

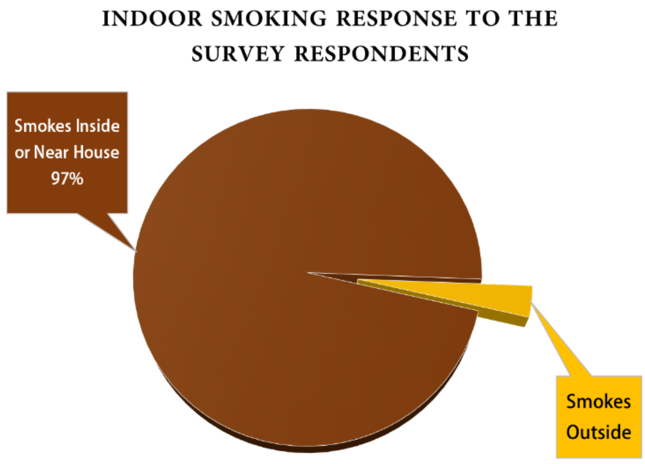




Fuel used in stoves also influences the type and severity of indoor pollutants created during cooking. As stove fuel, majority of the urban respondents use natural gas (42%) or LPG gas (27%) contained in cylinders. In rural areas, the use of gas as fuel in very low (nearly 8%) and 66% of the respondents use coal/firewood and another 17% use dung cake. In assessing the general awareness level of the population, few questions were asked in this regard to the respondents. About 27% respondents said that they were aware of the fact that the smoke produced during cooking is harmful to children, while 73% were not even aware of it. On a positive note, 75% were aware of the fact that it may cause respiratory problems such as difficulty in breathing, whooping cough, etc. Again, about 50% of the respondents use their cooker for 2 to 4 hours daily, 45% use for a further extended period of 4 to 8 hours, and 5% use more than 8 hours. Cooking hour also influences the emission concentration over time.

Indoor Smoking: The second phase of the questionnaire was about another major source of indoor air pollution, which is smoking. About 17% of the respondents were themselves smokers and 83% were nonsmokers. About 97% of the smoker's reportedly smokes inside their houses, which is very injurious to health of the people living inside the household, especially the children. About 64% of the respondents have smokers in their families depicting that, a great number of populations are exposed to this particular source of pollution. In assessing the awareness level, the respondents were inquiring about the knowledge of hazardous impacts of passive smoking. About 83% smokers replied that they knew about it, while 17% said they were not aware. On the bright side, 90% of the respondents said that smoking should be prohibited inside houses, while 10% were against that. As for the question of issuing a law to prevent smoking, 92% responded positively while 8% were completely against it.





Pollution by gaseous emissions from toilet/sewerage: The final phase of the questionnaire was designed to assess indoor air pollution from harmful gaseous substances emitted from toilets or latrines, and other sewerage mediums inside the house. About 55% respondents have water-seal latrines, while 29% have twin-pit, 8% have semi-open, and 8% have completely open latrine facilities. More than half (57%) of the surveyed population said that, filthy smell spreads from their toilets indicating towards the presence of unhygienic harmful gases within the house premises. As for the question of proper ventilation in their toilets, 38% said that there persists insufficient ventilation, which may cause the trapping of airborne pollutants for an extended time period.

The respondents identified some other factors such as faulty drainage & sewerage systems, inappropriate waste dumping, use of mosquito coils, and emission from nearby tannery industries as also being responsible for polluting the air, especially indoor air. About 87% did not know about the CFC gas that derives from air-conditioners and refrigerators, while 13% aware of that. Again 81% did not know about CFC spread from perfume, body spray, and hair spray containers, while 19% already knew that. About 87% knew that mosquito coils are harmful and cause indoor air pollution, and 13% did not know. The people of Bangladesh have the perception that the LPG penetration in the residential sector for cooking purpose is having less impact on improving the ambient air quality.

4.1.3 Local Air Quality Monitoring Data: AQI Measurement of Dhaka City

4.1.3.1 Seasonal Variation of Air Quality in Dhaka

In Dhaka, the rain associated with the monsoon season is a major meteorological influence on the air pollution levels. Weather conditions are known to be one of the major driving forces of varying the concentration of air pollution (Jacob and Winnerb 2009). The emissions, dilution, transport, chemical transformation, and the deposition of atmospheric air pollutants are all influenced by meteorological variables, including temperature, humidity, precipitation, wind speed and direction, and mixing height. For example, rain-washes out water-soluble air pollutants and airborne particulate matter. Moreover, temperature also has an impact on forming and dissipating secondary air pollutants in the atmosphere, such as when higher temperatures expedite chemical reactions in the air. These variations in seasonal patterns are likely largely due to differences in the extent to which particulate matter is formed by primary (largely winter) or secondary (largely summer) processes.

As in Bangladesh, the climate is characterized by high temperatures, high humidity most of the year, and distinctly marked seasonal variations in precipitation. According to meteorological conditions, the year can be divided into four seasons: pre-monsoon (February–May), monsoon (June–September), post-monsoon (October–November), and winter (December–February). Winter season is characterized by dry soil conditions, low relative humidity, scanty rainfall, and low northwesterly prevailing winds. The rainfall and wind speed become moderately strong and relative humidity increases in the pre-monsoon season when prevailing southwesterly (marine). During monsoon season, the wind speeds further increases and the air mass is purely marine in nature. In the post-monsoon season, the rainfall and relative humidity decrease, so as the wind speed. The direction starts shifting back northeasterly.

Table 1: Seasonal Air Quality Index (AQI) Data recorded in ESDO Head Office.

Months	Monthly Average AQI Data	Season Wise Category
Feb 19	236.1	Pre-Monsoon
Mar 19	193.0	
Apr 19	146.1	
May 19	135.4	
Jun 19	89.7	Monsoon
Jul 19	90.3	
Aug 19	78.8	
Sep 19	98.9	
Oct 19	135.7	Post-Monsoon
Nov 19	161.7	
Dec 19	204.8	
Jan 20	235.1	Winter
Feb 20	220.5	
Mar 20	175.2	

From Table 1, it can be easy understandable that, during pre-monsoon season and winter season the air pollution escalates at the highest peak. Most of the months remain above unhealthy condition (AQI > 151). The air pollutants mainly $PM_{2.5}$ start to increase during winter due to high dryness and continues to remain high throughout the pre-monsoon season as well. Another important factor identified is that, during pre-monsoon and winter season most of the construction works run in a full fledge in Dhaka city. Large-scale development and construction activities like fly over; metro rail and real estate works produce most of the fine particulate matter in their processing. In monsoon and post-monsoon time, the air quality gets better due to heavy rain. Most of the air particles drop out with the rainwater. However, it is also one of the major reasons behind acid rain and other pollution in the water bodies.

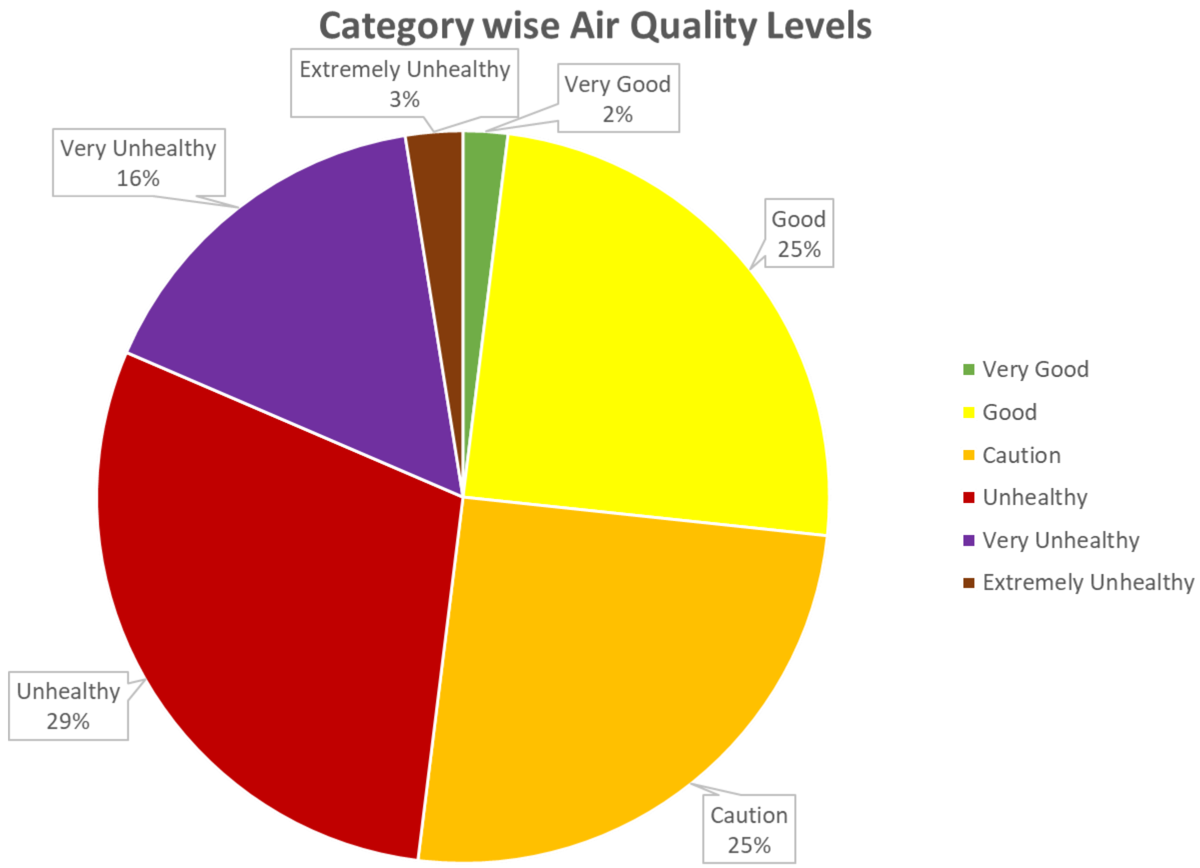


Figure 10: Category wise Air Quality levels of one year in Dhaka (Feb '19 to Jan '20).

Year-round observation suggests that, 2% of days, (9 days out of 356 days) were very good and 25% (57 days) were good in terms of ambient air quality in the Dhaka city from Feb 2019- Jan 2020. Approximately 171 days (48%) were found to show AQI value greater than 151, which indicates that those days were apparently unhealthy for the inhabitants of Dhaka City. Nearly 16% of the days were severely unhealthy and the rest of the 3% or hazardous beyond limit. As in Dhaka, there are significant emissions from automobiles and other anthropogenic activities like construction related to the extremely high population density and biomass/coal burning for cooking, brick kilns around the city, which contribute significantly to air pollution.

4.1.4 Transboundary Movement of Air pollutants In between Cross border Cities: Dhaka, Kolkata Delhi and Kathmandu

The city of Dhaka, Bangladesh, and its vicinity severely suffers from high levels of particulate matter (PM) concentrations in the atmosphere, especially during dry season (November–April). The region experiences several air pollution episodes in winter (November–January) when the atmosphere is polluted with $PM_{2.5}$ concentrations 10–14 times greater than the World Health Organization guideline value[41]. Not only does Bangladesh suffer from this severe pollution, but also many Asia, including’s in Asia including India, Pakistan, Nepal, and China also report heavy pollution scenarios in these seasons. Transboundary transport of PM is crucial in such a continental pollution scenario as fine particles having days to weeks of lifetime in the atmosphere can travel hundreds or thousands of kilometers and can pollute transboundary regions. PM outflow from the South Asian countries studied by revealed that the pollution from this region in winter season transports towards the northeastern direction to which Bangladesh is located.

To inspect the dynamics of transboundary movement of air pollutants between neighboring countries, ESDO conducted a comparative review of the air quality index value of the four big cities from bordering nations Bangladesh, India and Nepal. The cities were chosen because these cities remain polluted for years, holding high AQI data from 2017 and the winds enter into the capital city Dhaka travel from these cities. Therefore, the possibility of caring pollutants from these cities to Dhaka cannot be overseen. To recognize the issue such as the transboundary movement of pollutants inside Bangladesh, the connection needed to be built with neighboring cities. The recorded AQI index value of Dhaka, Kolkata, Delhi and Kathmandu from 2018- 2019 are shown in the table below. It showed that in Dhaka city the unhealthy days decreased from 157 to 144 days. In contrast, in New Delhi of India, unhealthy days reduced in 2019 but extremely unhealthy days increased (18 days in 2018 and 25 days in 2019). In Kolkata, air quality improved in the recent past, but still have high rates of unhealthy days than Kathmandu. (ANNEX-B for AQI Standards)

According to ESDO’s research, PM pollution in South Asia throughout the dry season is probably transported towards Dhaka city through different routes. Major routes of wind that carry PM pollutants towards Dhaka are the middle of India and entered the Dhaka city from the west, air from Iran and the Middle East, several from north-Europe, traveled with good height, over Nepal, and enter from the north, some of the wind from India with a long flight and shorter paths and enter from the north-west. Northern Indian regions, Nepal and its neighboring Indian regions, and the areas of the Indian state of West Bengal adjacent to the western border of Bangladesh are also highly responsible for contributing to PM pollution in Dhaka city[42].

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[41] M. M. Rana, N. Sulaiman, B. Sivertsen, M. F. Khan, and S. Nasreen, “Trends in atmospheric particulate matter in Dhaka, Bangladesh, and the vicinity,” Environmental Science and Pollution Research, 2016.

[42] B. A. Begum, P. K. Hopke, and A. Markwitz, “Air pollution by fine particulate matter in Bangladesh,” Atmospheric Pollution Research, vol. 4, no. 1, pp. 75–86, 2013.

Air Quality Index in 4 cities: Dhaka, Kolkata, New Delhi & Kathmandu (2018-19)

DHAKA AIR QUALITY INDEX 2018-19			
AQI	**CATEGORY**	**2018**	**2019**
0-50	Very Good	1	7
51-100	Good	54	90
101-150	Caution	77	91
151-200	Unhealthy	71	91
201-300	Very Unhealthy	78	47
301+	Extremely Unhealthy	8	8
>151	Number of Days above unhealthy	157	144

Source: **DHAKA US CONSULATE**

DELHI AIR QUALITY INDEX 2018-19			
AQI	**CATEGORY**	**2018**	**2019**
0-50	Very Good	7	5
51-100	Good	47	54
101-150	Caution	110	97
151-200	Unhealthy	94	95
201-300	Very Unhealthy	80	49
301+	Extremely Unhealthy	18	25
>151	Number of Days above unhealthy	190	167

Source: **DELHI US CONSULATE**

KOLKATA AIR QUALITY INDEX 2018-19			
AQI	**CATEGORY**	**2018**	**2019**
0-50	Very Good	12	49
51-100	Good	85	113
101-150	Caution	87	62
151-200	Unhealthy	95	51
201-300	Very Unhealthy	52	52
301+	Extremely Unhealthy	14	3
>151	Number of Days above unhealthy	159	104

Source: **KOLKATA US CONSULATE**

KATHMANDU AIR QUALITY INDEX 2018-19

AQI	CATEGORY	2018	2019
0-50	Very Good	63	53
51-100	Good	66	95
101-150	Caution	125	131
151-200	Unhealthy	85	65
201-300	Very Unhealthy	2	2
301+	Extremely Unhealthy	0	0
>151	Number of Days above unhealthy	86	64

Source: **KATHMANDU US CONSULATE**

The stations that are collecting PM data in Dhaka city start getting southerly wind dominantly from the end of March. Before that, the wind is mainly northerly, westerly, and northwesterly which came mostly from the east. These winds do not have a specific schedule. The trajectories normally show that the prime air masses responsible for higher concentrations at the stations in Dhaka city from November to March (post- monsoon and winter season) which is already mentioned in the previous section. Northwesterly winds dominantly contribute to the PM pollution during winter (November–January), whereas mixed wind directions are normally observed in pre-monsoon season (February–April).

Depending on the frequency of wind direction in the dry seasons (pre-monsoon and post-monsoon), the monitoring stations experience higher pollution from all the directions. However, higher contributions of fine particles, especially $PM_{2.5}$ and PM_{10} are observed from the north-west, north, and northeast directions. From the observations and findings, it can be said that the major air pollution in and around Dhaka city occurs whenever air masses traveled over northern India through the Dry Himalayan valley especially Kathmandu.

4.1.5 Air Pollution Situation in Bangladesh and Dhaka during COVID-19 Pandemic

A novel infectious disease of coronavirus family was identified in Wuhan, China in late December 2019, which was later named as COVID-19. In January 2020, WHO (World Health Organization) confirmed human-to-human transmission of COVID-19 through respiratory droplets (WHO, 2020). Later on, the same month, authorities confirmed a cluster of COVID-19 cases in Wuhan, which increased rapidly not only in the surrounding areas, but also spread in the whole country and an epidemic. On January 30, WHO declared worldwide public health emergency. In February, outbreaks begin in Iran, Italy and other countries around the globe. Subsequently, the epidemic turned into a pandemic the ended by end of March, Bangladesh has gone under strict lockdown owing to the advent of the deadly virus.

As countries around the world went into lockdown, the economic and industrial activities were kept mostly shut down. Among many other sectors, transport is the hardest-hit sector due to the ongoing lockdown condition. Road and air transport came to halt, as people are not allowed to travel or move freely in most of the affected countries. Reportedly, air travel dropped by 96% due to COVID-19, lowest in 75 years[43]. Furthermore, not only transport sector, but also industrial and manufacturing sector is heavily affected by the pandemic. Lockdown due to COVID-19 reduced transportation activities, resulting in less energy consumption and lower oil demand. Reduced transportation and fossil fuel consumption exert a significant impact on the environmental quality around the world including in Bangladesh.

Previously in Bangladesh, the state of environmental degradation was in worse condition. As per the Environmental Performance Index (EPI) 2018, prepared by Yale University and Columbia University, Bangladesh ranked 178 among 180 countries – only better than Burundi. The IQAir ranked Bangladesh the most-polluted country in terms of air pollution – measured in $PM_{2.5}$ – in the world in 2019. In 2019, according to global air pollution report, Bangladesh was the first in the list of the worst air quality among 180 countries. However, in recent times, due to the lockdown the air quality of Dhaka city has improved quite sharply. Bangladesh's capital Dhaka was ranked 27th in the world in consideration of the Air Quality Index (AQI) at the end of May 2020[44]. During this recent lockdown the air pollution rate has dropped as most of the construction work and transportation activities are halted for more than 2 months now. According to ESDO's research, from 15th March to 31st May, the air quality of the capital city has improved steadily. In table 3, the Air Quality Index (AQI) value of Dhaka city from 15th March to 31st May have been listed:

Table 5: Dhaka Air Quality Monitoring- Daily Report AQI data ($PM_{2.5}$)[45].

Months	March	April	May
March 15th – May 31st AQI Data		158	106
		182	130
		151	110
		156	95
		143	142
		167	85
		171	90
		132	150
		125	132
		138	147
		123	145
		85	133

[43] https://edition.cnn.com/2020/04/09/politics/airline-passengers-decline/index.html
[44] https://www.iqair.com/world-air-quality-ranking
[45] https://aqicn.org/city/bangladesh/dhaka/us-consulate/

		95	139
		158	128
	164	147	130
	143	96	109
	160	107	98
	161	93	86
	167	98	99
	169	89	134
	220	96	*
	205	133	*
	121	120	*
	156	104	*
	200	110	*
	205	95	*
	168	81	*
	152	104	61
	120	124	74
	121	107	88
	164		71

* Machine Error- No data recorded

These results indicated that from middle of March to end of May Dhaka have seen substantial improvement in air quality. According to AQI, data, (ANNEX-B) in between this time period 19 days were moderately healthy, 31 days were Unhealthy for Sensitive Groups, 27 days were Unhealthy and only 14 days were Very Unhealthy. No day was recorded hazardous between this time period.

According to recent data from the Real-time Air Quality Index (AQI) for the last 11 weeks (from 22nd March – 31st May 2020) of lockdown, the air pollution reduced in most of the Asian nations. Reportedly, due to imposed restriction on movement, air quality in Dhaka also improved compared to the usual, but yet, the quality did not rise up to the expected level. The city was ranked the 2nd most polluted city among the South Asian nations as per AQI value measured over the past weeks. This may be attributed to the disobeying of lockdown regulations by the city dwellers and subsequent unauthorized use of motor vehicles neglecting the imposed movement restriction. It is a clear reflection of the fact that, although officially declared, lockdown restrictions were not strictly followed or implemented in the capital city of Bangladesh.

Table 6: Average Air Quality Index (AQI) Data of last 11 weeks in 11 major Asian cities during COVID-19 pandemic.

Countries	Average Air Quality Index (AQI) Data Last 11 weeks (22^{nd} of March to 31^{st} of May)
1. Thailand	145
2. Bangladesh	122
3. Pakistan	116
4. Indonesia	107
5. India	103
6. Nepal	98
7. China	97
8. Viet Nam	62
9. Japan	59
10. Malaysia	53
11. Singapore	47

Figure 12: Images from the streets of Dhaka in May 2020, during the second month of the official lockdown in Bangladesh.

5.1 Health Risk Associated with Air Pollution in Bangladesh

The past 10 to 15 years have seen a remarkable increase in research on the effects of air pollution on health. It is now widely accepted that exposure to outdoor and indoor air pollution is associated with a broad range of acute and chronic health effects, ranging from minor physiologic perturbations to death from respiratory or cardiovascular disease. In Bangladesh, the health impact on humans is becoming a common case as the air quality in recent 10 years have decreased significantly. The impact has both short term and long-term effects on human health. In recent years, urban areas in Bangladesh are affected by the short-term high intensity air pollutions. Short-term effects of pollution include eye, nose and throat irritation, bronchitis, asthma and pneumonia and emphysema and allergic reactions. On the other hand, long-term effects are just results of regular exposure to constant polluted air like in ceramic and cement factory, construction activities, plastic burning and recycling industries etc.

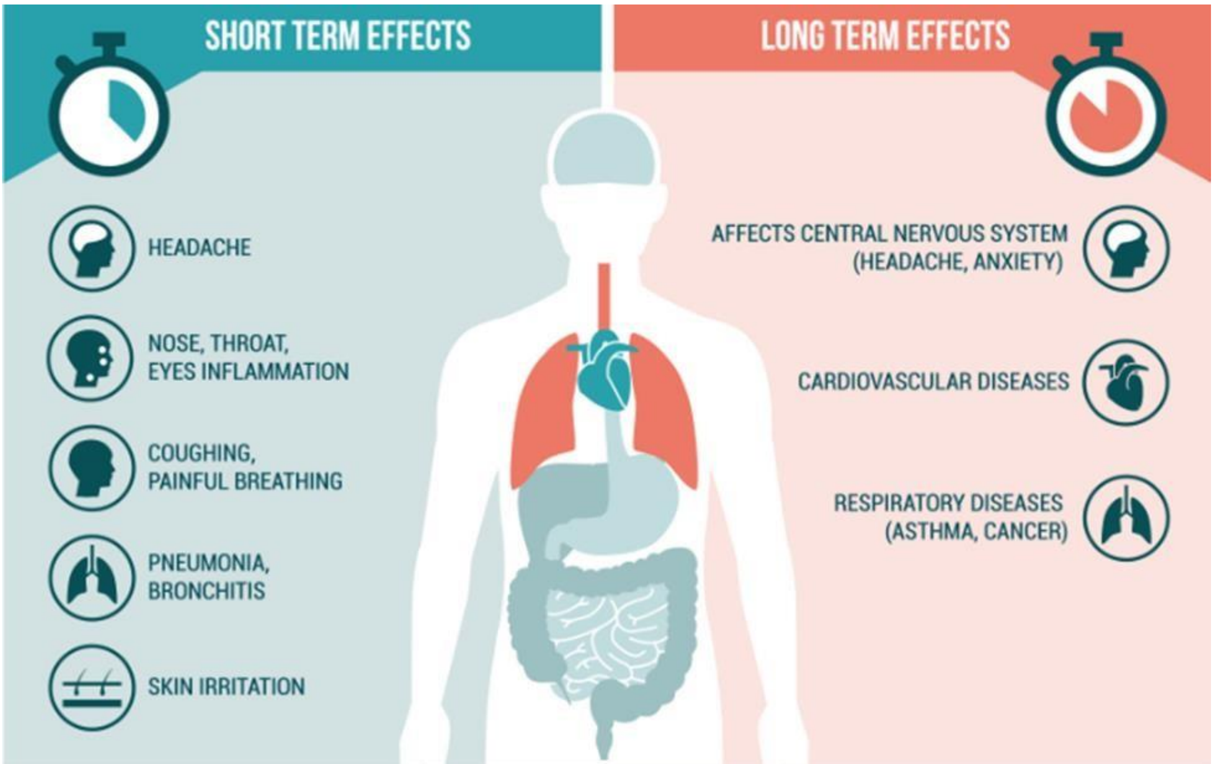

Figure 73: Effects of air pollution on human health.

5.1.1 Indoor Air Pollution Related Health Risks

Indoor air pollution is a substantial cause of respiratory illness and death and remains a major public health concern in the developing world. Bangladesh is a developing and overpopulated low land country located in South Asia. Nearly, 31% of people in peri-urban and rural areas live in poverty[46]. So that is why, more than three billion people depend on solid fuels (wood, animal dung, crop residues, charcoal, and coal) for cooking and heating, and, in the case of rural populations, approximately 90% household's use biomass fuels as their primary source of domestic

[46] Bangladesh Demographic and Health Survey (2011).

energy[47]. Polluted indoor air of industries, plastic recycling facilities, lead smelting and recycling sectors, etc. are associated with a range of health-damaging pollutants such as fine particles, carbon monoxide (CO2), nitrogen oxides (NO2), sulfur dioxide (SO2), benzene, butadiene, formaldehyde, polyaromatic hydrocarbons and a number of other chemicals[48]. Over the past decades, under-five mortality in Bangladesh has dropped by 72% from 144 deaths per 1,000 live births in 1990 to 41 in 2012. Despite this, pneumonia is still the leading single cause of under-five deaths in Bangladesh, accounting for one-fifth of all deaths.

Adverse effects of air pollution, on reproductive outcomes, and child health

Numerous studies have shown a significant association between exposure to air pollution and adverse birth outcomes, especially exposure to PM, SO_2, NO_x, O_3 and CO. There is strong evidence that exposure to ambient PM is associated with low birth weight. There is also growing evidence that maternal exposure, especially to fine PM, increases the risk of preterm birth. There is emerging evidence for associations between exposure to air pollution and other outcomes, such as stillbirth and infants born small for gestational age[49].

- **Infant mortality**

There is compelling evidence of an association between air pollution and infant mortality. As pollution levels increase, so too does the risk of infant mortality, particularly from exposure to PM and toxic gases. A growing body of research suggests that both prenatal and postnatal exposure to air pollution can negatively influence neurodevelopment, lead to lower cognitive test outcomes and influence the development of behavioral disorders such as autism spectrum disorders and attention deficit hyperactivity disorder. There is strong evidence that exposure to regular air pollutant produce in household activities or of painting materials can negatively affect children's mental development.

- **Childhood obesity**

A limited number of studies have identified a potential association between exposure to indoor air pollution and certain adverse metabolic outcomes in children. The findings include positive associations between exposure to air pollution in utero and postnatal weight gain or attained body mass index (BMI) for age, and an association has been reported between traffic-related air pollution and insulin resistance in children.

- **Lung function**

There is robust evidence that exposure to indoor air pollution damages children's lung function and impedes their lung function growth, even at lower levels of exposure. Studies have found compelling evidence that

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[47] Desai M.A., Mehta S., Smith K. Indoor smoke from solid fuels—Assessing the environmental burden of disease at national and local levels. Environ. Burden Dis. Ser. 2004.
[48] Naeher L.P., Brauer M., Lipsett M., Zelikoff J.T., Simpson C.D., Koenig J.Q., Smith K.R. Woodsmoke health effects: A review. Inhal. Toxicol. 2007;19:67–106.
[49] Dherani, M., Pope, D., Mascarenhas, M., Smith, K.R., Weber, M. and Bruce, N., 2008. Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: a systematic review and meta-analysis. Bulletin of the World Health Organization, 86, pp.390-398C.

prenatal exposure to air pollution is associated with impairment of lung development and lung function in childhood.

❖ **Asthma.**

There is substantial evidence that exposure to indoor pollutants increases the risk of children for developing asthma and that breathing pollutants exacerbates childhood asthma as well. While relevant, there are fewer studies on indoor air pollution, there is suggestive evidence that exposure from use of polluting household fuels and technologies is associated with the development and exacerbation of asthma in children.

❖ **Otitis media**

There is clear, consistent evidence of an association between indoor pollutant exposure and the occurrence of otitis media in children. Although relatively few studies have examined the association between non- tobacco smoke and otitis media, there is suggestive evidence that combustion derived indoor air pollution may increase the risk of otitis media.

❖ **Childhood cancers**

There is substantial evidence that exposure to traffic-related air pollution is associated with increased risk of childhood leukemia. Several studies have found associations between prenatal exposure to adverse air pollution and higher risk of retinoblastomas and leukemia in children[50].

5.1.2 Outdoor Air Pollution Related Health Risks

- **Bronchitis and Pneumonia**

Long-term exposure to air pollution can cause or aggravate lower respiratory conditions such as bronchitis and pneumonia. Health effects of pollution are most prominent in children, especially when they are affected by polycyclic aromatic hydrocarbons, or PAHs, which can cause acute bronchitis. PAHs are released when fuel such as wood and coal are burned, as well as from grilling food and vehicle emissions. In addition, indoor air pollution from cooking fuels is detrimental to people across the world. According to the World Health Organization, exposure to indoor pollution more than doubles the risk of pneumonia.

- **Asthma and Emphysema**

People with chronic conditions like asthma and emphysema are especially vulnerable to health effects of pollution. Nitrogen dioxide affects asthmatic people more intensely than others. It causes those with asthma to be more susceptible to lung infections and asthma triggers like exercise and pollen. Sulfur dioxide affects people with chronic conditions as well. Since it tightens the airways, it can cause people with asthma or emphysema to have stronger symptoms than normal and an increased lack of breath. Air pollution from industrial plants, factories and automobiles all contribute significantly to an increase in asthma attacks.

- **Allergic Reactions**

[50] Air pollution and child health: prescribing clean air 2018.

One of the short-term effects of pollution is an increase in the likelihood of allergic reactions. Not only do people with chronic conditions like asthma and emphysema need to pay attention to pollution indexes, but now people with allergies are also advised to do so. Pollution acted as a trigger to inflame already existing allergic reactions. Ozone is one of the main culprits. People who have strong allergies may want to stay clear of high traffic areas like freeways and highways; ozone is particularly acute in these areas.

Table 7: Sources and health impacts of Different Air Pollutants.

Pollutants	**Sources**	**Impacts**
1. Suspended Particulate Matter (SPM)	Motor vehicles Wood-burning Industrial activities	Respiratory infection Throat irritation Aggravated asthma
2. Sulfur Oxides	Vehicles (diesel-using) Factory emissions	Affect respiratory tract and permanent lung damage Bronchitis Emphysema Asthma Plant growth reduction Beans and tomatoes with bleached colorless spots
3. Nitrogen Oxides	Vehicle motors Power stations	Respiratory diseases Chest congestion Eye irritation Headache Suppressed growth of beans and tomatoes Increase abscission and reduce yield in citrus plants Spots and mild necrosis on cotton and bean plants Acute leaf failure
4. Lead	Windblown dust Vehicles Coal & wood-burning Metal production Phosphate fertilizer	Affected central nervous system Renal damage Hypertension Children are 3 times more at risk than adult Effects on plants
5. Carbon Monoxide	Petrol vehicles (2 and 3 wheelers)	Reduces the ability of blood to carry oxygen Exacerbates heart disorders
6. Aromatic Hydrocarbons	Unburned fuel from diesel engines	Drowsiness Eye irritation

7. Benzene	Unleaded petrol Emitted from catalytic converters	Carcinogen Affected central nervous system
8. Ozone	Reaction between VOCs and NOX in presence of sunlight	Reduced lung function Asthma Eye irritation Nasal congestion Lowered resistance to infection

Source: Gain et al., 1998

5.1.3 Occupational health risk due to indoor air pollution at industrial level

<u>Industrial Health Hazards</u>

In Bangladesh, industrial sector has more polluted indoor air than outdoor air. The common pollutants like particulate matter (PM), volatile organic compounds (VOCs), carbon monoxide (CO) and dust in the air are the main causes of respiratory problems in most of the industries. Cement and Ceramic industries are most polluted as they produce clay particles containing toxic chemicals with it. One of the main contributors to poor indoor air is a poorly designed, maintained, or operated ventilation system. In an effort to save energy in our industries, ventilation systems are prevented from pulling in enough outdoor air to maintain an appropriate, healthful balance. Respirable particles and gases created in these industries are affecting different parts of the respiratory parts of body of the workers. Irritation of the mucous membranes (eyes, nose, and throat) are most of the time common cases among the workers in cement industries. In ceramic industries, increased incidence of acute respiratory illness like cold, pneumonia, otitis media are most common. Other industries like sawmill and wood processing industries, steel industry, LPG refilling industries, Fertilizer producing industries, Lead Acid Battery Recycling Facilities etc. are also poor in their indoor air quality. No safe equipment are provided for the workers to work such polluted air.

<u>Health risk of construction workers:</u>

Construction industry around Dhaka city often termed as ‘high-risk’ sector creates significant impact on the health and safety of the construction workers. However, it is common to see a construction worker work at heights with equipment and building materials, these scenarios are plagued by potentially dangerous situations and poor working conditions. They are exposed to hazards that are difficult to quantify. The airborne dust, fibers resulted from stone masonry, removing rubble clean-up; toxin fibers used in paints, varnishes, glues, flooring and building materials causes respiratory disease such as lung cancer of both male and female workers. Amongst construction workers there is a high incidence of respiratory problems, with the main cause being exposed to dusts and respirable crystalline silica (RCS) resulting in silicosis. Other prevalent respiratory diseases amongst construction workers are chronic obstructive pulmonary disease

(COPD) and asthma. Dual exposure to both smoking and occupational hazards markedly increases the risk of lung diseases that will last forever until death. No protective mask is provided to the daily workers to protect themselves from the dusts. They normally use their own cloths to protect which are not enough for protection.

Indoor Air pollution in Plastic Recycling Factories

Plastic recycling factories serve as one of the major hubs of indoor air pollution at industrial level. In Bangladesh, the entire process followed for plastic recycling is traditional and it depends upon intensive manual input. Air pollutants prevailing in recycling factory premises pose serious health threats to the corresponding factory workers. In most of the cases, the air inside the factories is extremely polluted with dust and chemical particles. Overly heated recycling machine maintains a hot and humid weather making the workers uncomfortable. In the factories dedicated to the cutting and shredding of used plastic items, the workers feel breathing and hearing problem as highly concentrated microbeads particles are present in the air. The recycling process itself involves the release huge amount of greenhouse gases and toxic pollutants. The emission from recycling machine causes severe indoor air and dust pollution. Some long -term health problems reported by the workers include – asthma and respiratory diseases, deafness, loss of eyesight and skin problems. The respiratory problems emerge from the long-term inhaling of harmful pollutants during work hours. However, the recycle waste are often incinerated in open places that generates extremely toxic fumes, gases and heavy metals causing severe environmental pollution and health threats giving rise to outdoor air pollution as well.

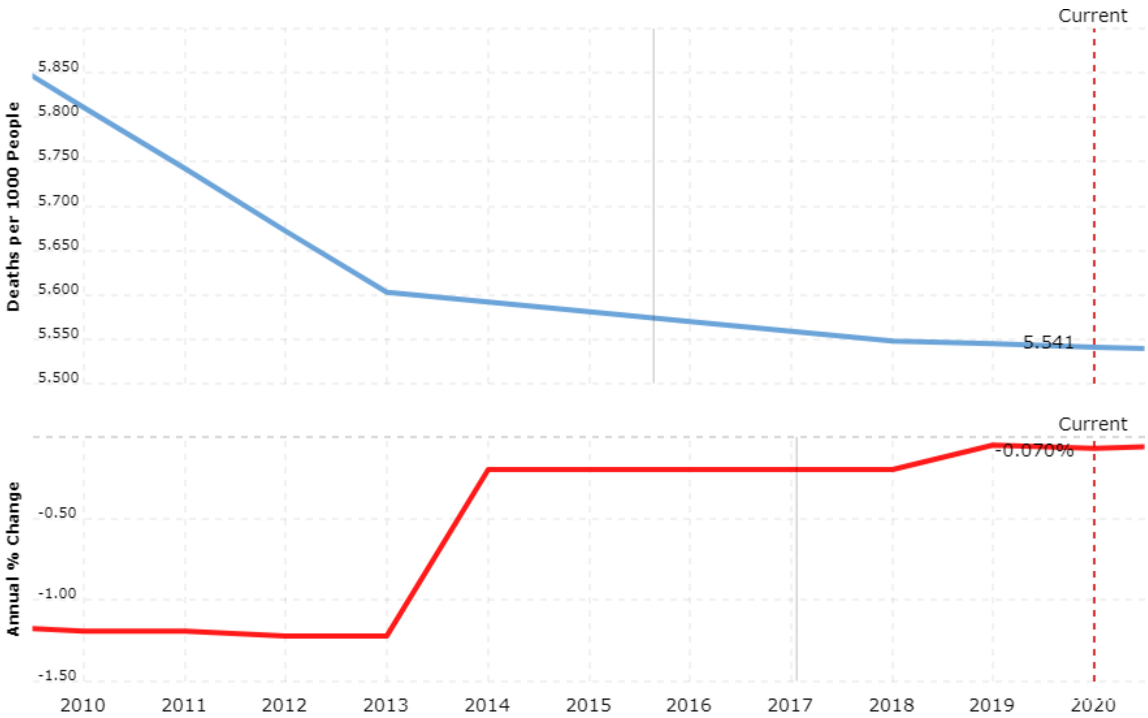
Figure 14: Workers without proper mask working in the plastic recycling facilities.

5.1.4 Death Caused by Air pollution in Bangladesh

Air pollution can lead to death in many cases. The World Health Organization estimates that indoor air pollution from solid fuel leads to approximately 1.6 million deaths per year. A new study on global air pollution has reported that at least 123,000 people died in Bangladesh in 2017 due to indoor and outdoor air pollution. The State of Global Air 2019, which used data from the period 1990-2017, estimated that if air pollution levels met the World Health Organization (WHO) guidelines, life expectancy in Bangladesh would have seen the highest expected gain of nearly

1.3 years[51]. Scientific evidence supports a causal relationship between exposure to ambient $PM_{2.5}$ and ischemic heart disease, cerebrovascular disease (ischemic stroke and hemorrhagic stroke), lung cancer, chronic obstructive pulmonary disease (COPD), and lower-respiratory infections (in particular, pneumonia).

Estimation was that, by 2019, at least 200,000 people in Bangladesh would potentially embrace death due to respiratory diseases and long time exposure to high concentration of polluted air. As air pollution exposure is linked with increased hospitalizations, disability, and early death from respiratory diseases, heart disease, stroke, lung cancer, and diabetes, as well as communicable diseases like pneumonia, the death rate increased sharply in recent years. In the last five years (2015-2019), the number of asthma patients rose by a factor of 24 to 78,806 in 2019 from 3,326 in 2015. Deaths from the disease went up 10-fold to 588 from 56 in the same period. Similarly, the number of cases of chronic obstructive pulmonary disease (COPD) rose from 1,610 in 2015 to 78,806 in 2019, an increase by a factor of 49. Deaths from it increased 19-fold to 588 in the same period, according to a recent report of the health directorate[52].



[51] STATE OF GLOBAL AIR-2019 Report

[52] https://tbsnews.net/environment/air-pollution-deaths-asthma-copd-rise-alarmingly-5-years

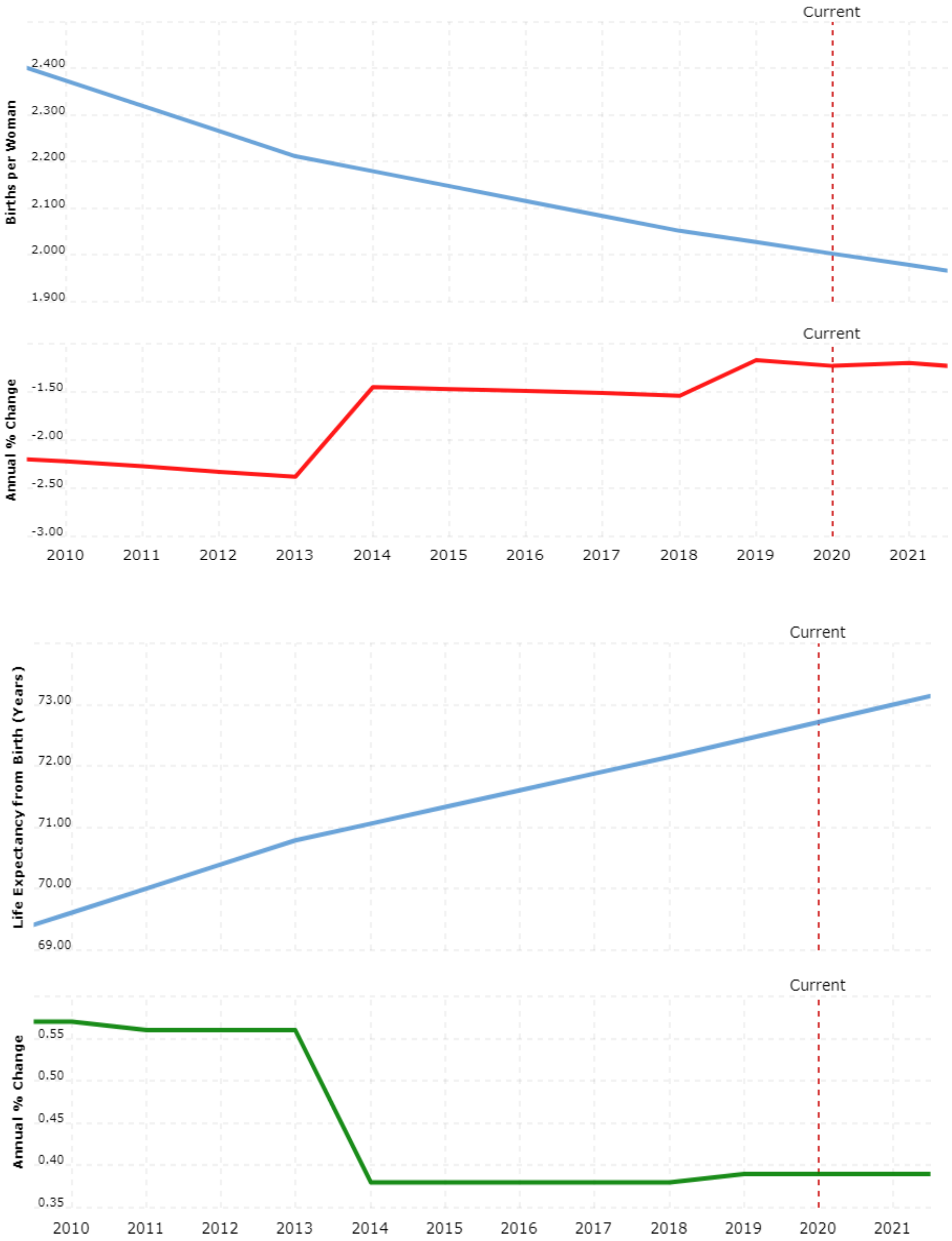


Figure 15: Estimated projectile of yearly Death per 1000 people, Birth per Women, and Life Expectancy from Birth and annual % change in last 10 years (2010-2020).

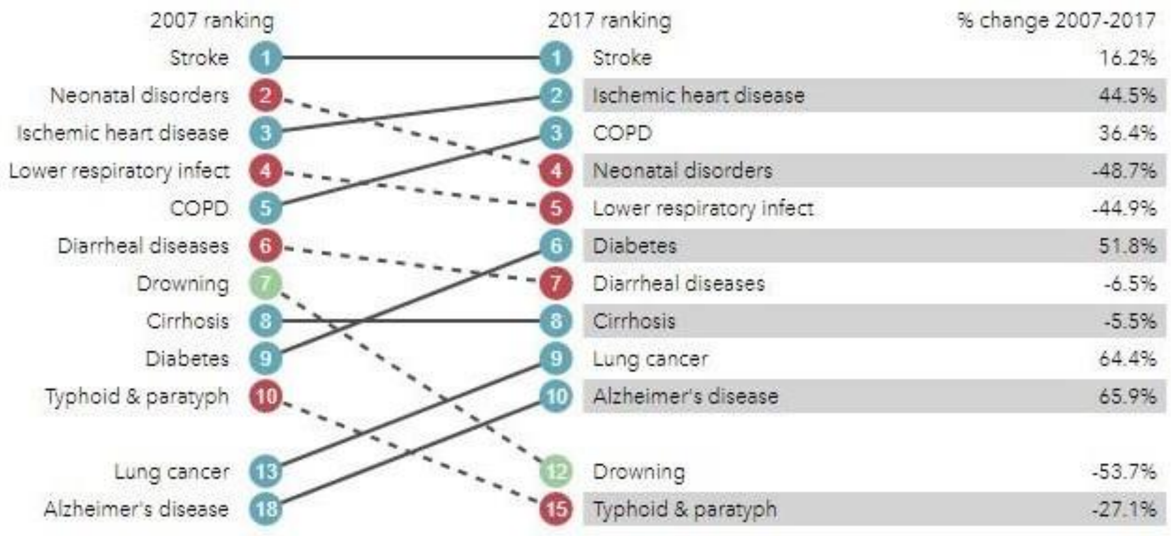


Figure 16: Top 10 causes of death in 2017 and percent change, 2007-2017 (all ages, number) in Bangladesh.

Most of the disease burden attributable to air pollution (82%) stems from chronic non-communicable diseases. As shown in Figure 22, air pollution accounts for 36.4% of deaths from chronic obstructive pulmonary disease (COPD), 51.8% of deaths from type 2 diabetes, 64.4% of deaths from lung cancer, 44.5% of deaths from ischemic heart disease, and 16.2% of deaths from stroke. Air pollution also contributes to a communicable disease (e.g., 35% of deaths from lower-respiratory infection). These contributions vary among districts with different relative levels of ambient and household air pollution.

5.1.5 Environmental Impacts of Air Pollution

Air pollution can cause a variety of environmental effects like acid rain, eutrophication, smog (Smoke+Fog), etc. The main problem associated with air pollution to environmental impact is that the airborne chemicals like PFAS, Lead, Mercury, etc. are deposited in the open water bodies and ultimately go to the groundwater aquifers. The unwanted chemicals mixed with water ultimately go in direct contact with domestic animals, fishes, and eventually enters into the food chain. Major environmental impacts of air pollution have been discussed briefly in the following segment:

Acid Rain:

Acid rain is precipitation containing harmful amounts of nitric and sulfuric acids. These acids are formed primarily by nitrogen oxides and sulfur oxides released into the atmosphere when fossil fuels are burned. These acids fall onto the Earth as either wet precipitation (rain, snow, or fog) or dry precipitation (gas and particulates). Acid rain damages trees and causes soils and water bodies to acidify, making the water unsuitable for some fish and other wildlife. It also speeds the decay of buildings, statues, and sculptures that are part of our national heritage.

Eutrophication:

Eutrophication is a condition in a water body where high concentrations of nutrients (such as nitrogen) stimulate blooms of algae, which in turn can cause death of fish and loss of plant and animal diversity. Air emissions of nitrogen oxides from power plants, cars, trucks, and other sources contribute to the amount of nitrogen entering aquatic ecosystems.

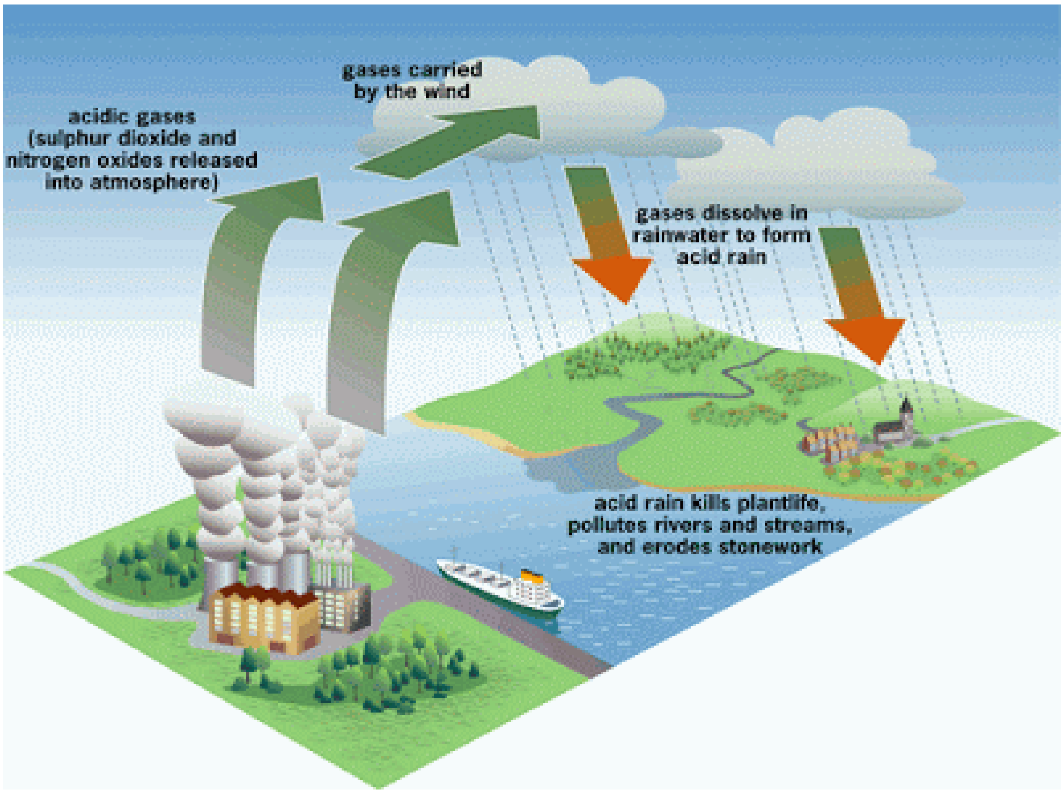


Figure 17: Effects of acid rain on environment[53].

Ozone Layer depletion:

At ground level, ozone is a pollutant that can harm human health. In the stratosphere; however, ozone forms a layer that protects life on earth from the sun's harmful ultraviolet (UV) rays. Nevertheless, this "good" ozone is gradually being destroyed by man-made chemicals referred to as ozone-depleting substances, including chlorofluorocarbons, hydro-chlorofluorocarbons, and halogens. These substances were formerly used and sometimes still are used in coolants, foaming agents, fire extinguishers, solvents, pesticides, and aerosol propellants. Thinning of the protective ozone layer can cause increased amounts of UV radiation to reach the Earth, which can lead to more cases of skin cancer, cataracts, and impaired immune systems.

Effect on wildlife

Toxic pollutants in the air, or deposited on soils or surface waters, can affect wildlife in a number of ways. Like humans, animals can experience health problems if they are exposed to sufficient concentrations of air toxics over time. Studies show that air toxics are contributing to birth defects, reproductive failure, and disease in animals. Persistent toxic air pollutants (those that break down slowly in the environment) are of

[53] https://sites.google.com/site/bio151theteam/artifact-5

particular concern in aquatic ecosystems. These pollutants accumulate in sediments and may bio-magnify in tissues of animals at the top of the food chain to concentrations many times higher than in the water or air.

Effect on Agriculture

There is a two-way relationship between agricultural production and air pollution: agricultural production contributes significantly to air pollution; in turn, air pollution can affect 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. Air pollutants may damage agricultural production in three major ways:

i) Direct visible injury, usually to leaf tissue - If extent, 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 by 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.

5.1.6 Air Pollution and Climate Change: Complexity of Inter Linkage

The Earth's atmosphere contains a delicate balance of naturally occurring gases that trap some of the sun's heat near the Earth's surface. This "greenhouse effect" keeps the Earth's temperature stable. Unfortunately, evidence is mounting that humans have disturbed this natural balance by producing large amounts of some of these greenhouse gases, including carbon dioxide and methane. As a result, the Earth's atmosphere appears to be trapping more of the sun's heat, causing the Earth's average temperature to raise - a phenomenon known as global warming. Many scientists believe that global warming could have significant impacts on human health, agriculture, water resources, forests, wildlife, and coastal areas.

Fossil fuel combustion causes both – climate change, air pollution, and is a dominant primary energy source globally. Fossil fuel combustion releases a mix of both – greenhouse gases and air pollutants. However, not all greenhouse gases are pollutants, e.g. carbon dioxide or methane.

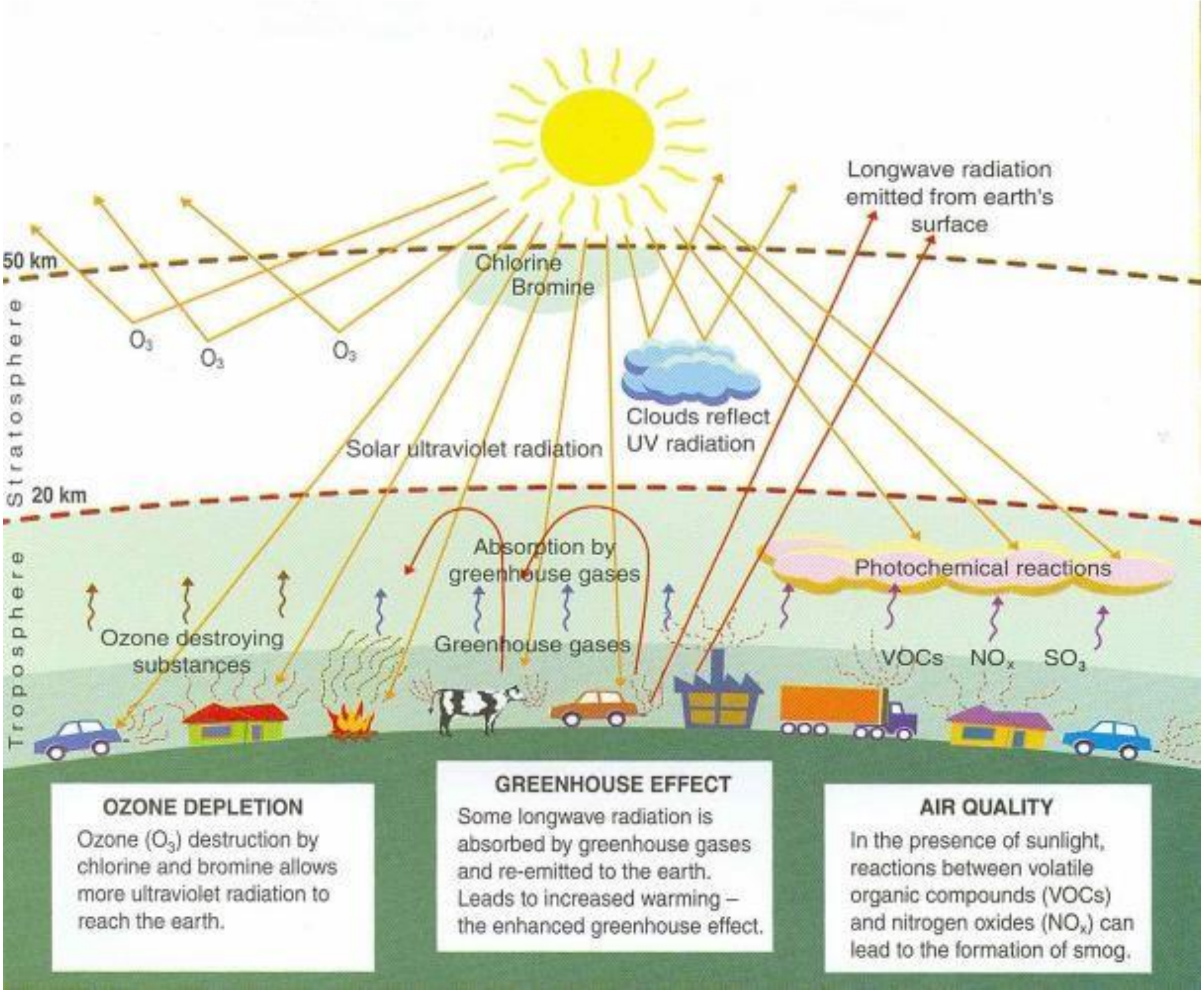


Figure 18: Climate system affected by air borne pollutants[54].

Air pollution is a global phenomenon affecting even the most remote and uninhabited parts of the Earth. Some primary air pollutants from secondary air pollutants because of chemical reactions in the atmosphere. Nitrogen oxides, carbon monoxide, volatile organic compounds and methane form tropospheric ozone, which negatively affects human health, ecosystems, and agricultural crops and warms the climate. Particulate matter can be a primary and a secondary pollutant because of chemical reactions in the atmosphere between sulphur dioxide, nitrogen oxides, ammonia and volatile organic compounds[55].

To complicate the matter even more, climate change is likely to have an impact on air quality as well via change in climatic patterns that might affect atmospheric transportation and chemistry. There is a consensus that air quality management especially with regard to tropospheric ozone pollution will be exacerbated by climate change and will require additional efforts if we compare climatic conditions now and ceteris paribus in 2050.

[54] Guerreiro, C.B., Foltescu, V. and De Leeuw, F., 2014. Air quality status and trends in Europe. Atmospheric environment, 98, pp.376-384.

[55] Guerreiro, C.B., Foltescu, V. and De Leeuw, F., 2014. Air quality status and trends in Europe. Atmospheric environment, 98, pp.376-384.

Climate change is the biggest global health threat of the 21st century and is increasingly recognized as a public health priority. Climatic variables are vita environmental factors, which establish ecological niches of tree species and their patterns of distribution. Species-distribution models (SDMs), and forecasted global climate data, indicated that up to 43% of a sample of tree species in Amazonia could become non-viable by 2095.

SECTION VI

6.1 POLICIES AND REGULATIONS TO CONTROL AIR POLLUTION IN BANGLADESH

Every country needs a practical and dynamic set of rules and regulations to prevent and mitigate environmental pollution. The environmental laws existing in Bangladesh may be categorized based on broad objectives as follows:

- Protection of environmental health
- Control of environmental pollution
- Conservation of natural and cultural resources.

The first regulation related to environment in Bangladesh was the Factory Act of 1965, through which workers' health-related issues were addressed. This was followed by the earliest recorded environmental protection act, known as the "Water Pollution Control Ordinance, 1970". However, none of these ordinances addressed air pollution problems. This major oversight may have been due to the almost negligible air pollution problems at that time. In view of growing environmental pollution, this ordinance was repealed, and the Environmental Pollution Control Ordinance (EPC), 1977, was promulgated. This ordinance provided for the control, prevention, and abatement of pollution of the environment in Bangladesh. It dealt with pollution of air, surface and ground waters, and soil by discharge of liquid, gaseous, solid, radioactive, or other substances.

Although the order passed under the EPC 1977, was legally in place, implementation of environmental laws never took place. The environmental scenario in Bangladesh changed considerably following rapid industrialization. The Ministry of Environment and Forest, and the Department of Environment was created in 1989.

As a signatory to Agenda 21, Bangladesh is committed to implement this international legal instrument through national programs and policies. The Environmental Policy of 1992 was an important development in this regard. Further, the Environmental Conservation Act, 1995, and the Environment Conservation Rules, 1997, were approved by the Bangladesh National Assembly to restrict and mitigate ever-growing environmental problems in the country.

Therefore, the Bangladesh National Environment Policy 1992, Environmental Conservation Act

1995, and the Environment Conservation Rules (ECR) 1997, now contain relevant policies, such as authority to inspect and regulate facilities, collect samples, impose civil penalties, adopt rules, and implement environmental clearances (see Table 6). Under the Rules of 1997, the following standards have been set.

- ❖ Ambient Air Quality Standards,

- ❖ Vehicle Exhaust Emission Standards,
- ❖ River Transport (Mechanized) Emission Standards,
- ❖ Standards for Gaseous Emission for Industries or Projects.

Table 8: *Policy Responses to Air Pollution through Acts, Rules, and Laws in Bangladesh.*

Act/Rule/Law	**Control/Prevention Response**
A. The Brick Burning (Control) Act, 1989 (Act number 8 of 1989) B. The Brick Burning (Control) Amendment Act, 1992	• Control of brick-burning • Required a license from the appropriate authority • Restricts brick-burning with fuel wood
C. Bangladesh Environmental Conservation Act, 1995 (ECA 1995)	• Declaration of ecologically critical areas • Regulation with respect to vehicles emitting smoke harmful for the environment • Environmental clearance • Regulations of the industries and other development activities-discharge permit • Promulgation of standards for quality of air, water, noise, and soils in different areas and for different purposes • Promulgation of acceptable limits for discharging and emitting waste
D. Environment Conservation Rules, 1997 (ECR, 1997)	• The National Environmental Quality standards for ambient air, various types of water, industrial effluent, emission, noise, vehicular exhaust, etc. • The requirement for the procedures environmental clearance • Requirement for IEE/EIA according to categories of industrial and other development inventories
E. Environment Court Law, 2000	The government has given highest pre-environmental pollution and passed 'Environment Court Act 2000' for completing environment related legal proceedings effectively

Apart from above mentioned stringent legal instruments, the Bangladesh government has adopted a range of policies relevant to air quality management. Policies can be directly aimed at improving air quality, or policies cover related areas (such as health, climate change, energy management, environment) or sectors (such as transport, industry, construction) that affect air pollution indirectly. The most important ones are:

- Revisit motor vehicle ordinance 1983: The existing motor vehicle ordinance 1983 is being revisited in view of rising vehicular emission in the cities. Stringent measures have been proposed to stop the black smoke from in-use vehicles. The import policy provides provisions for the importation of minimum Euro II diesel vehicles.
- Banning of Two-Stroke Engines: The two-stroke three-wheelers, known as baby-taxis, which were banned in Dhaka city in 31st December 2002 and the regulation was started from 1st January 2003.
- Ban on Fix Chimney Kiln (FCK) technology: In order to reduce emissions from brick kilns contributing to urban air pollution, the government has already announced the ban on Fixed Chimney

Kiln (FCK) technology effective from year 2010. This particular action was necessitated in view of rising pollution in the urban areas from brick kilns despite the effort to raise chimney heights to 120 feet in FCK. To make the brick making industry more energy efficient and less environmentally polluting, the government is actively considering imposing conditions like retrofitting of FCK with gravity settling chamber and use of internal fuel in the manufacture of green bricks. Apart from this, proven brick production technologies will be encouraged. In addition to this, dispersion modeling will be used in the issuance of permits to new brick kilns.

- Encouraging the use of CNG as auto fuel: Compressed natural gas (CNG) as a vehicle fuel was first introduced to Bangladesh in 1982 through a World Bank pilot project. In 1999, four private companies obtained permission to set up about five stations each (source)[56]. The government encouraged to use of CNG as an auto fuel in different types of vehicles. The government vehicles are gradually being converted to CNG. Many public transports including buses are fueled by CNG and auto rickshaws in Dhaka are compulsorily powered by CNG.
- Strategic Transport Plan for Dhaka City: The Bangladesh government has approved the Strategic Transport Plan for Dhaka city. The approval comes with introduction of environment-friendly mass transit like BRT, LRT and metro systems in Dhaka. This will ensure co-benefits of air quality management and climate change mitigation.
- National Energy Policy: In order to reduce air pollution in Dhaka and other cities, the government in its National Energy Policy emphasized the best possible use of CNG in the transport sector. It also provided fiscal incentives in the form of tax cuts on the import of equipment for compression and refueling of natural gas. This particular policy decision immensely contributed to the growth of CNG as an auto fuel in Bangladesh.

Table 9 Bangladesh-Country level policies that affect air quality[57].

GOALS	CURRENT STATUS	CURRENT / PLANNED POLICIES & PROGRAMMES
GENERAL OVERVIEW	**The overall situation with respect to air quality in the country, including key air quality challenges:** Brick kilns and transport (emissions and	**National Ambient air quality standards**: Meet WHO Interim Targets, except NO_2 and SO_2. National ambient air quality standards (NAAQS) have been

[56] http://www.ebangladesh.com/2801#:~:text=Rezwan,cost%20for%20many%20vehicle%20owners
[57] Country Synthesis Report on Urban Air Quality Management: Bangladesh. Asian Development Bank and the Clean Air Initiative for Asian Cities, 2006, http://www.nytimes.com/2013/07/15/world/asia/bangladesh-pollution-told-in-colors-and-smells.html?_r=0, http://urbanemissions.info/model-tools/sim-air/dhaka-bangladesh.html, http://www.worldbank.org/en/news/feature/2014/07/24/cleaning-dhakas-airbangladesh, http://www.thedailystar.net/renewable-power-development-with-incentives-20979, http://d335hnnegk3szv.cloudfront.net/wpcontent/ uploads/sites/837/2015/06/Siddique-Zobair_SREDA-Activities-Copy.pdf, http://baqconference.org/2012/assets/Uploads/BAQ-2012Swapan-Kumar- Biswas.pdf, http://www.slideshare.net/mithilamarufa/rural-electrification-using-pv-success-story-of-bangladesh, http://www.sreda.gov.bd/index.php/actspolicies-rules/24-4-cap-final/file, https://energypedia.info/wiki/Bangladesh_Energy_Situation, http://www.who.int/quantifying_ehimpacts/national/countryprofile/bangladesh.pdf?ua=1, http://www.unep.org/Transport/New/PCFV/pdf/Maps_Matrices/AP/matrix/AP_Matrix_June2015.pdf

	road dust) are two of the biggest sectors contributing to air pollution; also cement and metal smelting; Dhaka ranks high on the list of major cities with poor urban air quality. Unplanned construction, steel re-rolling and cement industries are some other major sources of air pollution. Dhaka is one of the major cities in Bangladesh, which suffers air quality of below standard during some of the days of dry season especially November to march. In Bangladesh Air Quality Standards have been set out for CO, Pb, NO_X, PM, PM_{10}, $PM_{2.5}$, O_3 and SO_2. The ambient air quality monitoring data from the Continuous Air Monitoring Stations (CAMS) suggest that PM10 and PM2.5 are the most critical pollutants often exceed the national ambient air quality standard (NAAQS) during dry season. In Dhaka City, the concentration of particulate matter in dry season has found to exceed NAAQS for more than 100 days of a year. It is observed that the gaseous pollutants remain within the limiting values of the NAAQS. **Air quality monitoring system**: The ambient air quality-monitoring network in Bangladesh consists of eleven (11) fixed Continuous Air Monitoring Stations (CAMS). Real-time measurements of ambient level pollutants are being monitored in 8 major cities namely, Dhaka, Narayanganj, Gazipur, Chittagong, Rajshahi, Khulna, Barisal and Sylhet. The data generated by the CAMS are used to define the nature and severity of pollution in the cities; identify pollution trends in the country; and develop air models and Air Quality Index for public information.	enshrined in the Environment Conservation Rules 1997 (ECR). Currently the Government is considering the revision of the existing NAAQS to meet WHO air quality guiding values. **National Air Quality Policy:** There is no stand-alone act or rule dealing air quality. The air quality issues are addressed in the Bangladesh Environment Conservation Act 1995 and Environment Conservation Rules 1997. Brick Manufacturing and Kiln Construction (Control) Act 2013 has been enacted to reduce emissions from brick kilns. **Air Quality legislation**: Not specifically. Initiatives underway to amend Brick Manufacturing and Kiln Construction (Control) Act 2013 aiming to facilitate energy efficient and less polluting brick industry. Initiatives being made to amend Environment Conservation Rules 1997 in order to be conformed to the existing environment challenges. **Air Quality Programme:** Converting traditional brick kiln into energy efficient kiln to reduce air pollution. Reviewing import policy order to impose ban on importing coal with high Sulphur content. Clean Air and Sustainable Environment (CASE) project is being implemented with the objective of abating air pollution from transport and brick kilns
REDUCE EMISSIONS FROM INDUSTRIES	**Industries that have the potential to impact air quality:** Cement, brick industry, unplanned construction acting are the main sources of air pollution. (Textile and garment factories are not major sources of air	**Emission regulations for industries:** Environmental Conservation Rules 1997 regulates industrial emission; Brick Manufacturing and Kiln Construction (Control) Act 2013 has been enacted to reduce emissions from brick kilns.

	pollution in the context of Bangladesh). Monitoring of stack emissions and ambient AQ not fully implemented; lack of AQ information on emissions and concentration levels hampers effective enforcement of regulations Measurement of in-stack emission is carried out for enforcement purpose. However, the Department of Environment lacks enough equipment and technical manpower for rigorous stack emission monitoring. GDP of country: US$ 172.9 billion (2014) Industries' share of GDP: 30% Electricity sources: Natural gas (63%) and furnace oil (21%)	**Small installation's emissions regulate:** Regulated by the Environment Conservation Rules, 1997. For Environmental Clearance purpose industries/projects are categorized into 4 classes, namely, Green, Amber-A, Amber-B and Red. Small installations are mostly Green or amber-a category projects which, for obtaining environmental clearance. **Renewable energy investment promoted:** Yes, but inadequate financial incentive or regulatory support – need feed-in tariffs towards promotion of Renewable Energy (according to Sustainable and Renewable Energy Development Authority of Bangladesh); Renewable Energy Policy 2009: Equipment and spare parts exempted from duty and 5% VAT, 5 years income tax exemption **Energy efficiency incentives:** Programs include energy audits (yet to launch), distribution cook stoves cook stoves, improved brick kiln, improved rice parboiling, distribution of CFL bulbs and energy star labeling.
REDUCE EMISSIONS FROM TRANSPORT	**Key transport-related air quality challenges**: transport dominates as an air pollution source in Dhaka; re-suspended soil from unpaved roads, high traffic volumes, congestion, poor vehicle maintenance, old vehicles Limited enforcement of registration legislations: "The Bangladesh Road Transport Authority has a legal mandate to ensure gross polluting vehicles do not operate on the road network. However, its capacity to carry out this mandate is limited." (CAI-Asia) 46% of the fleet are is motorcycles; many are 2-stroke	**Vehicle emission limit**: Euro 1 for diesel driven vehicle and Euro 2 for patrol driven vehicle. **Fuel Sulphur content**: Bangladesh Petroleum Corporation (BPC) has begun importing diesel fuel with a lower sulphur content of 0.05% (500 parts per million, or ppm) since 2015, although the official standard is still 5,000ppm **Restriction on used car importation**: not older than 4 years **Actions to expand, improve and promote public transport and mass transit**: Greater Dhaka Sustainable Urban Transport Project **Actions to promote non-motorized transport**: Construction of 70km of sidewalks with surface drainage and ancillary road improvements has been completed by the Clean Air and Sustainable Environment project (CASE Project). **Other transport-related actions**: Electric rickshaws banned as they

		consume electricity mainly through illegal connections; 2-stroke engines are banned in some cities
REDUCE EMISSIONS FROM OPEN BURNING OF AGRICULTUR AL / MUNICIPAL WASTE (OUTDOOR)	**Outdoor, open burning**: burning of municipal and agricultural waste common The Government of Bangladesh creates awareness of harmful impacts of open burning.	**Legal framework**: Bangladesh Environment Conservation Act, 1995 and Environment Conservation Rules 1997 broadly cover the issue of open burning.
REDUCE EMISSIONS FROM OPEN BURNING OF BIOMASS (INDOOR)	**Dominant fuels used for cooking and space heating**: 89% households use solid fuel, mostly wood, agricultural wastes and cow dung (99% in rural areas, 60% in urban) **Impact**: 49,000 deaths/year from indoor pollution (9,400 from outdoor air pollution); 230 million cases of respiratory diseases/year	**Indoor air pollution regulated:** Bangladesh Labor Act 2006 covering mostly working condition of a premise in general regulates Indoor air pollution. However, this Act does not stipulate any specific standard of the pollutant. **Promotion of non-grid / grid electrification**: electrification rate 60%; supply not reliable; Infrastructure Development Company Ltd (government owned) has targeted to finance off-grid systems in rural areas **Promotion of cleaner cooking fuels and clean, cook stoves:** Bangladesh Country Action Clean, Cook Clean Cook stoves to distribute cook stoves to 30 million households by 2030. Govt of Bangladesh has financed 4.5million USD to promote environment friendly clean cook stoves. Approximately 0.6 million households are now using improved cook stoves in the country.

SECTION VII

7.1 ESDO initiatives to Prevent Air Pollution in Bangladesh and Recommendations

ESDO as a Bangladeshi organization is working hard to spread the message about the need for environmental conservation and to ensure the protection of biological diversity and ecological balance. Since the official formation of ESDO in 1990, we have focused on generating knowledge amongst the wider community about how human activity can negatively influence the environment of Bangladesh. From the start of the organization, we have addressed the air pollution associated problems and impacts of Dhaka city dwellers. We stood our ground and protested against three-wheeler vehicles with two-stock engines in 2001 and ultimately it was successfully banned on 31st December 2002 from the roads in Dhaka city. We also raised awareness for lead-free petrol use and we took part in both policy and media advocacy against the pollution that occurred due to high lead and carbon emission from vehicles. We have successfully worked with the government to raise awareness about air pollution among general people through social media.

Figure 19: ESDO campaign on Stop-Two-Stroke engine vehicle in 2001.

We have carried out an extensive survey on indoor air pollution in 49 districts of Bangladesh. The findings of the survey are added in this study report. We have also been collecting and monitoring $PM_{2.5}$ concentration in Dhaka city from February 2019 and conducted a detailed outdoor pollution survey around

Dhaka city. We have tried to bring out the common people's thoughts, problems, and health impacts due to high air pollution. We have visited several industries to monitor the air pollution condition and assessed the indoor condition of those industries. We have addressed the impact of COVID-19 Pandemic on Dhaka ambient air quality and the monitoring data and findings have been incorporated in this study.

ESDO is working hard through social media awareness against air pollution from the start of the organization. We are still creating different infographics to aware of mass people through websites, Facebook, Twitter, Instagram, and other social media disseminate the knowledge and suggest possible solutions to reduce pollution sources.

Recommendations

To maintain air quality standards at different levels, distinct strategic interventions and measures are to be planned and implemented:

- **Indoor air quality:** Improvements of building voids, passive house standards, improvements of ventilation systems in residential and commercial sectors.
- **Local air quality:** Improvements in efficiency of privately managed heating and hot water systems, modal shift in urban transportation, improvements of building envelopes.
- **Urban air quality:**
    - Vehicle emission standards (fuel economy) of passenger and freight transport,
    - Improvements in the efficiency of large combustion facilities (power supply or industrial),
    - Modal shift in urban transportation,
    - Improvements in efficiency of privately managed heating and hot water systems,
    - The accumulated effect of energy efficiency related to various electric appliances (boilers, electric appliances, air conditioners, fridges, and lightning systems).
- **Transboundary Movement of Pollutant:** To improvement in Bangladesh Ambient Air Quality necessary steps should be taken to reduce the unwanted transboundary air pollution. Neighboring countries should be working together to reduce the pollutants at time of the production. Industries near border areas should be give terms to reduce their emissions and use improved technologies. International policy for transboundary air pollution should be established and authority should tract the pollutant sources and take proper action against it. Convention on Long-Range Transboundary Air Pollution (LRTAP) should be signed between South-Asian countries like Central Asia, Europe, North America and protocols should be establish to stop specific pollutant movement. Each of these Protocols should target pollutants such as sulphur, nitrogen oxide, persistent organic pollutants, volatile organic compounds, ammonia, and toxic heavy metals.

Limitations of the Study

- Inadequate funding, an ongoing COVID-19 situation, planned data collection from neighboring countries, observation and other primary data could not be collected sufficiently.
- Limited information of sectorial and geographical (including trans-boundary) contribution to ambient air quality, resulting in actions based on perception rather than actual contributions.
- Considering time and resource constraints, the scope of this research has been kept limited to the specific source identification and seasonal impacts on air by pollutants.

SECTION VIII

8.1 Conclusion

The fact that air pollution is hazardous to human health is well known. This study presents a clear picture of air pollution trend in and around Dhaka, Bangladesh from past to present, its major causes and effects and promotes a green agenda for the people of Bangladesh and identifies that an integrated approach is required to improve the overall environment of the country. The major effects on the human being are climate change, ecosystem quality and emission of hazardous gases in the atmosphere. From our study, construction activities contribute has been found to be contributing the most for ambient air quality degradation in Dhaka city. It has also been identified that the ceramic industries create significant harmful impact on the environment. Nevertheless, it is unavoidable because of its demand in the global market, the demand of ceramic products increases considerably every year. This causes even more harmful impact to the environment; these pollutants affect entire nature. On the other hand, the transboundary movement of particulate matters from bordering countries are creating more acute condition for general people as the air quality is getting more worse day by day. Therefore, it is necessary to act quickly, neighboring countries should work together to reduce the pollution level and create a condition where every child can cleaner air.

For Bangladesh, climate change is a major environmental challenge, and both greenhouse gases and air pollutants have largely the same source and their effects can be closely linked. Its low elevation, high population density and inadequate infrastructure all put the nation in harm's way, along with an economy that is heavily reliant on farming. On the other hand, according to World Health Organization (WHO) every one person between 10 people suffer different respiratory disease due to air pollution in Bangladesh. So, both climate change and air pollution should be brought under proper regulation to build a sustainable future for the next generation.

It is important to incorporate public opinion on the future action plan to control ambient air pollution for effective involvement of public perception in development policy intervention. The public perception survey 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. Policies related to cleaner industrial processes are moderately important in Bangladesh. It is important for the public to be accountable for the successful implementation of any governmental policies to improve the air quality.

Government should take immediate preemptive measures to prevent air pollution in Bangladesh before it goes beyond control. To reduce or minimize pollution sources govt. can take initiatives such as development of environment friendly construction working plans and introduction of modern and improvised brick manufacturing technology widely to control air quality. Furthermore, the government can improve efficiency of resource management and monitoring process through strengthening enforcement, system accountability, and policy implementation at the local and national level. Both public and private sectors should expand green funding. It is very important to increase awareness among people through mass media and their participation in decision-making. Research in this sector in collaboration with public and private sectors should also be encouraged.

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ANNEX- A

Questionnaire FGD for Air Pollution Survey (Community)

Time: ……………   Date: ………… . . . .

Part-1 [Personal Information]	
Name	
Sex	∆ Male ∆ Female
Age	∆ ≤ 19 20-29 ∆ 30-39 40-49 ∆ ≥ 50
Education	∆Illiterate ∆ Primary education ∆High school education ∆Higher
Part-2 [General Information]	
1. How many days you are living here?	
2. Past situation of this area	
3. Present situation of this area	
4. What are the problems for this situation?	
5. Location of Children Exposer	
6. What is your suggestion?	
Part-3 [Health Impact]	
1. Health impact on Common people and children for Air Pollution	✓ Respiratory Problem ✓ Spread of Infectious Disesses ✓ Headache and Loss of Concentration ✓ Gastrointestinal Problem ✓ Skin problem (Allergy, Rashes, Iching) ✓ Others……
2. Problem Faced During Pregnancy/After Pregnancy for Air Pollution	
Part-4 [Air Pollution Situation & Observation]	
1. Genarl Condition by Observation	
2. Air Pollution related info---	✓ Gas and Dust Emission ✓ Industrial Smoke ✓ Automobile Exhaust ✓ Others……

Questionnaire for Air Pollution Survey (Community)

Time: ……………   Date: ………… . . . .Location…………………

Part-1 [Personal Information]	
Name	

Sex	∆ Male ∆ Female
Age	∆ ≤ 19 ∆ 20-29 ∆ 30-39 ∆ 40-49 ∆ ≥ 50
Education	∆ Illiterate ∆ Primary education ∆ High school education ∆ Higher
Income	∆ ≤ 10,000 - 20,000 ∆ 20,000 - 35,000 ∆ 35,000 - 50,000 ∆ ≥ 50,000

Part-2 [Source of Air Pollution]	
1.Pollution Source of your area?	∆ Construction ∆ Vehicle ∆ Fumes/Dust ∆ Industry ∆ Biomass ∆ Senitary Condition (open or close toilet) ∆ Others…………………………………… ∆ ……………
2. Locaton of your residence from factroy/road	Far ∆ Not far or near ∆ Within the Community

Part-3 [General Informantion]	
1. How many days you are living here?	
2. How many industries Present inside the Community?	
3. Problem associated with nearby Factory	∆
4. Duration of your stay in locality/residence	∆ ≤ 6 hours ∆ 6-8 hours 8-10 ∆ hours ∆ ≥ 10 hours
5. Location of Children Exposer	∆ School ∆ College ∆ University Playing Ground
6. Children Exposed to these conditions	∆ ≤ 6 hours ∆ 6-8 hours 8-10 hours ∆ ≥ 10 hours
Part-4 [Health Impact]	
1. Health impact on Common people and children for Air Pollution	✓ Respiratory Problem ✓ Spread of Infectious Disesses ✓ Headache and Loss of Concentration ✓ Gastrointestinal Problem ✓ Skin problem (Allergy, Rashes, Iching) ✓ Others……
2. Problem Faced During Pregnancy/After Pregnancy for Air Pollution - Observed conditions around the community	
Part-5 [Air Pollution Situation & Observation]	
1. Genarl Condition by Observation	
2. Air Pollution related info---	✓ Gas and Dust Emission ✓ Industrial Smoke ✓ Automobile Exhaust ✓ Others……
Part-6 [Solution of Air Pollution]	
Suggestion	

Questionnaire for Air Pollution Survey (<u>Community-Slum</u>)

Time: …………… **Date:** ……………… **Location**………………………………………

Part-1 [Personal Information]	
Name	∆ ∆ ∆ ∆
Sex	∆ Male ∆ Female
Age	∆ ≤ 19 20-29 ∆ 30-39 40-49 ∆ ≥ 50

Education	Illiterate Primary education High school education Higher
Part-2 [Source of Air Pollution]	

1. Pollution Source of your area?	Δ Construction Δ Vehicle Δ Fumes/Dust Δ Industry Δ Biomass Burning Δ Others…………………………………………………
Part-3 [General Information]	
2. Type of work in the slum	
3. Duration of your working time	Δ ≤ 6 hours Δ 6-8 hours Δ 8-10 hours Δ ≥ 10 hours
4. How many days are you living here?	
5. Type of Waste Generate	
6. Dumping Area of Waste	
7. Dumping Procedure	
Part-4 [Health Impact on People and Children]	
1. Air pollution related Health impact	✓ Respiratory Problem ✓ Spread of Infectious Disesses ✓ Headache and Loss of Concentration ✓ Gastrointestinal Problem ✓ Skin problem (Allergy, Rashes, Iching) ✓ Others……
Part-5 [Air Pollution Situation and observation]	
1. General condition by observation	
2. Environmental impact of Air Pollution	✓ Gas and Dust Emission ✓ Industrial Smoke ✓ Automobile Exhaust ✓ Others……
Part-6 [Solution of Air Pollution]	
Suggestion	

Questionnaire for Air Pollution Survey (Worker)

Time: …………… Date: ………….. Location………………………………

Part-1 [Personal Information]	
Name	
Sex	Δ Male Δ Female
Age	Δ ≤ 19 Δ 20-29 Δ 30-39 40-49 Δ ≥ 50
Education	Δ Illiterate Δ Primary education Δ High school education Δ Higher
Income	Δ 10,000 - 20,000 Δ 20,000 - 35,000 Δ 35,000 -50,000 ≥ 50,000
Source of Income	Δ Only this ΔOthers
Duration of the profession	Δ ≤ 6 months -1 year Δ 1 year – 3 year Δ 3 year – 5 year ≥ 5 years
Part-2 [Source of Air Pollution]	
1. Pollution Source of your area?	Δ Construction Δ Vehicle Δ Fumes/Dust Δ Industry Δ Others…………………………………………………
Part-3 [Occupational Condition and Health Impact]	

1. Factory Type	∆ Cement ∆ Ceremic ∆ Tannery ∆ Manufacturers/SEM Details………………………………………………..
2. Type of work	
3. Duration of your working time	∆ ≤ 6 hours ∆6-8 hours ∆8-10 hours ≥ 10 hours
4. How much time you stayed inside the factory?	∆ ≤ 6 hours ∆6-8 hours ∆8-10 hours ≥ 10 hours
5. Raw materials used for production	
6. Health impact on Working Period for Air Pollution (Choose more than one if you like)	✓ Respiratory Problem ✓ Spread of Infectious Disesses ✓ Headache and Loss of Concentration ✓ Gastrointestinal Problem ✓ Skin problem (Allergy, Rashes, Iching) ✓ Others……
Part-4 [Air Pollution- Situation Observe]	
1. General condition by observation	
2. Air Pollution Relate with…	✓ Gas Emission ✓ Dust Emission ✓ Industrial Smoke ✓ Automobile Exhaust ✓ Others……………..
Part-5 [Solution of Air Pollution]	
1. Pollution reducing steps taken by factory	
2. Suggestion	

ANNEX- B

AQI	Air Pollution Level	Health Implications	Cautionary Statement (for PM2.5)
0 - 50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	None
51 -100	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
151-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects	Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.
300+	Hazardous	Health alert: everyone may experience more serious health effects	Everyone should avoid all outdoor exertion

ANNEX- C

Pictorials of Air Pollution Survey