Research Article

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Advances in Applied Science Research

2020
Vol.11 No.4:8

Spatial and Temporal Trends of Air Quality around Dhaka City: A GIS Approach

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Citation: Rahaman MO, Roksana K, Mukit M, Rahaman MM (2020) Spatial and Temporal Trends of Air Quality around Dhaka City: A GIS Approach. Res Vol.11 No.4:8

Abstract

An Air Quality Index (AQI) is an index used to describe how polluted the air currently is or how polluted it is forecast to become. People's health risks increase as the air quality index (AQI) rises. Particulate and gaseous pollutant emissions from industries and auto-exhausts are responsible for rising discomfort, increasing airway diseases, decreasing productivity, and the deterioration of artistic and cultural patrimony in urban centers. Understanding the temporal and spatial distribution of air quality at the landscape scale is essential in assessing the potential ecological conditions for ecological restoration and making regional management decisions. Keeping the air quality acceptable has become an essential task for decision-makers as well as for non-governmental organizations. Corresponding to different regional air quality standards, different Dhaka regions would have their air quality index. This study's main purpose is to analyze the concentration data of air quality parameters in ambient air of Dhaka and visualize the trends of the major concentrations of the air parameters through ArcGIS.

Keywords: Air Quality Index; Spatial and temporal trends of air quality; Chronological climate changes

Received: November 16, 2020; **Accepted:** December 04, 2020; **Published:** December 11, 2020

Introduction

Air pollution is one of a variety of manmade environmental problem. Air pollution may be defined as an atmospheric condition in which various substances are present at concentrations high enough above their normal ambient levels to produce a measurable effect on people, animals, vegetation or materials. Recently, air pollution has received priority among environmental issues in Asia, as well as in other parts of the world. Dhaka is a major cultural and manufacturing center. The common types of industries in and around the periphery of Dhaka are ready-made garment manufacturing, jute, tanneries, textile, tea processing, fertilizer, cement, paper and pulp, chemicals and pesticides, food and sugar, pharmaceuticals, petroleum refinery, distillery, rubber, plastics, and brick manufacturing, assembling buses, trucks, and motorcycles, assembling radios and televisions. Air of Dhaka is being polluted day by day very badly. A new source of air pollution is an increasing 'hole' in the ozone layer in the atmosphere above Antarctica, coupled with growing evidence of global ozone depletion. Air pollution has also long been known to have an adverse effect on human beings, plants, livestock and aquatic eco system through acid rain.

Dhaka is fast turning into an inhabitable city. Dhaka city air reported to containing higher proportion of lead and carbon monoxide must be considered very alarming. Air pollution has become a matter of great concern for us in recent years. Those who are living in cities in Asian countries including Dhaka have already realized how seriously air pollution has been poisoning life and degrading the environment.

Faulty vehicles, especially diesel run vehicles, brick kilns, and dust from roads and construction sites and toxic fumes from industries contribute to air pollution. Industrialization and mechanized vehicles are two major sources of air pollution in our country. The number of automobiles has been increasing in Dhaka city at the rate of at least 10 to 20% annually, which has been contributing to air pollution on the one hand and traffic congestion on the other. The International Atomic Energy Agency stated in its News Briefs that pollution levels of lead in Bangladesh are among the world's highest during dry season, according to Bangladesh Atomic Energy Commission, with levels falling during periods of medium and heavy rainfall.

The volume of poisonous particles in the city air has reached far beyond the permissible level for human body in recent years.

The Dhaka city dwellers are always at a serious health risk due to the highly polluted air, warned health experts. The increasingly high concentration of toxic elements in the air is causing a foggy blanket in the city sky at present. The website reveals that the air quality of the city is lethal for human body especially during winter and post winter.

According to the website, poisonous carbon monoxide, Sulphur dioxide, nitrogen dioxide, suspended particulate matter and particulate matter exist in Dhaka's air beyond permissible level for human body. The main purpose of this paper is to present, analyze and discuss the air quality data generated at 5 locations around Dhaka city through ArcGIS software.

Specific objectives of this project are:

1. To analyze the concentration data of SO_2, NOx, CO, O_3, PM_{10} and $PM_{2.5}$ in ambient air of Dhaka city
2. To evaluate the major parameters in accordance with BNAAQS and identify AQI
3. To visualize the spatial and temporal trends of the major concentrations of the air parameters through ArcGIS

Literature Review

The 2018 Environmental Performance Index (EPI) suggests air quality became the primary environmental concern to human health globally [1], pollution from fuel cost US$2.9 trillion globally in 2018 which was quite 3% of worldwide GDP. Moreover, it caused 4.5 million deaths leading to 1.8 billion absences of working days, 4 million child-asthma, and a couple of million preterm childbirths [2]. EPI considers three indicators to work out air quality: household solid fuel use, particulate ($PM_{2.5}$) average exposure, and $PM_{2.5}$ exceedance where PM exposure may cause adverse physical conditions [3,4,1]. Furthermore, these particulates could infiltrate the human lung and cause cardiovascular and respiratory diseases [5]. Aside from this, WHO Air Quality Guidelines also present a foundation for global limits on air pollutants that cause considerable public health risks [4] consistent with a joint study conducted by the planet Bank and therefore the Institute for Health Metrics and Evaluation, almost 90% of the people round the world sleep in areas that exceed WHO thresholds of pollution (Bank 2016). The worldwide concern is that it's the fourth leading explanation for premature death, which accounts for about five million deaths per annum whereas severe respiratory diseases are the second-largest explanation for death in children under five [6]. Therefore, improving air quality levels worldwide is important to enhance overall human health also on avert environmental hazard. World ranking of nations supported estimated average $PM_{2.5}$ concentration reveals that four out of the five most polluted countries are in South Asia—Bangladesh, Pakistan, India, and Afghanistan. Delhi, the capital of India, has ranked highest $PM_{2.5}$ emitter followed by Dhaka, the capital of Bangladesh, as in second position (AirVisual 2018). Since economic process is the key driver of upper pollution, developing economies have different problems than developed ones, making pollution an important indicator for sustainable development. Bangladesh, being an emerging economy, is losing 1% of her GDP per annum thanks to pollution consistent with the Country Environmental Analysis (CEA), an International Bank for Reconstruction and Development analytical tool. Besides, previous study findings on global pollution revealed that it caused 0.123 million deaths in Bangladesh in 2017 (Institute 2017). The country has about 5000 brick kilns in several areas including 1000 round the capital city Dhaka, which are liable for emitting about half the $PM_{2.5}$ within air during season [7,8,9]. Dhaka being one among the foremost densely populated cities within the world is susceptible to pollution where smoke generated from brick kilns, motor, and traffic run on fuel with higher level of sulfur and mud produced from constructions are causing pollution. The town is already suffering from water logging thanks to increase amount of waste as a result of unplanned urbanization and industrialization. Besides, wetland encroachment and led exposure are added more risk to many people here [10]. More than 50% of pollution occurs here thanks to illegitimate and technologically backdated brick kilns. Therefore, public also as environmental health is under potential threat. Rapid increase leading to brisk and unplanned urbanization, increasing number of vehicles in Dhaka and other cities of the country, use of fossil fuels, and industrial emissions are inevitably causing severe pollution. During this respect, Dhaka ranked because the second least livable city within the world by the worldwide Livability Index 2018, and EPI 2019 positioned it 179th among 180 countries [1]. Against this backdrop, to affect pollution problem is of great importance for a developing country like Bangladesh to understand the potential harm related to it. Air pollution is caused by both the natural or anthropogenic discharge of detrimental elements into the ambiance. It becomes a serious concern for the town residents in mega cities. To tackle local, regional, also as trans boundary air quality problems, government initiative is important because pollution not only harms its ambient but also transgresses the boundaries. Bangladesh introduced air quality standards in 1997, under the environmental conservation rules 1997 (Standard 1997). The Department of Environment (DoE) is additionally working to stay pollution in restraint by operating the Clean Air and Sustainable Environment (CASE) project (Ministry of Environment and Forests 2018). Particulate (PM_{10} and $PM_{2.5}$) is one among the most concerns of pollution for Bangladesh. Studies on chemical speciation of PM collected at Dhaka have postulates that gaseous pollutants make a crucial contribution to the particulate pollution of Dhaka [12]. Besides, several studies are directed to look at particulate pollution in Dhaka, and Chittagong, the 2 largest cities of Bangladesh [8,11].

Methodology

By using GIS, we can find out what is occurring within a distance of a feature, by identifying an area-affected by an event or activity. The GIS analysis used in this research report is thematic

classification and query of feature attributes to examine spatial patterns and relationship between pollution monitoring sites selected and network. The flowchart of the adopted methodology has been shown below **(Figure 1).**

The Air Quality Index is a value which represents an area's air quality status. In general, the AQI value of 100 corresponds to the national pollutant air quality standard, which is the level set by the mandated environmental protection agency for the protection of environmental threats. Air quality is considered to be unhealthy when AQI values are above 100, first for certain sensitive groups of individuals, then for everyone as AQI values get higher. **(Table 1).**

Six categories of AQI exist, namely Good, Satisfactory, Moderately Polluted, Poor, Very Poor and Severe. Eight pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, and Pb) for which short-term (up to 24-hour average period) National Ambient Air Quality Standards are prescribed will be considered in the proposed AQI. A sub-index is calculated for each of these pollutants based on the measured ambient concentrations, corresponding standards and probable health impact. The worst sub-index reflects AQI in general. Probable health effects have also been suggested for various categories of AQI and pollutants, with primary input from the group's medical experts. For the identified eight pollutants, the AQI values and corresponding ambient concentrations (health breakpoints) as well as associated probable health impacts are as follows **(Table 2).**

Source of data

The source of air quality parameters are the Ministry of Environment, Forest and Climate Change (MoEF). They executed a project named Clean Air and Sustainable Environment (CASE) project for monitoring air quality. This monitoring is performed demonstrate attainment or non-attainment of national ambient air quality standards to assess the trends of air pollution levels. They also provide meteorological data like solar radiation, relative

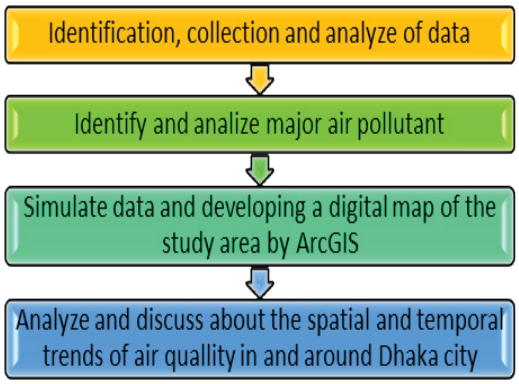


Figure 1 Data source flowchart.

Table 1 Air Quality Index for Bangladesh.

Air Quality Index (AQI) for Bangladesh		
Air quality index	**Category**	**Color**
0-50	**Good**	**Green**
51-100	**Moderate**	**Yellow Green**
101-150	**Unhealthy for sensitive people**	**Yellow**
151-200	**Unhealthy**	**Orange**
201-300	**Very Unhealthy**	**Red**
301-500	**Extremely Unhealthy**	**Purple**

Table 2 Air quality parameter breakpoints.

AQI Category (Range)	PM_{10} 24-hr	$PM_{2.5}$ 24-hr	NO_2 1-hr	O_3 8-hr	O_3 1-hr	CO 8-hr (ppm)	SO_2 24-hr
Good (0-50)	0-54	0-12	0-53	0-54	-	0-4.4	0-35
Satisfactory (51-100)	54-154	12-35.4	53-100	54-70	-	4.4-9.4	35-75
Moderate (101-150)	154-254	35.7-55.4	100-360	70-85	70-164	9.4- 12.4	75-185
Poor (151-200)	254-354	55.4-150.4	360-649	85-105	164-204	12.4-15.4	185-304
Very poor (201-300)	354-424	150.4-250.4	649-1249	105-200	204-404	15.4-30.4	304-604
Severe (301-500)	424+	250.4+	1249+	200+	404+	30.4+	604+

humidity, ambient temperature, rainfall etc. Monitoring data from network stations are transferred to a central data centre at the Department of Environment office in Dhaka and simultaneously transferred to Air Quality Management System based on NILU AIRQUIS system established under BAPMAN project. The data are stored in AIRQUIS database for quality check, control, evaluation, validation, statistical analysis. Quality controlled data are then stored in the final database for further analysis, reporting, presentations and future use **(Figure 2).**

Study area

Real-time measurements of ambient level pollutants were made at major cities (Namely, Dhaka, Narayangonj, Gazipur, Chittagong, Rajshahi, Khulna, Barisal and Sylhet) of Bangladesh. Our study area is in and around Dhaka city which includes Dhaka, Gazipur and Narayanganj, having 5 fixed Continuous Air Monitoring Stations (CAMS). We found out mainly two types of Data; air quality parameter data and meteorological data **(Figure 3).**

Results and Discussion

Major air pollutant selection

Six contaminants (i.e., particulate matter, sulfur dioxide, nitrogen oxides, ozone, carbon monoxide and lead) are called air pollutants (CAP) requirements for their abundance as ambient pollutants and their potential to affect human health, plants and assets. The Government of Bangladesh (GoB) has set standards for each CAP to monitor its presence in the air **(Figure 4).**

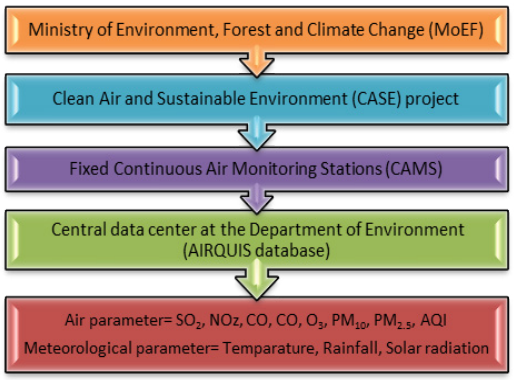
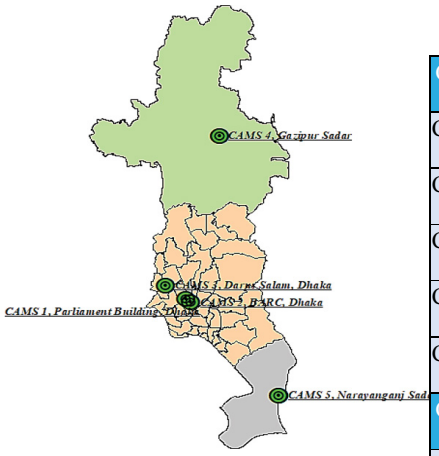


Figure 2 Data source flowchart.



CAMS ID	Location	Lat/Lon
CAMS-01	Parliament building area, Sher-e-Bangla Nagar	23.76255N 90.382E
CAMS-02	BARC, Farmgate	23.757N 90.3888E
CAMS-03	Darus-Salam	23.7806N 90.35528E
CAMS-04	Gazipur Sadar	23.9938N 90.418"E
CAMS-05	Narayanganj Sadar	23.6304N 90.5083E
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Figure 3 Map and location of study area.

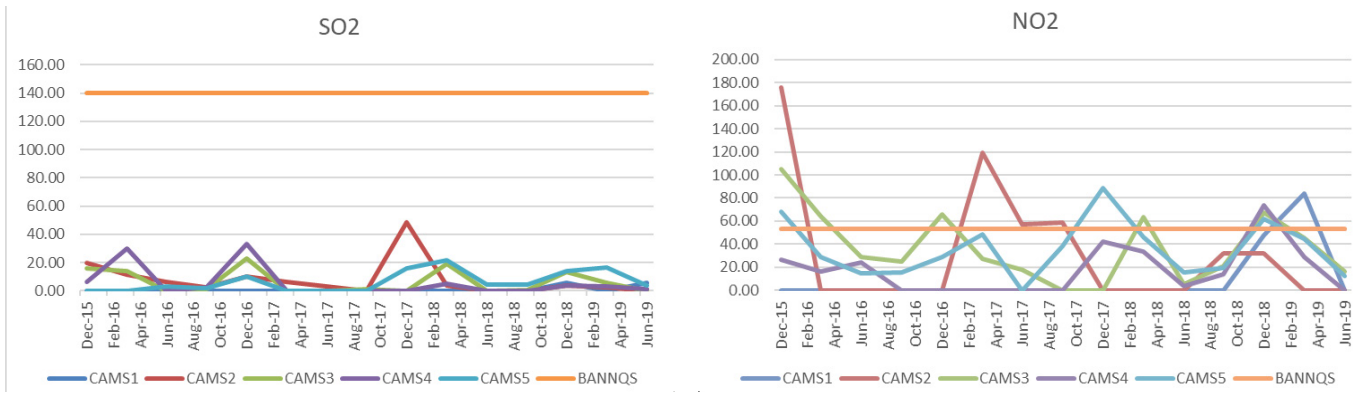

Figure 4 Air pollutant concentration and BNAAQS limit.

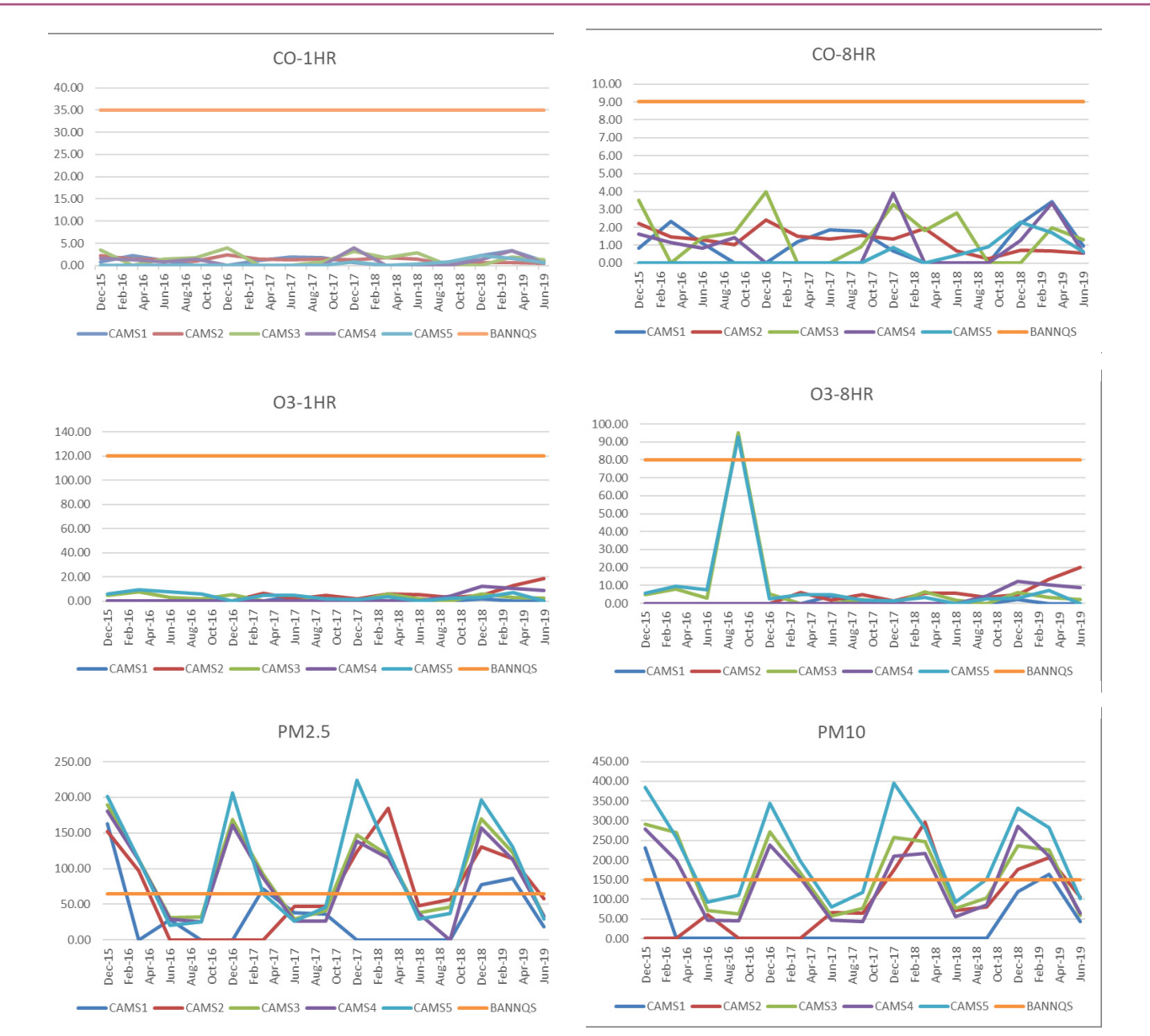

Figure 5 Spatial and temporal analysis of pollutants.

Data collected from CAMS operated by the DoE air quality monitoring network from December 2015 to June 2019 have been analyzed and reported as a plotted graph in the **Figure 4.** The availability of data was 60-90 percent for all pollutant parameters tracked by various CAMS, with few exceptions. Air quality results for a few contaminants were not recorded because either the analyzer was not operating or the data collection rate was too poor. From the analysis of the data and the graphs of different pollutants concentration over the time, the findings that are -

I. PM_{10} and $PM_{2.5}$ are the most critical pollutants. From BNAAQS point of view, 24-hour average for both PM_{10} and $PM_{2.5}$ concentrations were exceeding the limit significantly.

II. NO_2 concentration was exceed many times. Though it was not regular but it was also alarming.

III. The gaseous pollutants measured at different CAMS did not exceed limit values of the BNAAQS. So, they were not harmful in accordance with the limit standard.

Major air pollutant projection through ArcGIS

Air quality data were statistically analyzed in this study to understand the spatial and temporal trend analysis of the components around Dhaka city. In order to observe time-wise and location-wise air quality positions in the country, statistical parameters (mean, percentiles, etc of specific particulate matter (PM) are calculated for each year. The comprehensive analyses of AQ data characterize the air quality of the country's urban centers as follows **(Figure 5).**

a) The seasonal impacts are highly affected by air quality patterns in all area around Dhaka city, especially regular and intense downpour in the wet season (May to October) helping to improve the cities' air quality. The key concern is the dry seasonal (November-April) PM pollution throughout Dhaka.

b) The gaseous compounds (i.e., SO_2, CO, NOx, and O_3) in the city air, regardless of the seasons, comply well with the respective government-set requirements. The NO_2 concentration is located very close to the limit values only in some instances.

c) Fine particles ($PM_{2.5}$) typically dominate PM concentrations all the time around Dhaka during the dry season, while sometimes coarse particles (PM_{10}-$PM_{2.5}$) are found to be equal to or sometimes greater than the fine particles.

d) The findings indicate Narayanganj as the most polluted around Dhaka. $PM_{2.5}$ is also alarming near Gazipur, though, in Dhaka and Gazipur, PM concentrations in the dry season are mostly similar, although the Dhaka is urban, congested than Gazipur.

e) A decreasing trend in annual concentrations of PM_{10} and $PM_{2.5}$ is observed in Dhaka. In 2018-19, the Dhaka station experienced much lower concentrations of PM_{10} and $PM_{2.5}$ (annual) compared to 2015-16. This decrease in annual PM air concentrations can be attributed to the ongoing reforms of governmental measurements and awareness.

Conclusion

Air quality index (AQI), a comprehensive index that covers and integrates pollutants simultaneously and can reflect the comprehensive status of ambient air quality. It can investigate the spatial and temporal variation of air quality in Dhaka city, Bangladesh. With the help of AQI, one can limit one's activity outdoors if one can, and if one must be outside, do so late in the day or early in the morning when air pollution levels are at their lowest. GIS map would also be useful for Residents at to make an assessment as according to the air quality index for that particular area especially for the residents with the respiratory disorders can select a safer place to reside. As according to the prevalence of higher pollutant levels we can determine the potential pollutant source and can regulate it after studying the GIS Spatial Interpolation Maps. Finally, Understanding the air quality index is important because it would keep us informed about how to protect our health from air pollution.

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