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Air Pollution in Dhaka City During Wintertime: Local vs. Transboundary Transport

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Abstract

Air pollution is considered as the largest environmental health threat in the world. Last few years, it has also increased dramatically in different cities of Bangladesh. The air pollution of Dhaka city as well as other urban areas is very crucial for a sustainable environment. This research is mainly concentrated on studying a variety of air pollutants both qualitatively and quantitatively during wintertime and checking the transboundary air pollution of Dhaka City. In the study area, air pollution was found to be at very dangerous levels. Even, air pollution has been found to be significantly higher in concentration during nighttime in Dhaka City. According to public perception and health physicians, air pollution causes many health problems such as eye irritation, headaches, COPD problem, skin cancer, hypertension, cardiovascular diseases, nausea, and asthma. Regular air quality monitoring can be effective for proper control measures of pollutants emissions that may protect the inhabitants from various illnesses. It can provide a guideline for the sustainable development of environment of city dwellers.

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Introduction

Dhaka has been announced one of the worst cities with higher death rates (86 deaths/100,000 people) owing to prolonged exposure to $PM_{2.5}$ than the global urban median (58 deaths/100,000 people)(Health Effects Institute, HEI, 2022) with an annual average exposure of 71.4 $\mu g/m^3$ for $PM_{2.5}$. According to the world air quality report 2021, Bangladesh is the 1st ranked polluted country and Dhaka city is the 2nd ranked polluted city in the world. Random urbanization, industrial advancement, and over utilization of natural resources are the root causes of air pollution in Bangladesh. Therefore, these activities are now recognized as the big threats for sustainable development, particularly for environment, human health (Alam, *et al*., 2018; Fowzia and Rashedur, 2020; Rahman *et al*., 2019), cloud properties (Haque *et al.,* 2022), and climate change (Begum *et al*., 2013 and 2017) contributing to the low air quality of most of the

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cities in Bangladesh (Hopke *et al*., 2019). Some air pollutants, for example, oxides of nitrogen (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), and particulate matters ($PM_{2.5}$ and PM_{10}) are found in high concentration in the atmosphere. Among the diverse air pollutants, particulate matter (PM) is the prime environmental threat on the Earth (HEI, 2018). The exact composition and size of PM may vary by region, time, meteorological conditions and so on (WHO, 2001). Some notable man-made sources of PM such as industrial activities, fossil fuel burning, construction and demolition activities, brick kilns, road dust, domestic waste, sewerage waste and smoking are rendering Dhaka as one of the most seriously polluted cities in the world (Rouf *et al.,* 2011; USEPA, 2009).

Because of geographical location, Bangladesh is extremely exposed to the effects of climate change. According to Bollasina group (2011), the impacts of climate change in Bangladesh are the changes in seasonal weather patterns, sea level rise, salinity, drought, heavy rain and flooding. Dhaka city and its surrondings suffer greatly from high levels of PM during dry season (November-April) (WHO, 2014; Hossain *et al*., 2019). The region sees many outbreaks of air pollution during deep winter (November to January), when $PM_{2.5}$ concentrations in the atmosphere are 10 to 14 times greater than the WHO recommended threshold (Rana *et al.,* 2016). The maximum pollution comes from regional sources, including constructions, dusts, vehicles, and brick-kilns (Azkar *et al*., 2012). In addition, the Gangetic Delta regions and other Asian countries, such as India, Nepal, Pakistan, China, and Mongolia etc. record extreme pollution problems in this time of the year (Singh *et al*., 2015). Besides, the trans boundary transport of PM towards Dhaka city is also significant as $PM_{2.5}$ with days to weeks of atmospheric lifetime can travel hundreds or thousands of kilometers (Seinfeld, & Pandis, 1998) and pollute trans boundary regions. According to a study by Lawrence, & Lelieveld, 2010, a fraction of pollution comes in Bangladesh from the northeast Indian regions during wintertime. Thus, this study examined the likelihood of transboundary PM transfer into Dhaka city alongwith local pollution and found hotspots of PM pollution in the dry season.

Materials and Methods

Aerosol sampling

$PM_{2.5}$ aerosols were collected everyday on day/night basis (each 12 hours period) during wintertime(11 January, 2020 to 9 February, 2020) at Jagannath University(JnU) sampling station(23.42° N, 90.24° E). For sampling, a medium-volume air sampler was placed at the top of science building (4 storeyed), using pre-combusted (450°C, 6h) quartz fiber filter (Pallflex 2500 QAT-UP, 90 mm diameter). After loading, the filters were wrapped with aluminum foil paper and stored at -20°C into the non-frost refrigerator until the analysis. All the procedures during sampling time were strictly conducted to avoid any type of contamination of the samples. It was also recorded some meteorological parameters *viz*. wind direction, wind speed, humidity and temperature etc.

Collection of CAMS data of BARC, Dhaka

To compare and validate the $PM_{2.5}$ data of JnU sampling station, it was collected the data of particulates masses ($PM_{2.5}$ and PM_{10}) from the archives of Continuous Air quality Monitoring Stations(CAMS) at Bangladesh Agricultural Research Council (BARC) in Dhaka under the Department of Environment (DoE), Bangladesh. We further used the daily average data of nitrogen oxides (NOx), sulphur dioxide (SO_2), ground level ozone (O_3), carbon monoxide (CO) of CAMS (BARC). The collected data was employed to measure the pollution level of Dhaka city during 2020 wintertime (exactly 11 January, 2020 to 9 February, 2020).

Sample analysis

To measure the masses of $PM_{2.5,}$ a microbalance (METTLER Model MT5) was used gravimetrically for taking the weight of filters before and after exposure [Begum *et al*. 2006]. Before weighing, the static charge of each filter was eliminated by A Po-210 electrostatic charge eliminator (STATICMASTER). Additionally, the loaded air filters were equilibrated at constant temperature in the balance room for 48 hours before every weighing. The temperature and humidity of the balance room was controlled by keeping 22°C and 50%, respectively. For humidity correction, the unloaded filters were used.

Results and Discussion

To know the trend of air quality of Dhaka urban area, the collected $PM_{2.5}$ aerosols at JnU station were analyzed and showed the results with day-night variation. Besides the fine particulate matter, the PM_{10}, CO, SO_2, NO_X, O_3 (Ground level) variables of CAMS (BARC) were assessed for 2020 wintertime.

Table 1. Daily average concentration of $PM_{2.5}$ at JnU Station & CAMS (BARC)

Date	$PM_{2.5}$ (Daytime) at JnU	$PM_{2.5}$ (Nighttime) at JnU	$PM_{2.5}$ of CAMS (BARC, Dhaka)
11 Jan,20	98.41	201.33	133.5
12 Jan,20	84.13	509.33	153.9
13 Jan,20	200.00	328.00	180.1
14 Jan,20	227.00	610.67	211.9
15 Jan,20	501.60	661.33	216.4
17 Jan,20	71.43	240.00	140.6
18 Jan,20	169.84	636.00	150.5
19 Jan,20	231.75	233.33	226.6
20 Jan,20	236.51	168.00	133.5
22 Jan,20	193.65	285.33	149.3
24 Jan,20	76.19	80.00	145.9
25 Jan,20	207.94	270.67	146.3
28 Jan,20	317.46	502.67	209.4
31 Jan,20	147.62	160.00	144.8
02 Feb,20	219.05	260.00	133.1
03 Feb,20	217.46	253.33	146.6
04 Feb,20	146.03	284.00	164.2
05 Feb,20	214.29	329.33	170.9
07 Feb,20	157.14	68.00	148.8
08 Feb,20	223.81	329.33	174.2
09 Feb,20	169.84	261.33	170.6

Concentration of Particulate matter($PM_{2.5}$ and PM_{10})

The $PM_{2.5}$ aerosol samples of JnU station revealed that the concentration of $PM_{2.5}$ masses in Dhaka city is greater than that of Bangladesh National Ambient Air Quality Standards(BNAAQS) (65µg/m^3 for 24 hrs.) shown in Table 1. The result also stated that the $PM_{2.5}$ concentration was higher in nighttime than in daytime. It is significant that the $PM_{2.5}$ concentration of JnU station both in daytime and nighttime is notably higher than that of CAMS of BARC in Dhaka.

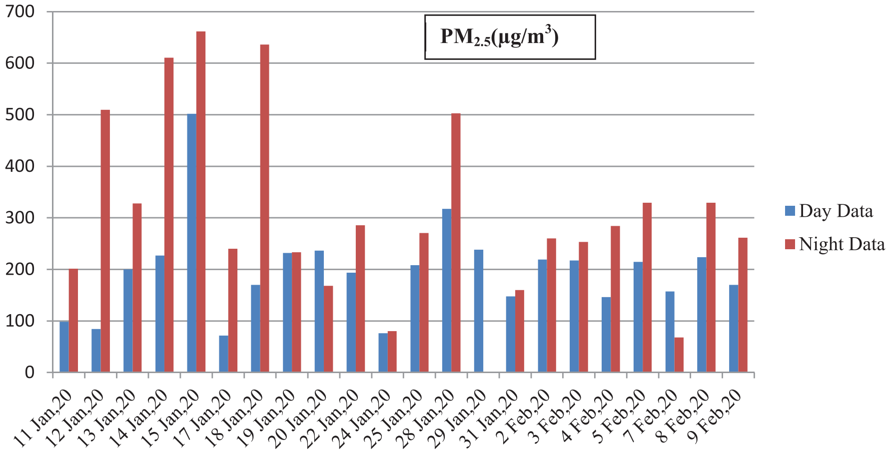

Fig. 1. Daily average concentration of $PM_{2.5}$ of Dhaka city

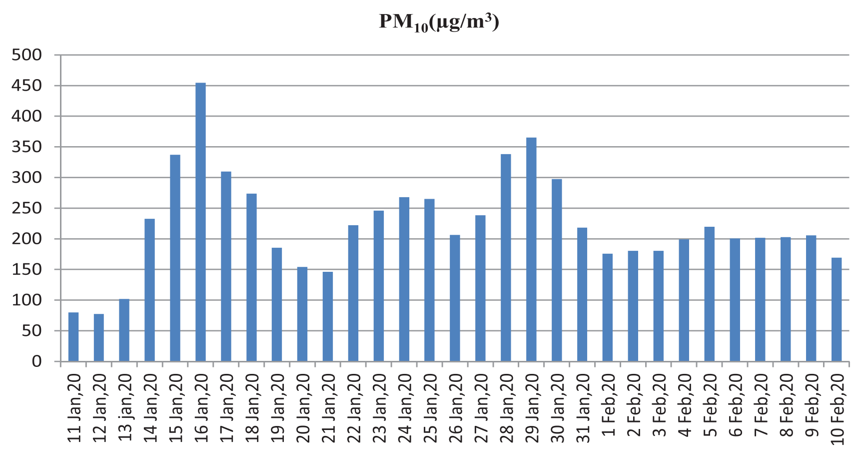

Fig. 2. Daily average concentration of PM_{10} of Dhaka city

The greater PM concentrations at night may be attributed for the reduced dispersion of the boundary layer at night. The higher nighttime concentration of fine particulate matters in Dhaka city was due to heavy duty vehicles were only authorized to operate at night by Dhaka City Corporation, as well as coal burning industries in Northern India, contributed to greater PM concentrations in nighttime. The highest $PM_{2.5}$ concentration was observed in nighttime on 15 January 2020 (660 µg/m^3) given in Figure 1. The higher level of $PM_{2.5}$ in Dhaka city can be explained by the enormous increasing of motor vehicles, infrastructure, and industrial expansion which lead a steady deterioration in the ambient air conditions. This city is also surrounded by many brick fields operating by burning low-quality coal and biomass without effective pollution management, contributing higher level of PM around the city (UNDP, 2015; Haque *et al*., 2018). It was observed that the concentration of $PM_{2.5}$ masses collected at JnU is comparatively higher than that of $PM_{2.5}$ masses of CAMS in this city. Furthermore, the PM_{10} pollution of this city was also higher than that of BNAAQS(150µg/m^3 for 24 hrs.) shown in Fig. 2. In 2020 January, Dhaka city met relatively higher PM_{10} pollution as compared to February.

Carbon monoxide (CO)

Dhaka city mainly meets the carbon monoxide emission from the fossil fuels and biomass burning, industrial process, and natural activities (Randall *et al.* 2015). During the study period, the CO pollution was noticed well below from the BNAAQS limit (9 ppm for 8 hrs). Thus, CO is not a critical air pollutant for this city. It is notable that the highest peak of CO was found in the middle of January, 2020 (Fig. 3).

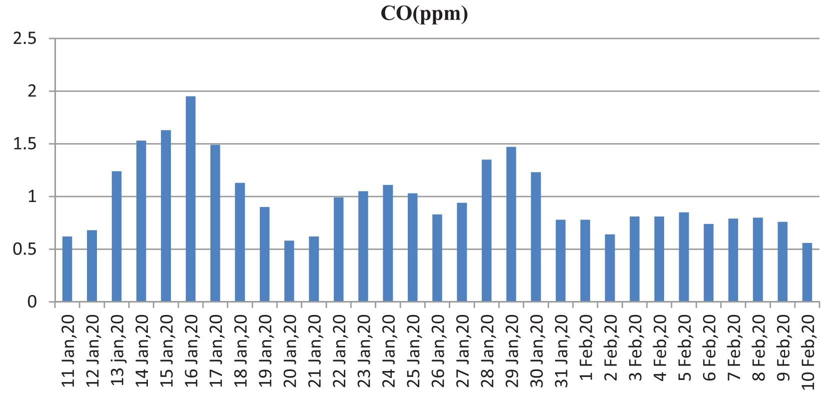

Fig. 3. Average concentration of CO (ppm, 8hrs) of Dhaka City

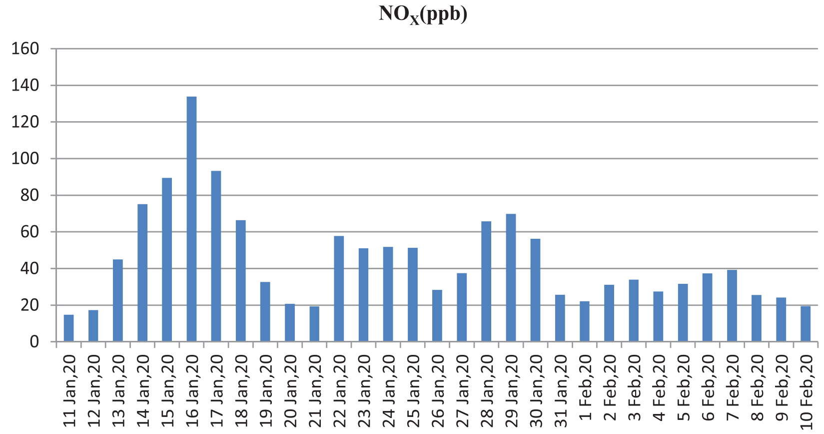

Fig. 4. Average concentration of NOX (ppb) of Dhaka City

Nitrogen oxides (NOx)

NOx pollution in urban cities is often from motor vehicle emissions. The pollution further comes from the coal and oil igniting in power plants, metal refinement industries, and some food processing industries (Artíñano, 2004; Dept. of the Environ. and Heritage 2005; Smargiassi, 2005). A recent study also reported that brick kilns is an another significant source of NOx pollution along with other pollutants such as PM, SO_2 etc. (Guttikunda, 2012). The trend of nitrogen dioxide concentration in Dhaka city is a little bit irregular and in many cases, it exceeds the BNAAQS (53 ppb, 2005). The NOx data of CAMS implies that this pollution was higher in January as compared to February 2020 showing the highest peak on 16 January (Fig. 4). The NOx level in Dhaka City gives a clear message that the pollution is not as significant as particulate matter pollution.

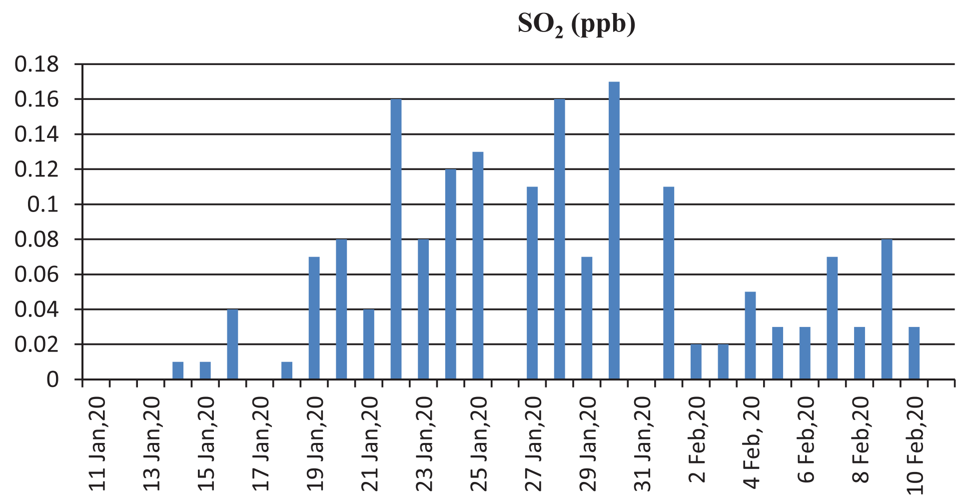

Fig. 5. Average concentration of SO_2 (ppb)

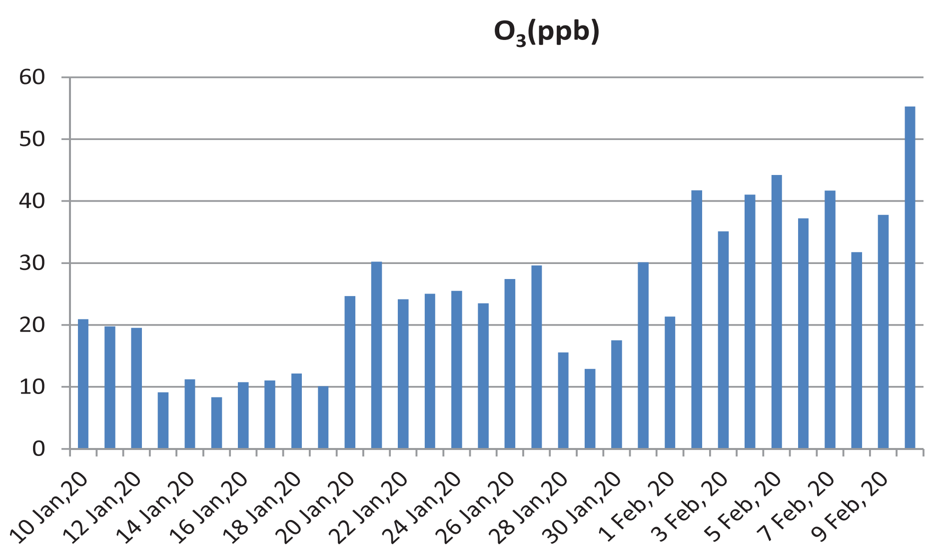

Fig. 6. Average concentration of O_3 (ppb)

Sulfur dioxide (SO_2)

The sulfur dioxide pollution in Dhaka Metropolitan city is not a major concern like ambient particulate matters as its concentration is well below the BNAAQS (75ppb) given in Fig. 5. The result demonstrates that SO_2 pollution peaked in late January before drastically declining in early February, 2020.

Ozone (O_3)

Ground level ozone (O_3) is a secondary air pollutants generating from the chemical conversion of NOx and volatile organic compounds (VOC) in presence of sunlight (Guo 2012). According to BNAAQS, its acceptable limit is 80 ppb (8 hrs average). During the study time, the O_3 pollution in Dhaka Metropolitan area was below from the BNAAQS limit showing the highest level pollution in February.Thus, this result indicates that the ground level ozone in Dhaka city area is not much more health hazard like particulates pollution (Fig. 6).

Sources of pollutants

The study of backward trajectories indicates that air masses were mostly originated from Northern India during wintertime in Bangladesh (Fig.7). It implies that the long-range transport also largely contribute to air pollution in Dhaka. However, local pollution from the surrounding area of Dhaka urban area can not be ignored. The highest peak in $PM_{2.5}$ concentration during the winter is due to seasonal variations as well as meteorological influences. A fraction of $PM_{2.5}$ may be from regional contribution, in addition to local source contribution because of their comparatively long residence times. The wind direction pattern

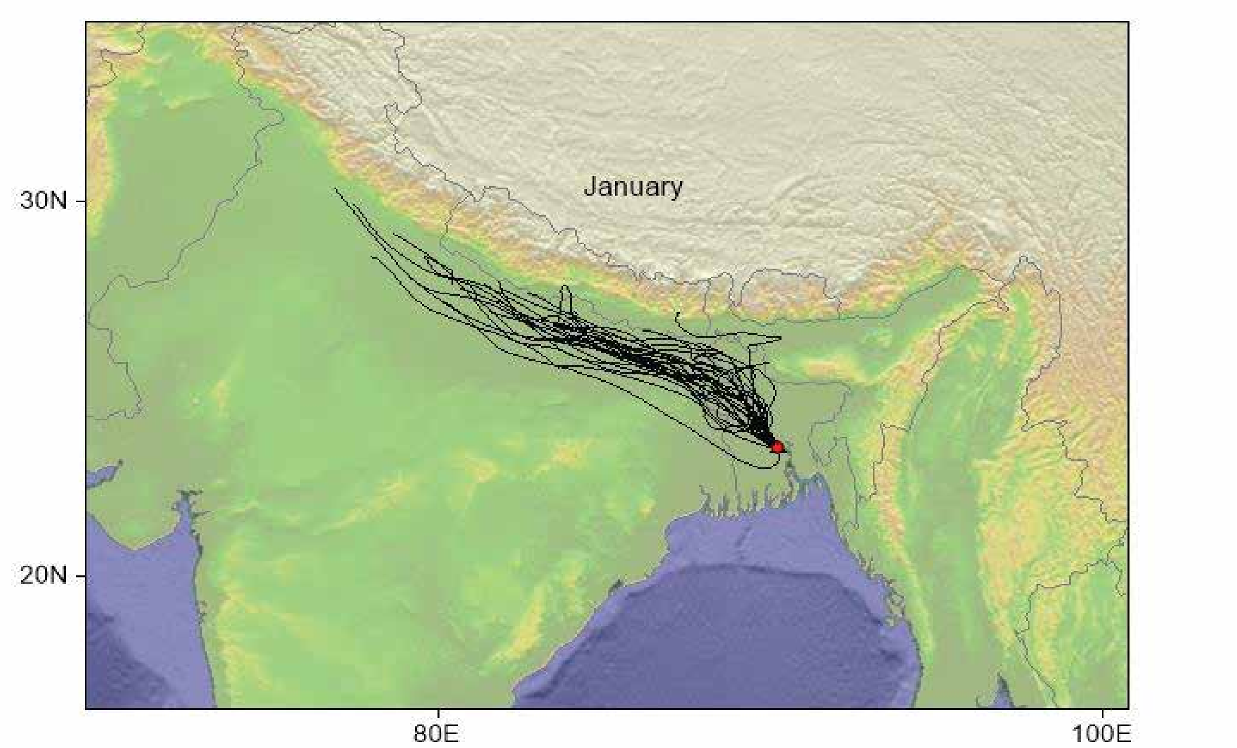

Fig. 7. Backward trajectories for Dhaka City

revealed that the predominant wind directions throughout the winter are north and northwest. In Figure 7, the calculated air mass trajectories for days with significant effects of fine particles are depicted using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT4) model (Draxler and Rolph, 2003). Moreover, Islam *et. al.,* (2014) also claimed that trans-boundary air pollution also affects the PM concentrations in Dhaka city during winter. Furthermore, according to Begum *et al.* (2013), fine particles less than 2.2 μm (aerodynamic diameter) in size make up between 30 and 50 percent of the PM_{10} mass in Dhaka. Additionally, they assert that these particles are primarily anthropogenic in origin and originate from transportation-related sources. Therefore, the PM concentrations was much higher than the BNAAQS limit due to a variety of climatic variables, long-distance winter travel, and local sources (Sarkar *et al.,* 2015; Islam, 2021).

Conclusions

The study describes the present situation of air quality of Dhaka city using information gathered from JnU monitoring stations and CAMS at BARC in Dhaka, Bangladesh, throughout the study period. The particulates and NOx pollution in Dhaka city exceeded WHO standards and SO_2, O_3 pollutions are found below the BNAAQS/WHO limits. The data also reveals that the middle of January when the concentrations of $PM_{2.5}$, PM_{10}, NOx are at their peak is dangerous for Dhaka Metropolitan area. However, as the day goes on, the amount of ground level O_3 rises. Moreover, high temperatures are frequently linked to severe ozone pollution. The quantities of air contaminants on excessively typical days are significantly influenced by meteorological circumstances. Thus, the pollution level and weather condition of Dhaka city are very conducive to the formation of haze pollution.

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