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ASSESSMENT OF AMBIENT AIR QUALITIES AT SOME LOCATIONS OF GAZIPUR CITY

M. Rehnuma*, M. Ahmed, M. A. Haque, H. R. Tori and U. Habiba
Department of Environmental Science and Resource Management
Mawlana Bhashani Science and Technology University, Tangail-1902, Bangladesh
*Corresponding author's mail: rehnuma.mausumi@gmail.com

ABSTRACT

The study was conducted to assess ambient air qualities at some locations of Gazipur City. The sampling was done at eight stations of Gazipur City for 30 minutes duration using 'Aeroqual Series 500' during the month of January (dry season), 2023. The concentrations of $PM_{2.5}$, PM_{10}, CO_2, CO, O_3, NO_2, CH_4, NH_3, SO_2 ranged from 0.21 - 0.43 mg/m^3, 0.35 - 1.00 mg/m^3, 1103 - 1507.67 mg/m^3, 0.03 - 3.86 mg/m^3, 0 - 0.03 mg/m^3, 0.094 - 0.097 mg/m^3, 0 - 4.66 mg/m^3, 0.06 - 0.30 mg/m^3, 0 - 0.23 mg/m^3, respectively. The detected levels of $PM_{2.5}$, PM_{10} and SO_2 exceeded APCR (2022); WHO and US standards. NO_2 was found below the limit of APCR (2022) standards but exceeded WHO limit. The higher values of CO_2, CH_4, and NH_3 were observed due to industrial and vehicular emissions. Heavy coal burning in the brickfields near Gazipur City may have contributed to the high concentration of SO_2. To reduce emissions, appropriate engine design control techniques, maintenance services and an efficient solid waste management system should be implemented. The development of a regulatory framework to restrict emissions from construction sites and adapting immediate action programs is required to overcome the threat of existing air pollution in the study area.

Key words: Air quality, assessment, Gazipur city.

Introduction

Air pollution is a major threatening environmental health risk for Bangladesh. Air pollution is caused by agro-based businesses including sugar, pulp, paper, tanneries, and textile, apparel, pharmaceutical, oil refinery, fertilizer, and chemical manufacturing in this country (Haque, *et al.*, 2020). The level of pollution in metropolitan centers of Bangladesh remain rising due to the emission from diesel run vehicles, brick kilns and dust from roads and construction sites and toxic fumes from industries. Prior to 1999, there was little to no administrative government effort to monitor or reduce ambient air pollution in Bangladesh. In 1999, the government began establishing frameworks and regulations to meet USEPA and Bangladesh National Air Quality standards, especially for Dhaka City. A number of controls have been implemented to attain the ambient air quality including the substitution of compressed natural gas (CNG) for two-stroke engines in three-wheelers, which was a revolutionary move for the progressive improvement of the overall air quality (Salam *et al.*, 2013) and the reduction of the lead present in the air. One of Bangladesh's most sophisticated industrial cities, Gazipur City is recently dealing with a tremendous increase in population and physical expansion (BBS, 2015). The ambient PM level in this city is being influenced by the burning of biomass and coal in brickfields, vehicle exhaust, industrial pollutants, and residential emissions and the high particulate matter (PM) levels and reduced vision throughout the winter are becoming major issues (Mukta *et al.*, 2020). This study hence, was carried out: i) to measure the air quality parameters such as $PM_{2.5}$, PM_{10}, CO_2, CO, O_3, NO_2, CH_4, NH_3 and SO_2 in eight locations of Gazipur City, ii) to compare the analyzed values with available standards and iii) To draw appropriate recommendations regarding building green Gazipur city in Bangladesh.

Materials and Methods

Study Area: The study was conducted in eight locations of Gazipur District namely Shimultoly, West Chattar, Titas Gas T&D Station, Shibbari Bus Stand, BMTF mor, DUET gate, Salna Bazar, Montribari during the dry season of 2023. The sampling stations were selected from residential areas, industrial areas, commercial areas and traffic places based on their importance such as their surroundings, traffic volume, and population density.

Data Collection and Analysis: Measurement of nine different air pollutants namely $PM_{2.5}$, PM_{10}, CO_2, CO, O_3, NO_2, CH_4, NH_3, SO_2 were done using Aeroqual Series 500 sensors at each selected sampling station. The primary data was collected three times a day (morning, noon, and evening) during January (dry season) 2023.The Microsoft Office Excel and SPSS IBM v26 software were used to present and analyze the collected data.

Table 1. Locations of eight sampling stations of the study area

No	Station No	Locations	Longitude	Latitude
1	St-1	Shimultoly	$90^0$24'45"E	$24^0$01'57"N
2	St-2	West Chattar	$90^0$24'47"E	$24^0$02'30"N
3	St-3	Titas Gas T&D Station	$90^0$24'55"E	$24^0$00'34"N
4	St-4	Shibbari Bus Stand	$90^0$24'59"E	$23^0$59'47"N
5	St-5	BMTF Mor	$90^0$25'12"E	$24^0$01'30"N
6	St-6	DUET Gate	$90^0$25'02"E	$24^0$01'05"N
7	St-7	Salna Bazar	$90^0$23'07"E	$24^0$01'33"N
8	St-8	Montribari, Salna	$90^0$23'21"E	$24^0$01'57"N

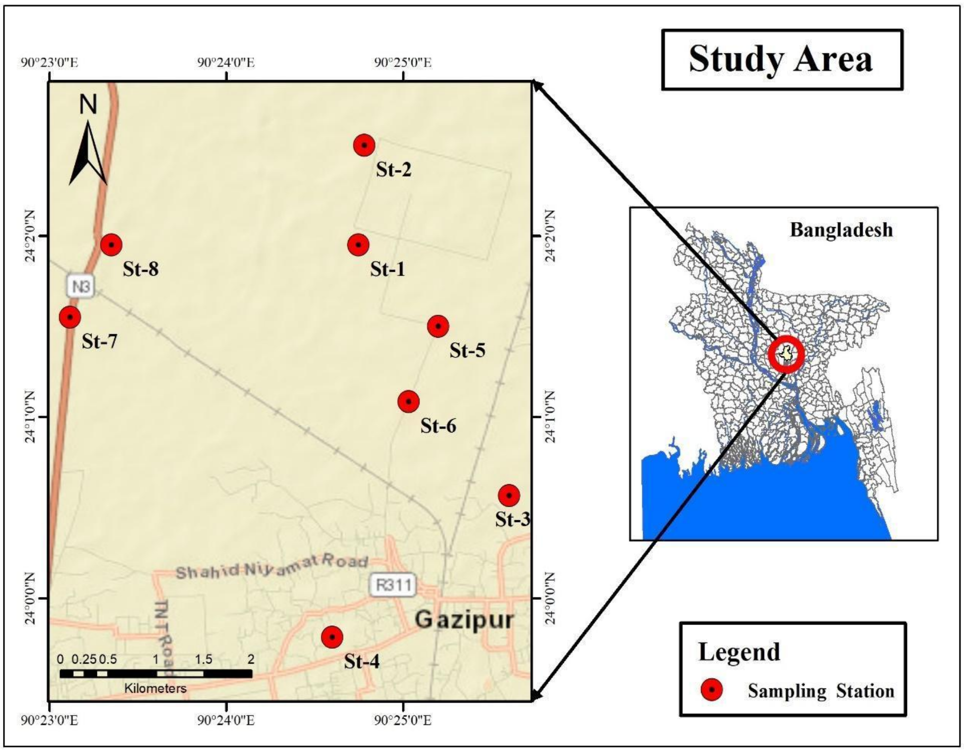

Fig. 1. Map showing the locations of the study area

Results and Discussion

The mean concentration of $PM_{2.5}$ for studied locations ranged from 0.21 to 0.43 mg/m^3 (Table 2). The highest value (0.43 mg/m^3) was found at St-7 and the lowest value (0.21 mg/m^3) was found at St-5. The highest value of St-7 indicated that the air of that location is heavily enriched with fine particulate matter due to the poor maintenance of the roads, industrial emissions, from brick kilns that burn clay, and large, uncontrolled construction and infrastructure development project sites as St-7 is an industrial area including a highway that sees a variety of everyday traffic. All the values of $PM_{2.5}$ found in this study exceeded the limit of national standard Air Pollution Control Rules (APCR), 2022 along with WHO and US standards. Rehnuma, Riad, and Shakur, (2020) observed the mean concentration of $PM_{2.5}$ ranged from 0.026 to 0.056 mg/m^3 in different locations of Tangail Sadar Upazila Which is ~7 times lower than the present study. Masum and Pal (2020) observed the mean concentration of $PM_{2.5}$ was 124.52 and 41.16 $\mu g/m^3$ during dry and wet season respectively in Chittagong districts where the mean concentration of $PM_{2.5}$ in present study was ~2 times higher than that of Chittagong during dry season. Mukta *et al.* (2020) recorded the concentration of $PM_{2.5}$ 132, 74.2, 171 and 32.5 $\mu g/m^3$ during post-monsoon, pre-monsoon, dry and monsoon season, respectively at Gazipur City. The findings of this study exhibited ~2 times higher value in the dry season at the same study area. Hoque *et al.* (2020) reported the concentration of $PM_{2.5}$ ranging from 29.6 to 183.87 $\mu g/m^3$ in Dhaka city which was similar to the present study.

The mean concentration of PM_{10} for studied locations ranged from 0.35 to 1.01 mg/m^3. The highest value (1.01 mg/m^3) was found at St-4 and the lowest value (0.35 mg/m^3) was found at St-2 (Table 2). Highest concentrations of PM_{10} were found near traffic places, construction and landfill sites which indicated that the air of that location was heavily enriched with particulate matter due to diesel-powered vehicles, motorized vehicles, brick kilns running in the winter and construction projects near the area. All the values found in this study exceeded the limit of national standard APCR, 2022 along with WHO and US standards (Table 3). The mean concentration of PM_{10} is 0.50mg/m^3 in this study which is ~25 times higher than those of the annual WHO standards. $PM_{2.5}$ particles are often produced by vehicles and more abundant than mechanically processed PM_{10} particles in air (Begum *et al.,* 2004).

The average concentration of CO_2 found to vary from 1103 to 1507.67 mg/m^3 (Table 2). The maximum value (1507.67 mg/m^3) was found at St-8 and the minimum value (1103 mg/m^3) was found at St-3. The major causes of CO_2 found in present study could be due to industrial emissions, burning of fossil fuel, energy production and brick kilns that burn clay. Rehnuma, Riad, and Shakur (2020) observed the average concentration of CO_2 ranged from 920 to 1238 mg/m^3 from different locations of Tangail Sadar Upazila which was similar to the findings to this present study.

The average concentration of CO was found to vary from 0.03 to 3.86 mg/m^3 (Table 2). The highest value (3.86 mg/m^3) was found at St-1 and the lowest value (0.03 mg/m^3) was found at St-5. The highest value of St-1 indicated the abundance of CO in the air of that location due to fumes produced by burning of fossil fuel, small engines, fireplaces, solid waste combustion and some natural sources as St-1 was a residential area. According to WHO and US standards, the mean hourly concentration of COis 30 $mg/m^3$and 40 mg/m^3, respectively (Table 3). All the values found were below the limit of APCR, 2022, WHO and US standards (Table 3). The mean concentration of CO was 1.58 mg/m^3 in this study which was ~18 times and ~25 times lower than those of the hourly WHO standards and US standards, respectively. Mukta *et al.* (2020) observed the concentration of CO 1.4, 1.7, 2.4 and 0.7 ppm during post-monsoon, pre-monsoon, winter (dry season) and monsoon season, respectively in Gazipur City. Islam *et al.* (2014) found the average 24 hours daily concentration of CO ranged from 2519 to 7730 $\mu g/m^3$ in Dhaka City. These values were more or less similar with the present study.

The mean value of O_3 recorded ranged from 0 to 0.03 mg/m^3 (Table 2). The highest value (0.03 mg/m^3) was found at St-4 and the lowest value (0 mg/m^3) was found at St-1, St-2, St-6, St-7, St-8 respectively. O_3 comes primarily in the air from combustion of fossil fuel, industrial emissions, power plants, refineries, evaporation of paints and vehicle engines (Pénard-Morand, and Annesi-Maesano, 2004). The highest value of St-4 indicated that the air of that location contained a lot of O_3 due to the excessive number of vehicles, combustion of fossil fuel and industrial emissions as St-4 was a crowded region with a high traffic volume. All values observed in this study were found below the limit of national, WHO and US standards. Mukta *et al.* (2020) observed the mean concentration of O_3 in Gazipur City respectively 7.0, 4.0, 4.0 and 2.9 ppb during post-monsoon, pre-monsoon, dry and monsoon season, which was higher than the present study.

Table 2. Concentration of air pollutants at eight different locations of the study area during morning (M), noon (N) and evening (E) including average values for 30 minutes duration

Air pollutant	Time	Concentrations of air pollutant in different sampling stations(mg/m^3)							
		St-1	St-2	St-3	St-4	St-5	St-6	St-7	St-8
$PM_{2.5}$	M	0.343	0.306	0.191	0.387	0.127	0.344	0.427	0.364
	N	0.387	0.366	0.259	0.315	0.194	0.389	0.498	0.386
	E	0.431	0.286	0.44	0.529	0.297	0.422	0.369	0.194
	Avg.	0.387	0.319	0.297	0.410	0.206	0.385	0.431	0.315
PM_{10}	M	0.406	0.355	0.288	0.975	0.385	0.402	0.512	0.408
	N	0.423	0.358	0.352	0.781	0.409	0.503	0.587	0.412
	E	0.512	0.339	0.517	1.263	0.422	0.581	0.528	0.312
	Avg.	0.447	0.351	0.386	1.006	0.405	0.495	0.542	0.377
CO_2	M	1416	1112	1044	1027	1268	1268	1206	1206
	N	1207	1209	1059	1080	1027	1109	1276	1554
	E	1332	1532	1206	1500	1374	1248	1416	1763
	Avg.	1318.33	1284.33	1103	1202.33	1223	1208.33	1299.33	1508.67
CO	M	5.3	0	0	1.4	0	3.4	0	0
	N	0.2	0.2	0.7	0	0	2.5	0.8	3.9
	E	6.1	1.4	3	1.7	0.1	3.6	3.6	4.5
	Avg.	1508.67	0.53333	1.23333	1.03333	0.03333	3.16667	1.46667	2.8
O_3	M	0	0	0.002	0.035	0.001	0	0	0
	N	0	0	0	0.047	0.002	0	0	0
	E	0	0	0	0	0	0	0	0
	Avg.	0	0	0.00067	0.02733	0.001	0	0	0
NO_2	M	0.097	0.094	0.095	0.094	0.096	0.098	0.098	0.096
	N	0.096	0.095	0.093	0.094	0.097	0.097	0.097	0.096
	E	0.096	0.096	0.095	0.095	0.097	0.097	0.096	0.096
	Avg.	0.09633	0.095	0.09433	0.09433	0.09667	0.09733	0.097	0.096
CH_4	M	3	0	0	0	0	3	0	0
	N	3	2	0	0	0	4	0	3
	E	4	6	5	5	7	7	0	10
	Avg.	3.33333	2.66667	1.66667	1.66667	2.33333	4.66667	0	4.33333
NH_3	M	0.2	0.2	0	0	0	0.3	0.2	0.1
	N	0.2	0.1	0	0	0	0.3	0.1	0.1
	E	0.3	0.2	0.2	0.2	0.3	0.3	0.1	0.1
	Avg.	0.23333	0.16667	0.06667	0.06667	0.1	0.3	0.13333	0.1
SO_2	M	0.1	0.2	0	0	0	0.3	0.1	0.1
	N	0.1	0.2	0	0	0	0.2	0.2	0
	E	0.1	0.2	0	0.1	0.1	0	0.4	0
	Avg.	0.1	0.2	0	0.03333	0.03333	0.16667	0.23333	0.03333

M= Morning, N= Noon and E=Evening

Avg.= Average value

Table 3. Air quality standard in Bangladesh and global

Parameters		WHO Standard	US Standard	Air Pollution Control Rules, 2022
Concentration (mg/m^3)	$PM_{2.5}$	0.01 (Annual) 0.025 (24hr)	0.015 (Annual) 0.035 (24hr)	0.065
	PM_{10}	0.02 (Annual) 0.05 (24hr)	0.15 (24hr)	0.15
	CO_2	-	-	-
	CO	10 (8h) 30 (1hr)	10 (8hr) 40 (1hr)	5
	O_3	0.1 (8hr)	0.235 (1hr) 0.157 (8hr)	0.1
	NO_2	0.01 (Annual) 0.025 (24hr)	-	0.08
	CH_4	-	-	-
	NH_3	-	-	0.4
	SO_2	0.04 (24hr)	0.078 (24hr)	0.08

Nitrogen dioxide (NO_2) is a major contributor to acid rain, which may harm the ecosystem and diminish agricultural productivity along with some negative effects on human health (UNEP, 2011). The average concentration of NO_2 recorded varied from 0.094 to 0.097 mg/m^3. The maximum value (0.097 mg/m^3) was found at St-6 and the minimum value (0.094 mg/m^3) was found at St-3 and St-4. Highest concentration found in places where NO_2 primarily came from mobile combustion, power plants, industrial boilers, and emissions from aircraft, vehicles, and heavy construction sites. The highest value found from the study area was below the limit of APCR, 2022 standards (Table 3). The mean concentration of NO_2 was 0.095 mg/m^3 which was ~9 times higher than those of annual WHO standards.

The mean value of CH_4 observed ranged from0 to 4.66 mg/m^3 (Table 2). The highest value (4.66 mg/m^3) was found at St-6 and the lowest value (0 mg/m^3) was found at St-7. Anaerobic decomposition in wetlands, livestock production systems, biomass burning e.g. forest fires, charcoal combustion, and firewood burning, anaerobic decomposition of organic waste in landfills and emission during the extraction and transportation of fossil fuels are the primary sources of CH_4 in the air (Heilig, 1994).

The average value of NH_3 observed varied from 0.06 to 0.3 mg/m^3. The highest value (0.3 mg/m^3) was recorded at St-6 and the lowest value (0.06 mg/m^3) was recorded at both St-3 and St-4.The major sources of NH_3 found in present study caused by industrial emissions, motor vehicles, plant decomposition, and biomass burning as the study locations were located at highly populated area next to busy roads and includes development activities.

Due to the presence of sulfur in commercially available diesel and coal, diesel vehicles and brick kilns are the most significant sources of SO_2 in Bangladesh. (Haque, 2017). The mean concentration of SO_2 recorded ranged from 0 to 0.23 mg/m^3 (Table 2). The highest value (0.23 mg/m^3) was recorded at St-7 and the lowest value (0 mg/m^3) was recorded at St-3. The mean daily concentration of SO_2 was 0.04 mg/m^3 and 0.078 mg/m^3 in WHO and US standards respectively (Table 3). According to APCR, 2022 standards, the highest value of SO_2 was 0.08 mg/m^3. Gazipur city was an industrial and mixed area and the highest value observed in the present study exceeded the APCR, 2022 standards.

Table 4. Pearson correlation coefficient among air pollutants of Gazipur city

	$PM_{2.5}$	PM_{10}	CO_2	CO	O_3	NO_2	CH_4	NH_3	SO_2
$PM_{2.5}$	1								
PM_{10}	0.547	1							
CO_2	0.077	-0.243	1						
CO	0.481	-0.108	0.404	1					
O_3	0.332	0.950**	-0.246	-0.243	1				
NO_2	0.092	-0.31	0.313	0.396	-0.535	1			
CH_4	-0.181	-0.315	0.375	0.59	-0.252	0.256	1		
NH_3	0.339	-0.241	0.064	0.644	-0.404	0.629	0.556	1	
SO_2	0.506	-0.131	0.13	0.093	-0.327	0.483	-0.151	0.576	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 4 presents the Pearson correlation coefficient among air pollutants of the study area which showed a strongly positive correlation(r =0.950, p< 0.01) among PM_{10} and O_3which demonstrated that these pollutants were originated from similar sources where both pollutants have a number of detrimental impacts on human health such as chronic respiratory and cardiovascular disease, diminished lung function, alterations in lung tissue, acute respiratory infections, complications during pregnancy, and premature mortality (Bell, Ebisu, and Belanger, 2007; Bravo, and Bell, 2011).

Table 5 presents the cluster of pollutants studied in this study using Principal Component Analysis (PCA). Only strong factor loadings were used for the PCA interpretation in the present study. Three major clusters (PC1, PC2 and PC3) have been found for 9 variables based on their factor loading. The gaseous pollutants SO_2, NH_3 and NO_2 belong to PC1, whereas PM_{10}, $PM_{2.5}$ and O_3 belong to PC2. CH_4 and CO belong to PC3. The first factor (F1) explains 39.08 %of the total variance which shows strong positive factor loadings for SO_2 (0.931), NH_3 (0.702) and NO_2 (0.660). The second factor (F2) explains 24.26 % of the total variance which shows strong positive factor loadings for PM_{10} (0.943), $PM_{2.5}$ (0.742) and O_3 (0.869). In the third factor (F3), the total variance was of 16.22 % which shows strong positive factor loadings for CH_4 (885) and CO (0.855). Fig. 2 presents the Principal component analysis plot of air pollutants of the study area.

Table 5. Principal Component Analysis (PCA) of air pollutants of Gazipur city

Air pollutant	Component		
	PC1	PC2	PC3
SO_2	0.931	-0.035	-0.135
NH_3	0.702	-0.087	0.538
NO_2	0.660	-0.327	0.330
PM_{10}	-0.115	0.943	-0.175
O_3	-0.379	0.869	-0.191
$PM_{2.5}$	0.590	0.742	0.125
CH_4	-0.107	-0.214	0.884
CO	0.321	0.147	0.855
CO_2	0.074	-0.141	0.566
Eigen value	3.518	2.184	1.460
Variability (%)	39.087	24.268	16.223
Cumulative%	39.087	63.354	79.577

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 5 iterations.

Component Plot in Rotated Space

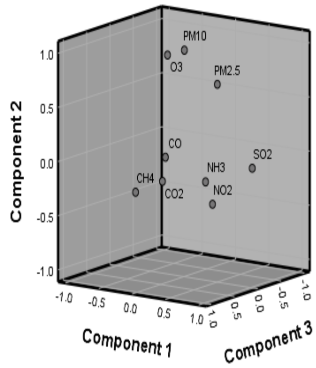

Fig. 2. Principal component analysis plot diagram of air pollutants of the study area

The PCA analysis signifying the fact that air is heavily enriched with gaseous pollutants derived from the automobile engine emission and its poor maintenance, industrial emissions particularly from clay burn brick kilns, unplanned solid waste management system along with uncontrolled construction and infrastructure development project sites around the Gazipur City.

Conclusion

The rapid growth of the RMGs, factories and other industries are accelerating the urbanization of Gazipur city. The present investigation revealed that the air of the Gazipur city has become severely polluted due to the uncontrolled industrial and automobile emission. Among the observed pollutants, the mean concentration of $PM_{2.5}$, PM_{10} and SO_2 exceeded the APCR, 2022, WHO and US standards which were very alarming. The high concentration of $PM_{2.5}$ and PM_{10} may be related to increased atmospheric emissions from burning biomass and fossil fuels as well as poor weather conditions for pollution dispersion. For SO_2, low atmospheric temperatures during the dry season coupled with heavy sulfur emissions from brick kilns where coal was the primary burned fuel may induce the trends to exist in lower atmosphere. To control the air pollution, the government should take immediate action to control this adverse effect of air pollution in this city. Efficient solid waste management systems along with appropriate automobile engine design with control strategies should be introduced for reducing the existing emission. Also developing the monitoring and maintenance cell in the industries and construction sites can be effective to prevent the harmful emissions from these major sources of air pollution in Bangladesh.

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