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Spatial Distributions of Gaseous Air Pollutants Including Particulate Matter in the Narsingdi City of Dhaka Division

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ABSTRACT

This study summarizes the concentration of major gaseous air pollutants in Narsingdi city of Dhaka division. To accomplish this study, we investigate fifteen sampling stations (Velanagar, Railway Station, Boro Bazar, Ghoradia, Brahmondi, Shaheprotap, Launch Terminal, Satirpara, Bus Terminal, Silmandi, Gangpar Bridge, Panchdona, Shekherchar and Anandi) of the study area. In this study, we measured six gaseous air pollutants together with $PM_{2.5}$ and PM_{10} during the month September, 2022 using air quality meter Aeroqual (Series500). Highest concentration of $PM_{2.5}$ was detected 58 µg/m^3 at Boro Bazar whereas highest concentration of PM_{10} was 165 µg/m^3 was at Anandi of the study area where emission from vehile, construction activities and waste burning are predominant. Moreover, in this study, we found statistically significant correlation with CH_4 and CO_2 ($r = 0.679$, $p > 0.01$), $PM_{2.5}$ and PM_{10} ($r = 0.630$, $p > 0.05$) indicating their sources of emission might be similar including fossil fuel burning in vehicles, industrial emissions and road dust. Furthermore, we calculated AQI value based on $PM_{2.5}$ concentration and highest AQI (152) value was observed in Boro Bazar of the study area followed by Bus Terminal (129), Gangpar Bridge (117), Anandi (112), Ghoradia (102), Brahmondi (89), Panchdona (84), Satirpara (83), Shaherpotap (82), Silmandi (80), Railway Station (78), Madhabdi (78), Shekherchar (76), Launch Terminal (76), Velanagar (59) and was very much compatible with US consulate, Bangladesh published data.

Keywords: Air pollution, CH_4, Cl_2, SO_2, NO_2, PM, Narsingdi, AQI, GIS, and Spatial distribution.

INTRODUCTION:

Air pollution poses world's most serious environmental health threats towards peoples and their properties (Hoque *et al.*, 2020; Mukta *et al.,* 2020). Other environmental implications of air pollutants include global warming, acid rain, and effects on wildlife (Gauderman *et al.*, 2004; Jansen *et al.,* 2005; Epton *et al.,* 2008). The principal air pollutants of concern are ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), methane (CH_4), chlorine (Cl_2), and particulates ($PM_{2.5}$ and PM_{10}), which are emitting due combustion of fossil fuels as well as biomass burning (Dianat *et al.*, 2016; Khaefi *et al.*, 2017; Hoque *at al.*, 2020). Air pollution is a pressing issue for Bangladesh, which ranks 169th (out of 178 countries) at the Environmental Performance Index for Air Quality (APT, 2016). Here, 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 (Hoque *et al.*, 2020; Mukta *et al.*, 2020). According to the Department of Environment (DoE), the density of airborne particulate matter (PM) reaches 463 micrograms per cubic meter (µg/m^3) in Dhaka city during the dry season (December-March), which is the highest level in the world (Air Pollution Reduction Strategy for Bangladesh, Final Report, 2012). Although, World Health Organization (WHO) air quality guidelines (2006) recommend a maximum acceptable PM level of 20 $\mu g/m^3$, whereas cities with 70 $\mu g/m^3$ are considered as highly polluted.

Poor ambient air quality is instigating damage to human health, agricultural production and materials (Mukta *et al*., 2020; Hoque *et al*., 2022b). So, it is high time to create awareness and motivation about air pollution management and control all over Bangladesh. However, in different time's 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 Program (UNEP), which have taken measures or have made schemes to minimize and limit air pollution. However, the Department of Environment (DoE), the Government agency funded with conserving the environment in Bangladesh, sought plans to create a policy which will reduce air pollution in Bangladesh under the framework of the Male declaration to regulate and avoidance of air pollution and its possible trans-boundary consequences for South Asia (Air Pollution Reduction Strategy for Bangladesh, Final Report, 2012).

Air pollution is a major anthropogenic environmenttal concern that has recently gained prominence among all environmental issues in Bangladesh. According to a World Bank report, the economic cost of pollution of air in healthcare sector of Bangladesh alone is estimated annually as U.S. $132-583 for Dhaka city and U.S. $200-800 for the four biggest cities in Bangladesh, which contributes 0.7-3.0% of the country's per year GDP (C. Brandon, Economic valuation of pollution of water and air in Bangladesh: World Bank Workshop negotiations draft, 1997). Moreover, a 20 percent cutback from the current level of PM_{10} in Dhaka would save health costs of around 169-492 million annually (World Bank, 2006). In addition, among the mega cities of the world, Dhaka leads the rankings, having 7000/yr cardiovascular mortality and 2100/yr excess cases of hospital admissions for COPD (Chronic Obstructive Pulmonary Disease) attributable to air pollution (Azkar *et al*., 2012; Gurjar *et al*., 2010).

Objectives of the study

This study was conducted to satisfy the following objectives:

1) To find out the concentration level of CO, CO_2, NO_2, SO_2, Cl_2, CH_4, $PM_{2.5}$ and PM_{10} at ambient air of Narsingdi Sadar.
2) To show the spatial distribution of these pollutants by using Geographical Information System (GIS).
3) To calculate AQI (Air Quality Index) for the study area.

MATERIALS AND METHODS:

Study area

Narsingdi is a district in central Bangladesh. It is situated north-east of Dhaka, capital of Bangladesh. It belongs to the division of Dhaka. The district is renowned for its synthetic textile industry. The study was conducted in fifteen areas of Narsingdi Sadar (23°55'8.79"N and 90°43'3.80"E) of Dhaka division including Velanagar, Railway Station, Boro Bazar, Ghoradia, Brahmondi, Shaheprotap, Launch Terminal, Satirpara, Bus Terminal, Silmandi, Gangpar Bridge, Panchdona, Shekherchar, Madhabdi and Anondi.

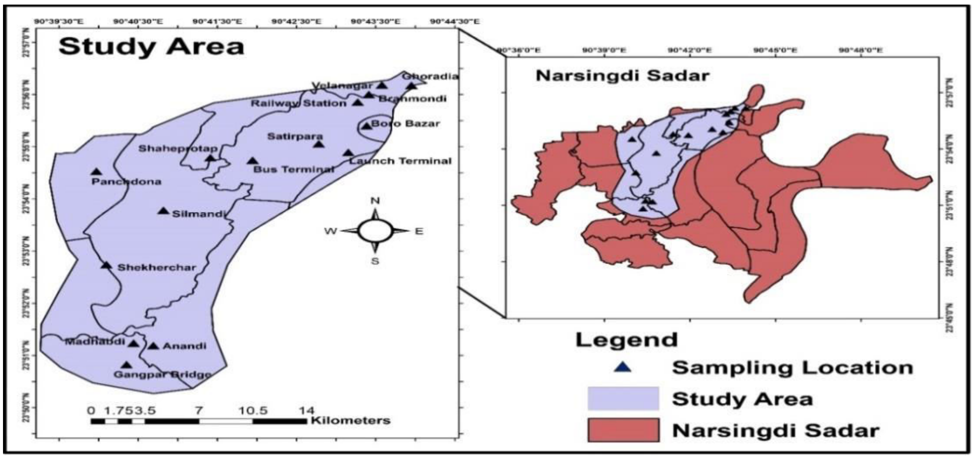

Fig. 1: Map of study area with sampling locations.

Data collection

The study was conducted from fifteen different locations of Narsingdi Sadar. The research was based on primary air quality data under direct supervision of supervisor. Primary data were collected by Aeroqual S500 (New Zealand), a portable air quality monitor during September 2022.

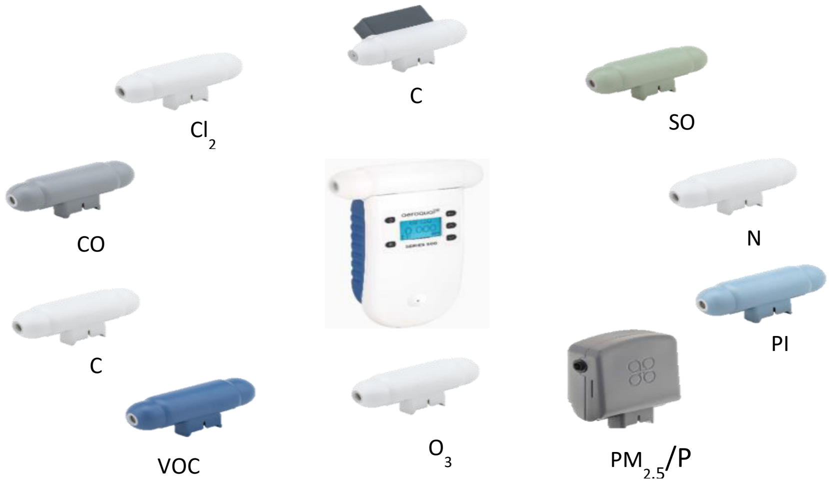

Fig. 2: Aeroqual S500 air quality monitoring instrument with sensors.

AQI calculation

In our study AQI is calculated by using following formula:

$$I = \frac{\text{I high} - \text{I low}}{\text{C high} - \text{C low}} \times (C - \text{C low}) + \text{I low}$$

Here,

I: AQI (Air Quality Index)

C: the pollutant concentration

C low: the concentration breakpoint that is ≤ C

C high: the concentration breakpoint that is ≥ C

I low: the breakpoint Index narrating to C low

I high: the breakpoint Index narrating to C high

C low, C high, I low, I high are from the US EPA Pollutant Breakpoint.

Table 1: The US EPA pollutant breakpoint for calculating AQI.

O_3 (ppb)	O_3 (ppb)	$PM_{2.5}$ (µg/m^3)	PM_{10}(µg/m^3)	CO (ppm)	SO_2 (ppb)	NO_2 (ppb)	AQI
C high – C low (avg)	*C high – C low* (avg)	*C high – C low* (avg)	*C high – C low* (avg)	*C high – C low* (avg)	*C high – C low* (avg)	*C high – C low* (avg)	*I high – I low* (avg)
0–54 (8-hr)	—	0.0–12.0 (24-hr)	0–54 (24-hr)	0.0–4.4 (8-hr)	0–35 (1-hr)	0–53 (1-hr)	0–50
55–70 (8-hr)	—	12.1–35.4 (24-hr)	55–154 (24-hr)	4.5–9.4 (8-hr)	36–75 (1-hr)	54–100 (1-hr)	51–100
71–85 (8-hr)	125–164 (1-hr)	35.5–55.4 (24-hr)	155–254 (24-hr)	9.5–12.4 (8-hr)	76–185 (1-hr)	101–360 (1-hr)	101–150
86–105 (8-hr)	165–204 (1-hr)	55.5–150.4 (24-hr)	255–354 (24-hr)	12.5–15.4 (8-hr)	186–304 (1-hr)	361–649 (1-hr)	151–200
106–200 (8-hr)	205–404 (1-hr)	150.5–250.4 (24-hr)	355–424 (24-hr)	15.5–30.4 (8-hr)	305–604 (24-hr)	650–1249 (1-hr)	201–300
—	405–504 (1-hr)	250.5–350.4 (24-hr)	425–504 (24-hr)	30.5–40.4 (8-hr)	605–804 (24-hr)	1250–1649 (1-hr)	301–400
—	505–604 (1-hr)	350.5–500.4 (24-hr)	505–604 (24-hr)	40.5–50.4 (8-hr)	805–1004 (24-hr)	1650–2049 (1-hr)	401–500

RESULTS AND DISCUSSION:

Spatial distribution of $PM_{2.5}$ in the study area

As shown in **Table 2**, concentration of $PM_{2.5}$ ranged from 16-58 µg/m^3, average is 31.55µg/m^3. However, this value is lower than the Nanjing, China 65.36 µg/m^3 (Hasnain *et al.*, 2021), Dhaka 77 µg/m^3 (Khuda K.E., 2020) and Delhi 182.49 µg/m^3 (Sethi *et al.*, 2020) and higher than the previous study of

Chittagong 21.2 µg/m^3 (Hoque *et al.,* 2022a). However, the spatial expansion of $PM_{2.5}$ showed that the highest value of $PM_{2.5}$ observed 58 µg/m^3 in Boro Bazar (**Fig. 3**). The sources of $PM_{2.5}$ of this area may be associated with fossil fuel burning vehicles, road side construction and public gathering.

Table 2: Concentration of air pollutants in the study area.

Measuring points	Concentration of Pollutants							
	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	CH_4 (ppm)	CO (ppm)	CO_2 (ppm)	NO_2 (ppm)	SO_2 (ppm)	Cl_2 (ppm)
Velanagar	16	19	15	0	606	5.747	0	0.03
Railway Station	25	62	37	0	693	5.742	0.1	0.02
Boro Bazar	58	62	20	0.5	600	5.734	0	0.03
Ghoradia	36	41	20	0	653	5.74	0	0.03
Brahmondi	27	58	19	0	640	5.721	0.1	0.02
Shaheprotap	27	31	18	1.7	588	5.736	0	0.03
Launch Terminal	24	26	13	0	571	5.732	0.1	0.03
Satirpara	27	31	12	0	600	5.738	0	0.03
Bus Terminal	47	132	14	0.1	598	5.752	0	0.02
Silmandi	26	32	15	0.5	690	5.744	0.1	0.02
Gangpar Bridge	42	152	13	0	602	5.735	0.1	0.03
Panchdona	28	29	12	0	600	5.746	0	0.02
Shekherchar	24	23	10	0.5	606	5.745	0	0.04
Madhabdi	25	52	11	0	600	5.741	0.1	0.03
Anandi	40	165	8	0	577	5.737	0.1	0.04
Minimum	16	19	8	0	571	5.721	0	0.02
Maximum	58	165	37	1.7	693	5.752	0.1	0.04
Average	31.55	61	15.8	0.22	614.93	5.74	0.0467	0.028

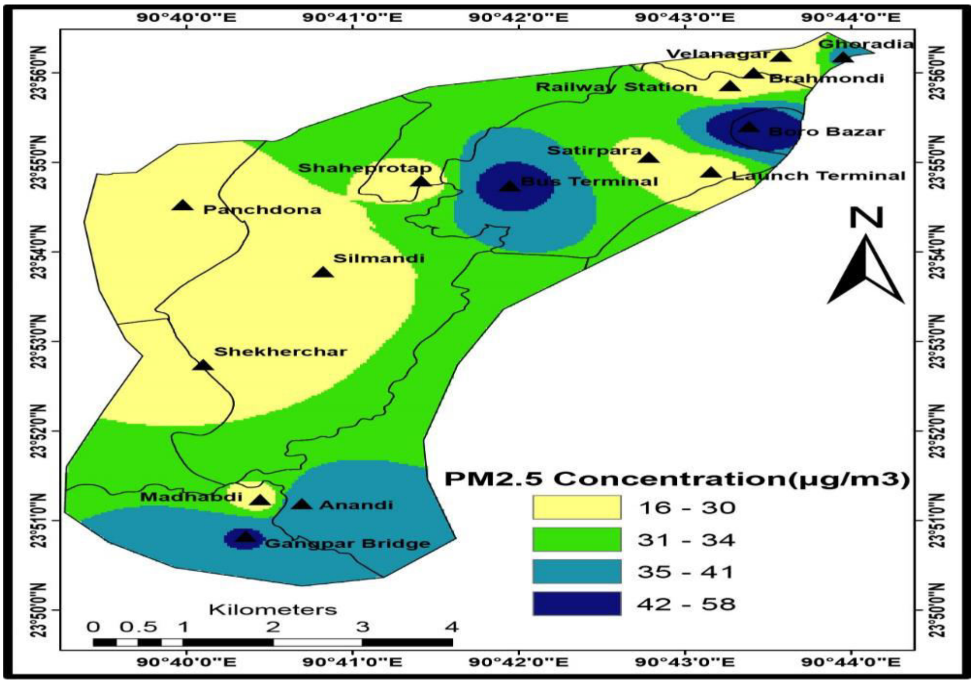

Fig. 3: Spatial distribution of $PM_{2.5}$ in the study area.

Spatial distribution of PM_{10} in the study area

As displayed in **Table 2**, concentration of PM_{10} ranged from 19-165 µg/m^3, average 61 µg/m^3. Interestingly, this value is lower than the Nanjing, China 102.75 µg/m^3 (Hasnain *et al.,* 2021), Dhaka 65.5 µg/m^3 (Khuda K.E., 2020), Delhi 299.78 µg/m^3 (Sethi *et al.,* 2020) and higher than the previous study of Chittagong 57.3 µg/m^3 (Hoque *et al.,* 2022a). However, the spatial expansion of PM_{10} showed that the highest value of PM_{10} obser-ved 165 µg/m^3 in Anandi (**Fig. 4**). The sources of PM_{10} of this area may be associated with roadside cons-tructions, waste burning, dust from open land and grinding operation.

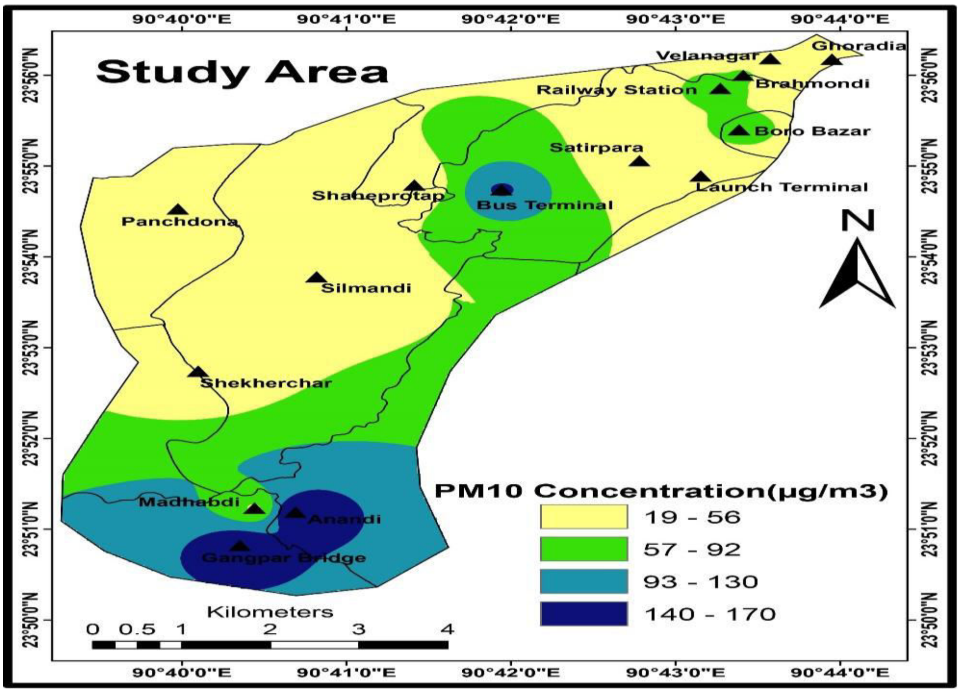

Fig. 4: Spatial distribution of PM_{10} in the study area.

Spatial distribution of CO in the study area

As demonstrated in **Table 2**, concentration of CO ranged from 0.0-1.7 ppm (avg. 0.22 ppm). In comparison, this value is lower than Nanjing, China 0.89 ppm (Hasnain *et al.,* 2021), Dhaka 1.8 ppm (Khuda K.E., 2020), Delhi 2.51 ppm (Sethi *et al.,* 2020) and Chittagong 1.2 ppm (Hoque *et al.,* 2022a) of the previous study. However, the spatial expansion of CO showed that the highest value of CO observed in Shaheprotap of the study area (**Fig. 5**). The sources of CO of that area may be associated with incomeplete combustion of vehicular emission.

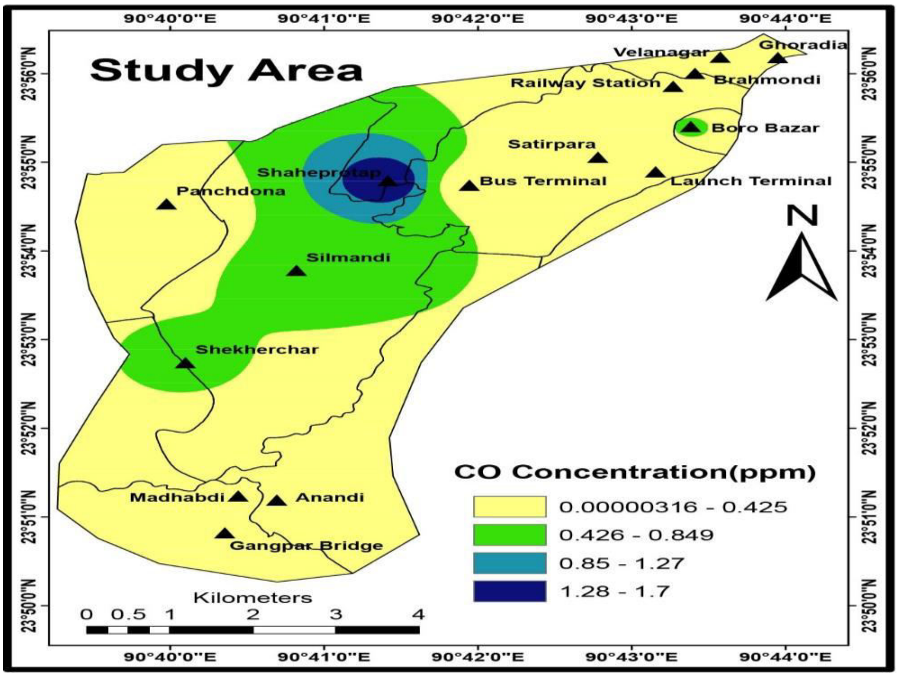

Fig. 5: Spatial distribution of CO in the study area.

Spatial distribution of NO_2 in the study area

As given in **Table 2**, concentration of NO_2 ranged from 5.72-5.75 ppm (avg. 5.74 ppm). Regrettably, this value is higher than the Nanjing, China 0.03 ppm (Hasnain *et al.,* 2021), Dhaka 0.08 ppm (Khuda K.E., 2020), Delhi 0.06045 ppm (Sethi *et al.,* 2020) and Chittagong 0.0244 ppm (Hoque *et al.,* 2022a) of the previous study. However, the spatial distribution of NO_2 showed that the highest value of NO_2 observed 5.75 ppm in Bus Terminal (**Fig. 6**). The sources of NO_2 of that area may be associated with vehicular combustion and waste burning nearby the bus terminal.

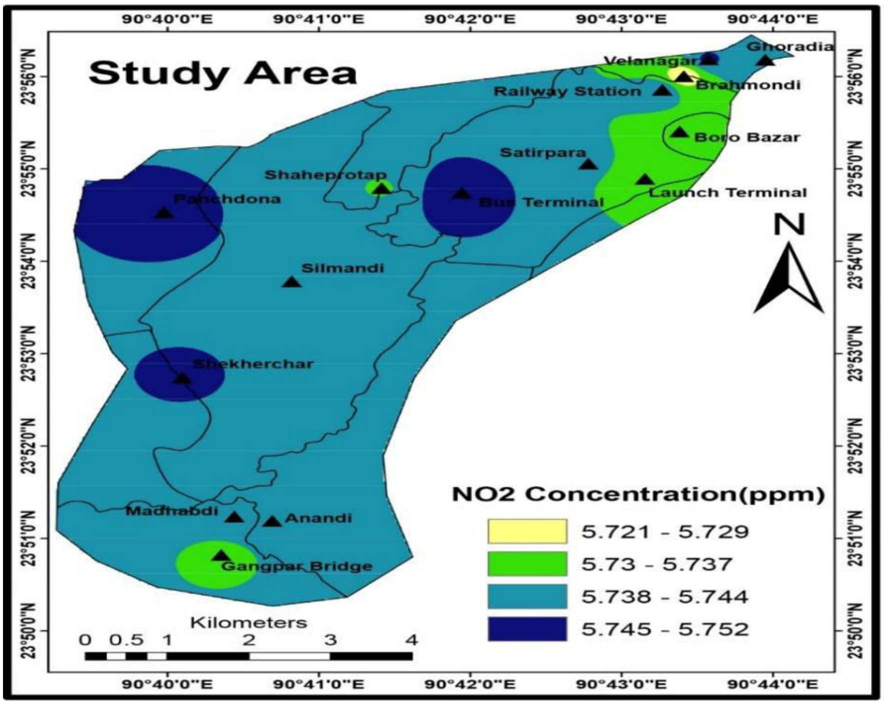

Fig. 6: Spatial distribution of NO_2 in the study area.

Spatial distribution of SO_2 in the study area

As given in **Table 2**, concentration of SO_2 ranged from 0.0-0.1 ppm (avg. 0.046 ppm). In comparison, concentration of SO_2 is higher than Nanjing of China 0.005 ppm (Hasnain *et al.,* 2021), Dhaka 0.016 ppm (Khuda K.E., 2020), Delhi 0.010 ppm (Sethi *et al.,* 2020) and Chittagong 0.013 ppm (Hoque *et al.,* 2022a) of the previous study. **Fig. 7** showed the spatial of SO_2 in the study area. As observed in **Fig. 7**, the highest value of SO_2 observed 0.1 ppm in Madhabdi followed by Anandi, Gangpar Bridge, Silmandi, Launch Terminal, Railway Station and Brahmondi. The sources of SO_2 of those areas may be associated with burning of sulfur containing fuels by locomotives, ships and motor vehicles.

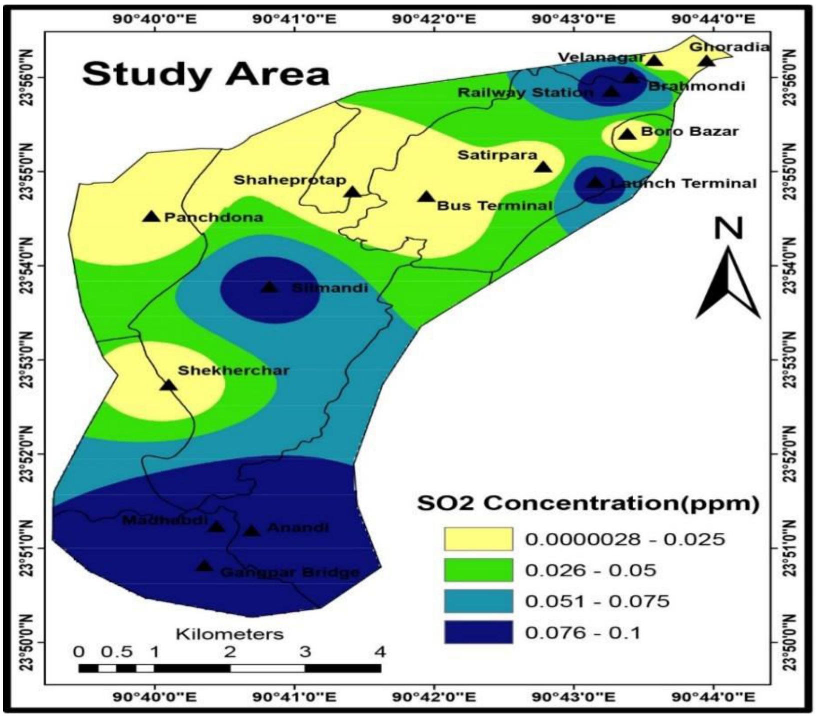

Fig. 7: Spatial distribution of SO_2 in the study area.

Spatial distribution of CO_2 in the study area

As displayed in **Table 2**, concentration of CO_2 ranged from 571-693 ppm (avg. 614.93 ppm). However, the spatial distribution of CO_2 showed that the highest value of CO_2 observed 693 ppm in Railway Station. The sources of CO_2 of that area may be associated with deforestation, land clearing for infrastructure, and degradation of soils.

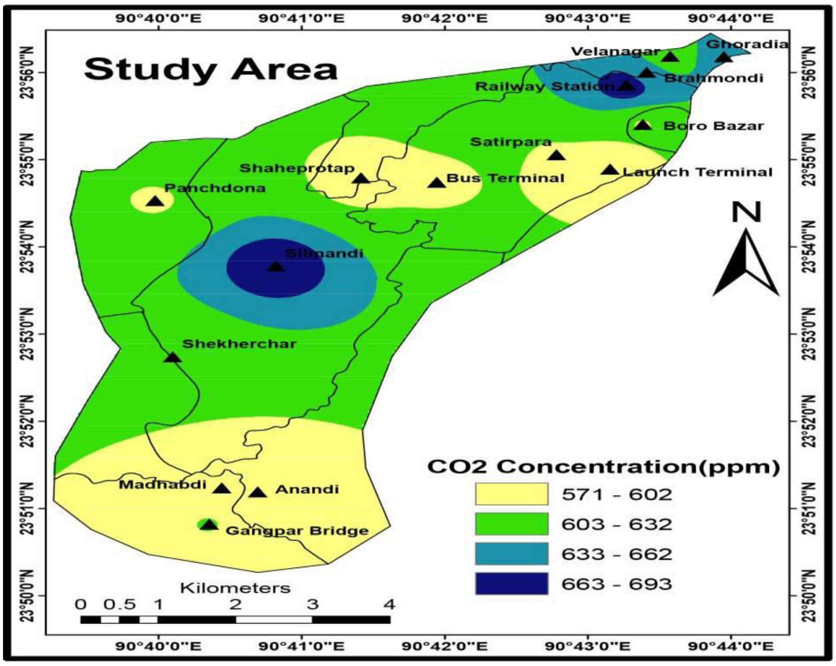

Fig. 8: Spatial distribution of CO_2 in the study area.

Spatial distribution of CH_4 in the study area

As given in **Table 2**, concentration of CH_4 ranged from 8-37 ppm (avg. 15.8 ppm). However, the spatial distribution of CH_4 showed that the highest value of CH_4 observed 37 ppm in Railway Station followed by Boro Bazar (20 ppm), Goradia (20 ppm), Bhramondi (19 ppm), Shaheprotam (18 ppm), Silmandi (15 ppm), Velanagar (15 ppm), Bus Terminal (14 ppm), Launch Terminal (13 ppm), Gangpar Bridge (13 ppm), Satipara (12 ppm), Pachonda (12 ppm), Madhabdi (11 ppm), Shekherchar (10 ppm), Anandi (8 ppm) (**Fig. 9**). The sources of CH_4 of the study area may be associated with organic waste decomposition at the surrounding area of the Railway Station.

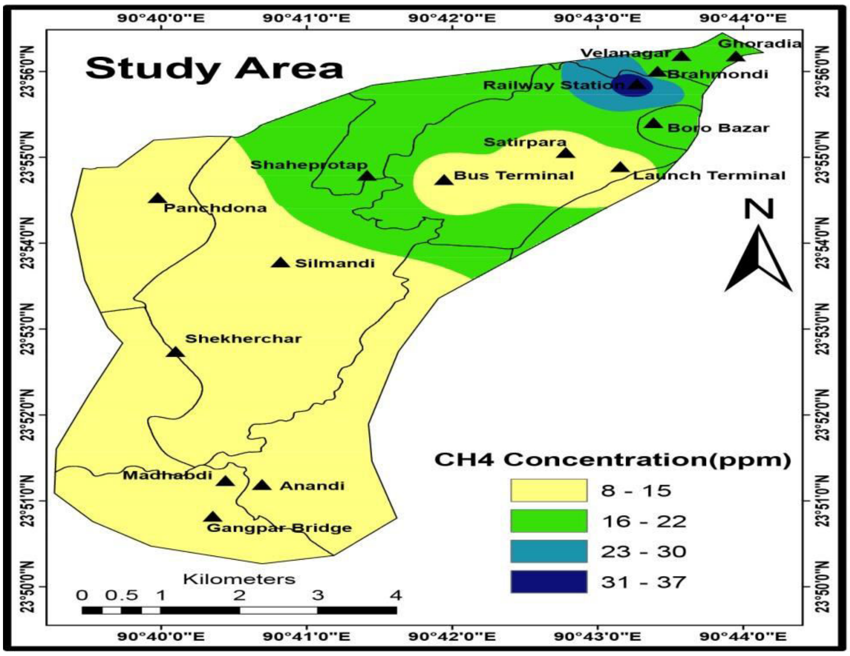

Fig. 9: Spatial distribution of CH_4 in the study area.

Spatial distribution of Cl_2 in the study area

As given in **Table 2**, concentration of Cl_2 ranged from 0.02-0.04 ppm (avg. 0.028 ppm). **Fig. 9** the spatial distribution of Cl_2 in the study area. As shown in **Fig. 9**, that the highest value of Cl_2 observed as 0.04 ppm in Anandi followed by Boro Bazar (0.03 ppm), Goradia (0.03 ppm), Shaheprotap (0.03 ppm), Velanagar (0.03 ppm), Launch Terminal (0.03 ppm), Gangpar Bridge (0.03 ppm), Madhabdi (0.03 ppm), Railway station (0.02 ppm), Bhramondi (0.02 ppm), Silmandi (0.02 ppm), Bus Terminal (0.02 ppm), Satipara (12 ppm), Pachonda (0.02 ppm), Shekherchar (0.04 ppm) (**Fig. 9**). Sources of Cl_2 of those areas may be associated with textile and dying industry, cooling hot water, bleaching activities and photochemical oxidation of different types of air pollutants. For workers who use Cl_2, the U.S. Occupational Safety and Hazard Administration (OSHA) regulates the level of Cl_2 in workplace air for safety. OSHA has set a permissible exposure limit (PEL) for Cl_2 at 0.1 ppm. Fortunately, the highest value of Cl_2 0.04 ppm in this study is lower than the OSHA's permissible limit 0.1 ppm.

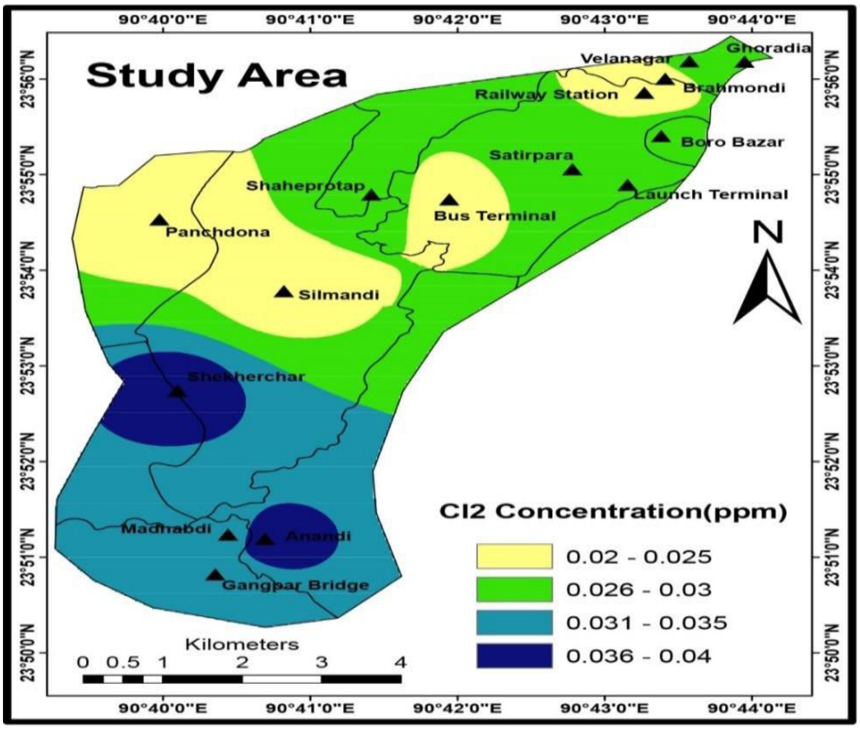

Fig. 10: Spatial distribution of Cl_2 in the study area.

Table 3: Comparison of measuring air pollutants data with previous study.

Country	Concentration of Pollutants					References
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)	
Dhaka	1.8	0.08	0.016	77	65.5	Khuda.K.E., 2020
Delhi	2.51	0.06045	0.00966	182.49	299.78	Sethi *et al.*, 2020
Gazipur	1.4	0.021	0.004	132	132	Mukta *et al.*, 2020
Nanjing, China	0.89	0.03	0.005	65.36	102.75	Hasnain *et al.*, 2021
Chittagong	1.2	0.0244	0.0128	21.7	57.3	Hoque *et al.*, 2022a
Narsingdi Sadar	**0.22**	**5.74**	**0.0467**	**31.55**	**61**	**This study**

Calculation of AQI value of the study area

The study measured the AQI values of the different locations of the study area based on $PM_{2.5}$ concentration. Among all the study locations, this study found out that the highest AQI value 152 was observed in the Boro Bazar of the study area followed by Bus Terminal (129), Gangpar Bridge (117), Anandi (112), Ghoradia (102), Brahmondi (89), Panchdona (84), Satirpara (83), Shaherpotap (82), Silmandi (80), Railway Station (78), Madhabdi (78), Shekherchar (76), Launch Terminal (76), Velanagar (59). In this study measured AQI value of the study area were compared with published AQI value of US consulate (website aqicn.org/city/bd) and were very much comparable to the US consulate published data (**Table 4**).

Table 4: Comparison of calculated AQI value of the study area with published data.

Location	Pollutant's ($PM_{2.5}$) Concentration (μg/m^3)	Measured AQI value	Published AQI (US consulate, Dhaka)
Velanagar	16	59	99
Railway Station	25	78	112
Boro Bazar	58	152	158
Ghoradia	36	102	125
Brahmondi	27	89	125
Shaheprotap	27	82	118
Launch Terminal	24	76	99
Satirpara	27	83	118
Bus Terminal	47	129	158
Silmandi	26	80	112
Gangpar Bridge	42	117	125
Panchdona	28	84	118
Shekherchar	24	76	99
Madhabdi	25	78	112
Anandi	40	112	158

According to AQI categories and colors, corresponding index values and cautionary statements for different levels of health concern, we have categorized every site of the study area based on air quality (**Table 5**). As given in **Table 5**, air pollution of Velanagr, Railway Sation, Brahmondi, Shaheprotap, Launch Terminal, Satirpara, Panchdona, Shekherchar and Madhabdi are in moderate condition, where air quality is acceptable during the study conducted. However, there may be danger for people who are unusually sensitive to air pollution. Whereas, air quality of Boro Bazar, Ghoradia, Bus Terminal, Silmandi, Gangpar Bridge and Anandi are in unhealthy condition to the sensitive groups. Where peoples of sensitive categories may be experienced health effect, but general public are may not be affected.

Table 5: Air Quality Index and health concern of the study area.

Location	Measured AQI value	Category and Color
Velanagar	59.2	Moderate
Railway Station	78.13	Moderate
Boro Bazar	152.29	Unhealthy for Sensitive Groups
Ghoradia	102.23	Unhealthy for Sensitive Groups
Brahmondi	89.29	Moderate
Shaheprotap	82.29	Moderate
Launch Terminal	75.99	Moderate
Satirpara	82.99	Moderate
Bus Terminal	129.32	Unhealthy for Sensitive Groups
Silmandi	80.19	Moderate
Gangpar Bridge	117	Unhealthy for Sensitive Groups
Panchdona	84.39	Moderate
Shekherchar	75.99	Moderate
Madhabdi	78.13	Moderate
Anandi	112	Unhealthy for Sensitive Groups

CONCLUSION:

In this study, we measured concentration of major gaseous air pollutants (CO, CO_2, NO_2, SO_2, Cl_2 and CH_4) and particulate matter ($PM_{2.5}$ and PM_{10}) by a portable sensory based air quality monitoring device (Aeroqual series 500). Average concentrations of air pollutants were as follows: CO (0.22 ppm), CO_2 (614.93 ppm), NO_2 (5.74 ppm), SO_2 (0.0467 ppm), CH_4 (15.8 ppm), Cl_2 (0.30 ppm), $PM_{2.5}$ (31.55 μg/m^3) and PM_{10} (61 in μg/m^3). The highest peak of CH_4 was (37 ppm) measured in railway station. Whereas, highest concentration of Cl_2 (0.30 ppm) was measured in Anandi. Interestingly, two waste dumping site were identified in the same study locations where highest CH_4 and Cl_2 were detected during the study. Average concentration of SO_2 was measured 0.50 ppm, which is higher than those of Nanjing, Chaina and Dhaka. Extended concentration of SO_2 emission in the study area maybe associated with sulfur containing coal burning in the brick field. The AQI values indicates that air pollution status in Velanagr, Railway Sation, Brahmondi, Shaheprotap, Launch Terminal, Satirpara, Panchdona, Shekherchar and Madhabdi were in moderate condition where air quality is acceptable. Whereas, air quality status of Boro Bazar, Ghoradia, Bus Terminal, Silmandi, Gangpar Bridge and Anandi were unhealthy for sensitive communities of people.

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CONFLICT OF INTERESTS:

All the authors of this manuscript agreed that they have no confliction to make the manuscript publishable.

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