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Spatial distributions of gaseous air pollutants including particulate matter in the Narsingdi city of Dhaka division

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 PM2.5 and PM10 during the month September, 2022 using air quality meter Aeroqual (Series 500). Highest concentration of PM2.5 was detected 58 µg/m3 at Boro Bazar whereas highest concentration of PM10 was 165 µg/m3 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 ($r = 0.679$, $p > 0.01$), PM2.5 and PM10 ($r = 0.630$, $p > 0.05$) 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 PM2.5 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 were very much compatible with US consulate, Bangladesh published data.

Key words: Air pollution, CH4, Cl2, Narsingdi, AQI

1. 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 [10] ozone (O3) nitrogen dioxide (NO2), carbon monoxide (CO), sulfur dioxide (SO2), methane (CH4), chlorine (Cl2), and particulates (PM2.5 and PM10), 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/m3) 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 µg/m3, whereas cities with 70 µg/m3 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 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 Program (UNEP), which have taken measures or [2] have made plans to reduce and control air pollution. However, 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 Male declaration on control and prevention of air pollution and its likely trans-boundary effects for South Asia (Air Pollution Reduction Strategy for Bangladesh, Final Report, 2012).

Air pollution is a major anthropogenic environmental concern that has recently gained prominence among all environmental issues in Bangladesh. According to a World Bank report, the economic cost of air pollution in the health sector of Bangladesh alone is estimated as U.S. $132–583 million per year for Dhaka and $200–800 million per year for the four largest cities of Bangladesh, which constitutes 0.7–3.0% of the country's GDP per year (C. Brandon, Economic valuation of air and water pollution in Bangladesh: Workshop discussion draft, 1997, World Bank). Moreover, a 20% reduction from the current level of PM_{10} in Dhaka would save health costs of around U.S. $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 Chronic Obstructive Pulmonary Disease (COPD) attributable to air pollution (Azkar et al., 2012; Gurjar et al.; 2010).

1.1. 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.

2. Materials and Methods

2.1. Study area

Narsingdi is a district in central Bangladesh. It is located 50 km north-east of Dhaka, capital city of Bangladesh. It is a part of the Dhaka Division. The district is famous for its textile craft 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.

Figure 1. Map of study area with sampling locations

2.2. 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.

Figure 2. Aeroqual S500 air quality monitoring instrument with sensors

2.3. AQI calculation

In our study AQI is calculated by using following formula:

Here,

I: the 6 Air Quality Index (AQI)

C: the pollutant concentration

C low: the concentration breakpoint that is ≤ C

C high: the concentration breakpoint that is ≥ C

I low: the index breakpoint corresponding to C low

I high: the index breakpoint corresponding 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

O3

(ppb)

O3

(ppb)

PM2.5

(µg/m3)

PM10

(µg/m3)

CO

(ppm)

SO2

(ppb)

NO2

(ppb)

AQI

(avg)

(avg)

(avg)

(avg)

(avg)

(avg)

(avg)

(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

3. Results and Discussion

3.1. Spatial distribution of PM2.5 in the study area

As shown in Table 2, concentration of PM2.5 ranged from 16-58 μg/m3, average is 31.55μg/m3. However, this value is lower than the Nanjing, China 65.36 μg/m3 (Hasnain et al., 2021), Dhaka 77 μg/m3 (Khuda K.E., 2020) and Delhi 182.49 μg/m3 (Sethi et al., 2020) and higher than the previous study of Chittagong 21.2 μg/m3 (Hoque et al., 2022a). However, 1 the spatial distribution of PM2.5 showed that the highest value of PM2.5 observed 58 μg/m3 in Boro Bazar (Figure 3). The sources of PM2.5 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

PM2.5

(µg/m3)

PM10 (µg/m3)

CH4 (ppm)

CO (ppm)

CO2 (ppm)

NO2 (ppm)

SO2 (ppm)

Cl2 (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

Figure 3. Spatial distribution of PM2.5 in the study area

3.2. Spatial distribution of PM10 [1] in the study area

As shown in Table 2, concentration of PM10 ranged from 19-165 μg/m3, average 61 μg/m3. Interestingly, this value is lower than the Nanjing, China 102.75 μg/m3 (Hasnain et al., 2021), Dhaka 65.5 μg/m3 (Khuda K.E., 2020), Delhi 299.78 μg/m3 (Sethi et. al., 2020) and higher than the previous study of Chittagong 57.3 μg/m3 (Hoque et al., 2022a). However, [8] the spatial distribution of PM10 showed that the highest value of PM10 observed 165 μg/m3 in Anandi (Figure 4). The sources of PM10 of this area may be associated with roadside constructions, waste burning, dust from open land and grinding operation.

Figure 4. Spatial distribution of PM10 [1] in the study area

3.3. Spatial distribution of CO in the study area

As shown 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 distribution of CO showed that the highest value of CO observed in Shaheprotap of the study area (Figure 5).

The sources of CO of that area may be associated with incomplete combustion of vehicular emission.

Figure 5. Spatial distribution of CO in the study area

3.4. Spatial distribution of NO2 in the study area

As shown in Table 2, concentration of NO2 ranged from 5.72-5.75 ppm (avg. 5.74 ppm). Regrettably, this value [2] 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, [8] the spatial distribution of NO2 showed that the highest value of NO2 observed 5.75 ppm in Bus Terminal (Figure 6). The sources of NO2 of that area may be associated with vehicular combustion and waste burning nearby the bus terminal.

Figure 6. Spatial distribution of NO2 [1] in the study area

3.5. Spatial distribution of SO2 in the study area

As shown in Table 2, concentration of SO2 ranged from 0.0-0.1 ppm (avg. 0.046 ppm). In comparison, concentration of SO2 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. Figure 7 showed the spatial of SO2 [1] in the study area. As shown in Figure 7, the highest value of SO2 observed 0.1 ppm in Madhabdi followed by Anandi, Gangpar Bridge, Silmandi, Launch Terminal, Railway Station and Brahmondi. The sources of SO2 of those areas may be associated with burning of sulfur containing fuels by locomotives, ships and motor vehicles.

Figure 7. Spatial distribution of SO2 in the study area

3.6. Spatial distribution of CO2 in the study area

As shown in Table 2, concentration of CO2 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.

Figure 8. Spatial distribution of CO_2 in the study area

3.7. Spatial distribution of CH_4 in the study area

As shown 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) (Figure 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.

Figure 9. Spatial distribution of CH_4 in the study area

3.8. Spatial distribution of Cl_2 in the study area

As shown in Table 2, concentration of Cl_2 ranged from 0.02-0.04 ppm (avg. 0.028 ppm). Figure 9, the spatial distribution of Cl_2 in the study area. As shown in Figure 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) (Figure 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 various 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 Cl2 0.04 ppm [1] in this study is lower than the OSHA’s permissible limit 0.1 ppm.

Figure 10. Spatial distribution of Cl2 in the study area

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

Country

Concentration of Pollutants

References

CO

(ppm)

NO2

(ppm)

SO2

(ppm)

PM2.5

(µg/m3)

PM10

(µg/m3)

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

3.9. Calculation of AQI value 1 of the study area

The study measured the AQI values of the different locations of the study area based on PM2.5 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 1 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 (PM2.5) Concentration(µg/m3)

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 location of the study area based on air quality (Table 5). As shown 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 risk for some 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 members of sensitive groups may be experienced health effect, but general public are less likely to 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

9 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/m3) and PM_{10} (61 in µg/m3). 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 status of air pollution 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 groups of people.

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