EurJChem An International Open Access Journal

European Journal of Chemistry

ATLANTA PUBLISHING HOUSE

Check for updates

View Journal Online
View Article Online

Effect of air pollution on plant life in the city of Chittagong, Bangladesh

Ahmed Jubaer [1], Mohammed Khorshed Ali [2], Saiyed Mahmud Tanvir Hassan [1], Md.Shahidul Islam [3], Muhammad Mahabub Alam [1], Sajia Islam [4], Mohammad Zahirul Islam Talukder [5] and Rubayat Tahrim Sourav [6]

[1] Environmental and Social Monitoring Department, EQMS Consulting Limited, Banani, Dhaka, 1213, Bangladesh
[2] Department of Computer Science and Engineering, Faculty of Science and Engineering, International Islamic University Chittagong, Kumira, Sitakunda, Chattogram, 4318, Bangladesh
[3] Department of Chemistry, University of Chittagong, Chittagong, 4331, Bangladesh
[4] Central Analytical and Research Facilities, Bangladesh Council of Scientific and Industrial Research, Dhanmondi, Dhaka-1205, Bangladesh
[5] Department of Environment, Ministry of Environment, Forest and Climate Change, Dhaka, 1207, Bangladesh
[6] Department of Environment, Ministry of Environment, Forest and Climate Change, Chattogram, 4202, Bangladesh

* Corresponding author at: Department of Computer Science and Engineering, Faculty of Science and Engineering, International Islamic University Chittagong, Kumira, Sitakunda, Chattogram, 4318, Bangladesh.
e-mail: khorshed.chem.cse@iiuc.ac.bd (M.K. Ali).

RESEARCH ARTICLE

10.5155/eurjchem.15.1.79-86.2511

Received: 31 January 2024
Received in revised form: 03 March 2024
Accepted: 08 March 2024
Published online: 31 March 2024
Printed: 31 March 2024

KEYWORDS

Plants
Leaves
Aerosol
Adsorption
Chlorophyll
Air pollution

ABSTRACT

Bangladesh faces a serious problem with air pollution, which has a negative impact on human health and tree health. Leaf damage, slow development, and decreased photosynthetic activity are just a few of the harmful effects on trees that have been linked to high concentrations of pollutants such as particulate matter, sulfur dioxide, and nitrogen oxides. These consequences affect the aesthetic value of green spaces in addition to interfering with the functions of the ecosystem that trees offer, such as air filtration and carbon sequestration. Given the seriousness of the problem, the present study plan was implemented to evaluate the amount of pollutants such as SO_x, NO_x, O_3, hydrocarbons, particulate matter 2.5, particulate matter 10 and suspended particulate matter in the air in several urban areas of Chittagong and to evaluate the amount of chlorophyll from the leaves of affected and without affected leaves so that it may understand how the photosynthesis process of plants is interrupted by air pollution. 2 Number Gate Circle, Akbarsha Lane Circle, Alongkar Mor Bus Stop, Barik Building Circle, BDR Field Circle, Halishahar Access Road, Artillery Center-North Halishahar, Bangladesh Forest Research Institute and CRB Circle were selected as sampling location based on their heavy traffic and crowdedness. For the analysis of chlorophyll, each plant leaves were collected in three sections such as unaffected, slightly affected, and affected for comparison. The data studied showed that the most polluted zone with particulate matter had a lower chlorophyll concentration in the surrounding tree leaves. This can indicate that particulate matter can hinder photosynthesis reactions.

Cite this: *Eur. J. Chem.* **2024**, *15(1)*, 79-86 **Journal website**: www.eurjchem.com

1. Introduction

Air pollution is a complex mixture of particulates, gases, and organic and inorganic substances found both in the outdoors and indoor air [1]. In Chittagong, Bangladesh's commercial city, common causes of air pollution include the textile, clothing, cement, sugar, chemical fertilizers, shipbuilding, and light engineering sectors. In recent decades, air pollution has become a significant problem with negative toxicological impacts on both human health and the ecosystem. Every year, millions of people around the world are affected by air pollution [2]. Common air pollutants are SO_x (sulfur oxides), NO_x (nitrogen oxides), CO (carbon monooxide), CO_2 (carbon dioxide), and airborne particulate matter such as PM2.5, PM10 or suspended particulate matter.

Sulfur dioxide is one of the extremely reactive gases referred to as sulfur oxides. Fossil fuel burning, wood pulping, papermaking, metal smelting, locomotives, and ships are all sources of sulfur oxide emissions that cause adverse respiratory consequences, including those that cause asthma and breathing problems [3,4].

Nitric oxide and nitrogen dioxide are combined to form nitrogen oxides (NO_x), which are released by natural sources, cars, and other fuel-burning processes. Nitric oxide (NO), which has a poor solubility in water, penetrates the respiratory system. Nitrogen oxides disturb Alveolar structures and their function by diffusing through the Alveolar cells of the lungs (epithelium) and adjacent capillary capillaries [5]. Approximately 20% of all premature deaths in Bangladesh are attributed to air pollution, according to a World Bank study. The three largest air pollution hotspots in Bangladesh are Dhaka, Narayanganj, and Chattogram [6].

Recent concern in respect to Bangladesh arises is the heat effect on human and plants due to ambient temperature. Although unhealthy temperatures, extreme temperatures, and even moderately high or low temperatures can have an impact

https://dx.doi.org/10.5155/eurjchem.15.1.79-86.2511

on death, the overall influence of humidity on mortality has not been epidemiologically demonstrated conclusively [7]. Additionally, in vulnerable plant species, these air pollutants can cause leaf damage, stomatal damage, early senescence, reduced photosynthetic activity, disturbed membrane permeability, and restricted growth and production. Moreover, the morphological characteristics and growth of plants are also affected by the highly dangerous heavy metals emitted by moving vehicles [8,9].

Nitric oxide and nitrogen dioxide are the two main phytotoxic pollutants connected to vehicle mobility. However, it is also conceivable that trace amounts of other nitrogen-containing compounds, such as nitrous acid, nitrous oxide, and ammonia, are also present in car emissions [10]. A study found that exposure to 35 ppb of nitrogen dioxide or nitric oxide for 21 days significantly impacts the nitrate reductase activity and oxygen evolution of bryophyte species. Similarly, *Polytrichum formosum*, when exposed to 60 ppb nitrogen dioxide for 37 weeks, experienced both an initial growth increase and a subsequent decrease [11].

Plants are greatly affected by ozone, including long-term exposure to low concentrations of ozone can cause obvious damage, such as chlorosis, changes in pigmentation or bronzing, and premature senescence. Stippling and flaking can appear after a brief exposure to elevated ozone levels. The physiological effects of ozone exposure include slower decomposition of early successional communities, reduced photosynthesis, increased turnover of the antioxidant system, damage to the reproductive process, increased dark respiration, and decreased carbon transport to roots [12]. Among the various air pollutants, particulate matter is particularly dangerous to people, since it is more harmful than any other. Lower chlorophyll a/b levels were observed in primary leaves exposed to particulate matter, suggesting that particulate matter (PM) had a shading effect on plants. Primary leaves exposed to particulate matter showed reduced sugar levels [13].

Lead has garnered significant attention as a persistent hazardous pollutant of concern, in part because of its prominence in the discourse around the increasing stress that human activities place on the environment. In the human body, lead poisoning can slow the synthesis process of adenosine triphosphate (ATP) and destroy DNA by overproducing reactive oxygen species (ROS). Additionally, lead dramatically reduces water and protein content, transpiration, seed germination, seedling development, and seedling growth [14]. Mercury is a metal that is easily transmuted into multiple oxidation states and is dispersed throughout various environments. There are two main cycles in which these changes could recur. The first involves the global circulation of elemental mercury (Hg) in the atmosphere. The second, more limited, depends on the activity of organisms that can transform inorganic mercury into organic mercury compounds, which are the most dangerous to living creatures [15].

The indirect and direct effects of sulfur dioxide on plants make it dangerous. There are two types of direct effects: acute and chronic, depending on the duration and intensity of exposure. Sulfur dioxide hinders photosynthetic processes by interfering with them. More water is lost when the stomata open due to the stimulation of sulfur dioxide [16]. Plants absorb CO_2 through the stomates in their leaves and simultaneously lose water through transpiration through the same route. Plants can reduce water loss per unit of carbon intake at higher atmospheric carbon dioxide concentrations, partly due to a decrease in stomatal conductance as the gradient of CO_2 between the environment and the interior of the leaf increases. If the leaf area is constant, this physiological reaction may decrease water loss from the land surface, increase soil moisture, and relieve plant water stress [17]. When it dissolves in water and forms nitrate and nitrite, which are both utilized by plants through the regular nitrate metabolism process, low concentrations of NO_2 can function as an airborne fertilizer. However, excessive accumulation of nitrite (NO_2) and cell acidification caused by high levels of NO_2 can have negative consequences such as the generation of reactive oxygen species (ROS) and the inhibition of N assimilation and plant growth. These can also lead to acute leaf damage, whole plant chlorosis, or even plant death [18]. When photochemical processes occur in its precursors, tropospheric ozone, a secondary gaseous pollutant, is produced. Tropospheric ozone has been reported to affect plant photosynthesis, affecting plant growth, nutrition, and crop yield. Secondary metabolites that are crucial for plant communication or plant attraction, repulsiveness, or defense may change in quantity or quality due to ozone pollutants [19]. Due to the 0.2 °C increase in global air temperature per ten years, temperatures are predicted to be 1.8-4.0 °C higher by 2100. Catastrophic collapse of the cellular structure may result from rapid cell death or damage at extremely high temperatures [20].

The purpose of this study is to establish a link between plant health and air pollution, thus identifying solutions to improve air quality and promote the well-being of both plants and humans.

2. Experimental

2.1. Sampling and sample preparation

In this study, high-volume APM 430 model air samplers (Envirotech, India) were used for the collection of SO_x, NO_x, and suspended particulate matter samples. Ozone gas was monitored using a smart sensor electrochemical ozone gas detector (model AS8908, Intel Instrument Pro). Lata Envirotech APM 250 (Lata Envirotech, India) was used to collect the PM10 and PM2.5 samples. Suspended particulate matter was collected on Millipore glass fiber filter paper (Whatman, GF/A, for size 8”×10”) where PM10 and PM2.5 were collected on PM2.5 PTFE (Polytetrafluoroethylene) membrane filters (Whatman, 46.2 mm) are designed for PM2.5 ambient air monitoring. The West-Geake method [21] was followed to collect and determine the ambient SO_x analysis. The high-volume air sampler APM 430 (Envirotech, India) with springer having 20 mL 0.04 M potassium tetra chloromercurate prepared by mixing 10.86 g of mercuric chloride and 6.0 g of potassium chloride and 0.066 g of EDTA were dissolved in distilled water and then the final volume of up to 1 liter with distilled water was run for eight hours in each selective location to collect SO_x sample. The Jacob and Hochheiser method was followed to collect and determine ambient NO_x analysis [22]. Springer in APM 250 (Lata Envirotech, India) contains 20 mL absorbent (4.0 g of sodium hydroxide and 1.0 g of sodium arsenite).

The leaves were collected in three groups between the winter and summer seasons (January to May 2023). The first group consisted of noninfected leaves, the second group of infected leaves, and the third group of slightly yellowish leaves. The sampling locations are listed with their GPS coordinates in Table 1 and the sampling map shown in Figure 1.

2.2. Extraction method

The leaves were stored in a 4 °C refrigerator covered with aluminum foil paper in a dark box for analysis. During the analysis period, one gram of finely cut fresh leaves was taken and ground with 20-40 mL of 80% acetone. The mixture was then centrifuged at 5000-10000 rpm for 5 min. The supernatant was transferred to a 25 mL volumetric flask and made up to the mark with 80% acetone.

Table 1. GPS coordinates of the sampling and monitoring location.

Monitoring point	Latitude	Longitude
2 Number Gate Circle, Chittagong	22°21'59.46"N	91°49'22.37"E
Akbarsha Lane Circle, Chittagong	22°21'46.30"N	91°47'33.78"E
Alongkar Mor Bus Stop, Chittagong	22°21'30.68"N	91°46'56.24"E
Barik Building Circle, Chittagong	22°19'9.93"N	91°48'44.02"E
BDR Field Circle, Chittagong	22°20'26.51"N	91°46'53.14"E
Halishahar Access Road, Chittagong	22°19'41.91"N	91°47'35.94"E
Artillery Center, North Halishahar, Chittagong	22°19'54.93"N	91°46'55.70"E
Bangladesh Forest Research Institute (BFRI), Chittagong	22°22'24.08"N	91°49'38.90"E
CRB Circle, Chittagong	22°20'33.35"N	91°49'15.34"E

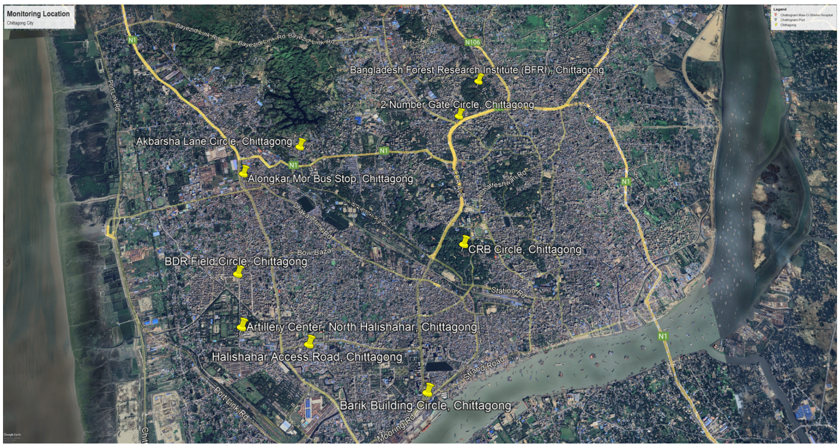

Figure 1. Sampling and monitoring map (Source: Google Earth).

The absorbance of the solution was red at 645, 663, and 652 nm for chlorophyll a, chlorophyll b, and total chlorophyll, respectively, against the blank solvent (acetone) using a spectrophotometer (T60, PG Instrument, UK).

2.3. Moisture content of leaves

The moisture content of leaves was measured by a simple oven-dry method at temperature 105 °C for 2 hours followed by gravimetric analysis [23].

2.4. Analysis

2.4.1. Determination of SO_x

Following the West-Geake method [24], the absorbance was measured at 560 nm after 30 min but before 60 min against the blank reagent using a spectrophotometer. From the calibration curve, the concentration of SO_2 in the absorbent reagent was measured. Then the concentration of SO_2 in the air was measured using Equations 1 and 2.

$$\text{Total volume of air passed through } SO_2\text{impinger} = \text{Avg. flow rate (lpm)} \times \text{Time (min)} \quad (1)$$

$$SO_2 \text{ concentration } (\mu g/m^3) = \frac{C \times A \times 1000 \times D}{V \times B} \quad (2)$$

where, C = SO_2 curve value (µg SO_2 in 25 mL), A = Sample taken for sampling (mL), V = Volume of air passed (L), B = Sample volume taken for analysis (mL) and D = Dilution factor.

2.4.2. Determination of NO_x

Following the Jacob and Hochheiser method [22], the absorbance was measured at 540 nm after 10 min against the blank reagent using a spectrophotometer (T60, PG Instrument, UK). From the calibration curve, the concentration of NO_x in the absorbing reagent was measured. Then the concentration of NOx in the air was measured using Equations 3 and 4.

$$\text{Total air volume of air passed through } NO_2\text{impinger} = \text{Avg. flow rate (lpm)} \times \text{Time (min)} \quad (3)$$

$$NO_x \text{ concentration } (\mu g/m^3) = \frac{C \times A \times 1000 \times D}{V \times B \times 0.82} \quad (4)$$

where, C = NO_2 curve value (µg NO_2 in 50 mL), A = Sample taken for sampling (mL), V = Volume of air passed (L), B = Sample volume taken for analysis (mL), 0.82 = Absorbing efficiency of this method, and D = Dilution factor.

2.4.3. Determination of ozone gas

An electrochemical smart sensor device, model AS8908, was used to detect ozone gas by the electrochemical method [25].

2.4.4. Determination of PM2.5 and PM10

The PM2.5 and PM10 particles were collected using a combined dust sampler (Lata Envirotech APM 250) for 24 hours for each location and analyzed according to Equations 5 and 6 [26].

$$PM2.5 = (Mf - Mi) \times 10^6 / Q_{avg} \times t \quad (5)$$

$$PM10 = (Mf - Mi) \times 10^6 / Q_{avg} \times t \quad (6)$$

where Q_{avg} = (Initial flow rate + Final flow rate)/2, Mf = Final mass of the conditioned filter after sample collection (mg), Mi = Initial mass of the conditioned filter before sample collection (mg).

Table 2. The concentrations of PM2.5, PM10, SO_x, and NO_x of different locations in Chittagong city.

Sampling date	Monitoring location	Temp. (°F)	Humidity (%RH)	Weather condition	Sampling hours	Conc. of PM2.5 (μg/m³)	Conc. of PM10 (μg/m³)	Conc. of NO_2 (μg/m³)	Conc. of SO_2 (μg/m³)
Jan 11, 2023	2 Number Gate Circle,	70	64	Haze	24	36.52	68.09	48.24	20.15
Feb 15, 2023	Chittagong	72	46	Haze	24	36.89	70.03	46.78	21.41
Mar 10, 2023		84	45	Haze	24	36.18	69.08	45.31	29.32
Average						36.53	69.07	46.78	23.63
Jan 15, 2023	Akbarsha Lane Circle,	70	83	Haze	24	35.15	65.14	43.51	23.17
Feb 11, 2023	Chittagong	77	50	Haze	24	33.11	64.10	42.64	21.01
Mar 3, 2023		82	48	Haze	24	33.19	65.09	45.20	21.61
Average						33.82	64.78	43.78	21.93
Feb 18, 2023	Barik Building Circle,	75	57	Haze	24	35.50	68.01	46.76	21.23
Mar 11, 2023	Chittagong	84	45	Haze	24	37.40	68.39	45.89	22.14
Apr 7, 2023		95	32	Sunny	24	36.40	69.29	46.32	23.41
Average						36.43	68.56	46.32	22.26
Feb 26, 2023	BDR Field Circle,	79	36	Haze	24	33.17	56.09	38.52	21.13
Mar 13, 2023	Chittagong	90	21	Fair	24	32.09	56.59	36.34	25.31
Apr 14, 2023		96	44	Sunny	24	32.15	55.56	31.53	22.32
Average						32.47	56.08	35.46	22.92
Mar 14, 2023	Halishahar Access Road,	82	54	Haze	24	36.40	67.14	42.91	24.11
Apr 15, 2023	Chittagong	95	55	Scattered clouds	24	33.07	66.01	41.72	23.11
May 12, 2023		93	56	Mostly cloudy	24	39.10	68.03	43.08	21.65
Average						36.19	67.06	42.57	22.96
Mar 18, 2023	Alongkar Mor Bus Stop,	81	70	Fog	24	38.20	69.65	41.32	22.34
Apr 18, 2023	Chittagong	90	75	Haze	24	35.30	68.68	48.74	22.41
May 19, 2023		88	66	Partly cloudy	24	35.80	68.13	44.94	22.14
Average						36.43	68.82	45.00	22.30
May 25, 2023	Artillery Center,	84	66	Mostly cloudy	24	35.50	54.05	31.38	23.43
May 27, 2023	North Halishahar	90	66	Partly cloudy	24	35.20	61.01	38.58	21.21
Jul 7, 2023		88	79	Mostly cloudy	24	34.50	56.03	37.68	21.90
Average						35.07	57.03	35.88	22.18
May 30, 2023	Bangladesh Forest Research	91	63	Haze	24	28.60	56.08	32.41	25.65
Jun 4, 2023	Institute	90	75	Haze	24	28.82	55.09	32.71	21.54
Jul 14, 2023	(BFRI), Chittagong	84	84	Mostly cloudy	24	30.10	56.03	33.36	18.45
Average						29.17	55.73	32.83	21.88
Jun 14, 2023	CRB Circle, Chittagong	91	71	Haze / windy	24	31.34	58.25	37.16	23.40
Jul 9, 2023		88	79	Mostly cloudy	24	32.20	58.18	31.31	22.23
Jul 21, 2023		91	66	Partly cloudy	24	33.20	57.29	30.32	22.53
Average						32.25	57.91	32.93	22.72

2.4.5. Determination of suspended particulate matter

Using a high-volume sampler (Envirotech), a suspended particle matter (SPM) sample was collected on a Millipore filter paper. In the upper section of the high-volume sampler, a filter paper was placed. Suspended particulate matter later than analysis by gravimetrically by analytical balance (Fix Scale, KD-TN 200, USA) by using Equation 7,

$$SPM \text{ in } \mu g/m^3 = \frac{(FFW-IFW)\times 10^6}{\frac{(IMR+FMR)}{2}} \times (FTR-ITR)\times 60 \quad (7)$$

where, IFW = Weight of initial filter paper, FFW = Weight of final filter paper, IMR = Initial manometer reading, FMR = Final manometer reading, ITR = Initial time reading and FTR = Final time reading.

2.4.6. Determination of chlorophyll a and b

Chlorophyll a, b and total chlorophyll were determined using the method described by Arnon [27]. After centrifuging the leaf sample with acetone solution, the supernatants were diluted by adding 80% aqueous acetone to give a reading in the range of 0.2 to 0.8 absorbance units at wavelengths of 645, 652 and 663 nm. Equations 8-11 were followed to evaluate chlorophyll a, b, and total chlorophyll.

$$\text{Chlorophyll a} = 12.7 \times \text{Absorbance taken at 663 nm} - 2.69 \times \text{Absorbance taken at 645 nm} \times \frac{V}{1000 \times W} \quad (8)$$

$$\text{Chlorophyll b} = 22.9 \times \text{Absorbance taken at 645 nm} - 4.69 \times \text{Absorbance taken at 663 nm} \times \frac{V}{1000 \times W} \quad (9)$$

$$\text{Total chlorophyll} = \frac{\text{Absorbance at 652 nm}}{34.5} \times \frac{1000 \times V}{1000 \times W} \quad (10)$$

where A is the absorbance found at the respective wavelengths, V is the final volume of the supernatant (25 mL), and W is the fresh weight of grained leaf (2 g).

$$\text{Chlorophyll a and b ratio} = \frac{\text{Chlorophyll a}}{\text{Chlorophyll b}} \quad (11)$$

2.4.7. Determination of leaf moisture content %

The oven dry method was used to determine the moisture content of the leaves of the plant at a temperature of 105 °C for 2 hours (Equation 12) [28].

$$\text{Moisture (\%)} = \frac{(W1-W2)\times 100}{W1} \quad (12)$$

where W1 = Weight (g) of the sample before drying and W2 = Weight (g) of the sample after drying.

3. Results and discussion

The particulate matter and gaseous pollutants were measured in different traffic locations in the ambient air of the city of Chittagong for 24 hours of continuous monitoring, where the average concentration of particulate matter of 2.5 microns or less in diameter (PM2.5) varies from 29.17 to 36.53 μg/m³ to in Chittagong city (Table 2). According to the Environmental Convention rule 2022, the maximum allowable concentration for PM2.5 for 24 hours continuous monitoring is 65 μg/m³. 2 No. Gate Circle area has the highest average concentration for PM2.5 pollutants.

Table 3. Concentration of ozone and SPM of different locations in Chittagong city.

Sampling date	Monitoring location	Temp. (°F)	Humidity (%RH)	Weather condition	Sampling hours	Conc. of SPM (µg/m³)	Conc. of ozone (ppb)
Jan 11, 2023	2 Number Gate Circle, Chittagong	70	64	Haze	8	132.875	20.00
Feb 15, 2023		72	46	Haze	8	135.106	40.00
Mar 10, 2023		84	45	Haze	8	138.783	20.00
Average					8	135.588	26.67
Jan 15, 2023	Akbarsha Lane Circle, Chittagong	70	83	Haze	8	110.610	20.00
Feb 11, 2023		77	50	Haze	8	114.540	10.00
Mar 3, 2023		82	48	Haze	8	112.310	20.00
Average					8	112.487	16.67
Feb 18, 2023	Barik Building Circle, Chittagong	75	57	Haze	8	125.752	20.00
Mar 11, 2023		84	45	Haze	8	125.640	30.00
Apr 7, 2023		95	32	Sunny	8	131.430	20.00
Average					8	127.607	23.33
Feb 26, 2023	BDR Field Circle, Chittagong	79	36	Haze	8	122.678	20.00
Mar 13, 2023		90	21	Fair	8	114.251	20.00
Apr 14, 2023		96	44	Sunny	8	116.410	20.00
Average					8	117.780	20.00
Mar 14, 2023	Halishahar Access Road, Chittagong	82	54	Haze	8	135.752	20.00
Apr 15, 2023		95	55	Sunny	8	128.640	30.00
May 12, 2023		93	56	Mostly cloudy	8	131.430	20.00
Average					8	131.941	23.33
Mar 18, 2023	Alongkar Mor Bus Stop, Chittagong	81	70	Fog	8	135.752	20.00
Apr 18, 2023		90	75	Haze	8	138.640	30.00
May 19, 2023		88	66	Partly cloudy	8	131.430	20.00
Average					8	135.274	23.33
May 25, 2023	Artillery Center, North Halishahar	84	66	Mostly cloudy	8	110.601	20.00
May 27, 2023		90	66	Partly cloudy	8	115.501	10.00
Jul 7, 2023		88	79	Mostly cloudy	8	126.203	20.00
Average					8	117.435	16.67
May 30, 2023	Bangladesh Forest Research (BFRI), Chittagong	91	63	Haze	8	103.251	20.00
Jun 4, 2023		90	75	Haze	8	105.356	10.00
Jul 14, 2023		84	84	Mostly cloudy	8	107.941	20.00
Average					8	105.516	16.67
Jun 14, 2023	CRB Circle, Chittagong	91	71	Haze / windy	8	103.251	20.00
Jul 9, 2023		88	79	Mostly cloudy	8	125.356	10.00
Jul 21, 2023		91	66	Partly cloudy	8	107.941	20.00
Average					8	112.183	16.67

People in this area are more vulnerable to the possibility of having diseases associated with the lungs such as cancer, respiratory tract infection, *etc*. as PM2.5 is a pollutant that is the combination of suspended particles of various chemical contents [29]. In 2021, the studied data showed that the average concentration of particulate matter (PM2.5) was 80.15, 83.14, 83.06, 67.03, 68.74, 69.20 and 69.17 µg/m³ for the WASA Circle, the GEC Circle, Proborthak Circle, Chawkbazar Circle, Alongkar Circle, New Market Circle, Oxygen Circle, respectively, in the city of Chittagong. The previously established data was too high than in the current study [26].

The average concentration of particulate matter of 10 microns or less (PM10) was found to vary from 55.73 to 69.07 µg/m³ in Chittagong city (Table 2). According to the Environmental Convention rule 2022, the maximum allowable concentration for PM10 for 24 hours continuous monitoring is 150 µg/m³. 2 No. Gate Circle area has the highest average concentration for PM10 pollutants. In the current study, motor vehicles such as trucks, laury, bus, cars, jeep, minibus, human holler, microbus, four-stroke engine driven, etc., have been identified as the main source of particulate matter pollution in the Chittagong study area [30]. The same study data revealed that the average concentration of particulate matter (PM10) was 163.44, 166.07, 171.43, 163.73, 153.36, 153.82and 153.79 µg/m³ for the WASA Circle, G.E.C. Circle, Proborthak Circle, Chawkbazar Circle, Alongkar Circle, New Market Circle, Oxygen Circle, respectively, in the city of Chittagong. The previously established data was too high than in the current study [26].

The average concentration of suspended particulate matter (SPM) (diameters ranging from < 0.1 µm and up to about 100 µm) was found to vary from 105.516 to 135.588 µg/m³ in Chittagong city (Table 3). Monitoring was carried out for 8 hours. Although there is no standard requirement set yet for suspended particulate matter in the environment of Bangladesh, the comparatively 2 Number Gate Circle area has the highest average concentration of suspended particulate pollutants. In 2016, the mean concentrations of SPM concentrations were found for A. The K. Khan Gate circle, the City Gate circle, the GEC circle, the Sholashar Gate-2 circle, the Agrabad circle, and the New Market circle were 238, 226, 276, 270, 241 and 257 µg/m³, respectively [31], which is higher than the current founded average value studied.

The average concentration of SO_x was found to vary from 21.88 to 23.63 µg/m³ in Chittagong city (Table 2). Monitoring was carried out for 24 hours. According to the rules of the Environmental Convention 2022, the maximum allowable concentration of SO_2 for continuous monitoring for 24 hours is 80 µg/m³. Where the maximum value was found at 2 No. Gate Circle area in Chittagong city, which is a high traffic zone. In 2014, a study found that the average concentration of SO_x in different locations in Chittagong city was 37.20, 26.25, 36.32, 31.41, 33.19, 35.48, 30.51, 35.63 µg/m³ for Muradpur Circle, WASA Circle, G.E.C Circle, Proborthak Circle, Chawkbazar Circle, Alongkar Circle, New Market Circle and Oxygen Circle, respectively [32], which are slightly higher than the current found data.

The average concentration of NO_x was found to vary from 32.83 to 46.78 µg/m³ in Chittagong city (Table 2). Monitoring was carried out for 24 hours. According to the rules of the Environmental Convention 2022, the maximum allowable concentration of NO_2 for continuous monitoring for 24 hours is 80 µg/m³. Where the maximum value was found at 2 No. Gate Circle area in Chittagong city, which is a high traffic zone. This study also found that the average NO_x concentration at different locations in Chittagong city was 44.91, 48.23, 44.89, 38.69, 42.57, 60.95, 50.53 and 57.60 µg/m³ for Muradpur Circle, WASA Circle, G.E.C Circle, Proborthak Circle, Chawkbazar Circle, Alongkar Circle, New Market Circle and Oxygen Circle, respectively [32], which were higher than the data currently established.

Table 4. Concentration of chlorophyll of different locations' plant leaves.

Sampling ID	Leaf condition	Sampling location	Conc. of chlorophyll a (mg/L)	Conc. of chlorophyll b (mg/L)	Conc. of total chlorophyll (mg/L)	Ratio of chlorophyll a/b	Moisture content (%)
S1	Non-infected and fresh	2 Number Gate Circle, Chittagong	1.57	0.93	4.01	1.68	2.86
S2	Infected		1.26	0.94	3.29	1.35	3.85
S3	Slightly yellowish		1.21	0.85	3.14	1.44	2.55
Average±SE			1.35±0.11	0.91±0.03	3.48±0.27	1.49±0.10	3.09
S1	Non-infected and fresh	Akbarsha Lane Circle, Chittagong	1.49	0.72	3.77	2.06	2.36
S2	Infected		1.30	0.79	3.33	1.64	3.76
S3	Slightly yellowish		1.36	0.77	3.48	1.77	3.69
Average±SE			1.38±0.06	0.76±0.02	3.527±0.13	1.87±0.13	3.27
S1	Non-infected and fresh	Barik Building Circle, Chittagong	1.56	0.9295	4.00	1.68	3.87
S2	Infected		1.21	1.0587	3.20	1.15	3.88
S3	Slightly yellowish		1.26	0.9295	3.27	1.36	3.87
Average±SE			1.35±0.11	0.97±0.04	3.49±0.25	1.40±0.16	3.87
S1	Non-infected and fresh	BDR Field Circle, Chittagong	1.61	1.09	4.15	1.48	7.85
S2	Infected		1.35	1.18	3.86	1.14	7.86
S3	Slightly yellowish		1.61	1.09	4.15	1.48	7.85
Average±SE			1.52±0.08	1.12±0.03	4.05±0.10	1.37±0.11	7.85
S1	Non-infected and fresh	Halishahar Access Road, Chittagong	1.60	1.12	4.16	1.43	3.88
S2	Infected		1.36	1.21	3.62	1.13	3.88
S3	Slightly yellowish		1.60	1.12	4.16	1.43	3.87
Average±SE			1.52±0.08	1.15±0.03	3.98±0.18	1.33±0.10	3.88
S1	Non-infected and fresh	Alongkar Mor Bus Stop, Chittagong	1.49	0.73	3.78	2.05	3.58
S2	Infected		1.30	0.80	3.20	1.63	3.59
S3	Slightly yellowish		1.49	0.73	3.78	2.05	3.58
Average±SE			1.43±0.06	0.75±0.02	3.59±0.19	1.91±0.14	3.58
S1	Non-infected and fresh	Artillery Center, North Halishahar	1.60	1.11	4.15	1.43	7.57
S2	Infected		1.66	1.09	4.01	1.52	7.58
S3	Slightly yellowish		1.60	1.11	4.15	1.43	7.57
Average±SE			1.62±0.02	1.11±0.01	4.10±0.05	1.46±0.03	7.57
S1	Non-infected and fresh	Bangladesh Forest Research (BFRI), Chittagong	1.61	1.10	4.16	1.47	8.31
S2	Infected		1.68	1.07	4.31	1.56	8.32
S3	Slightly yellowish		1.61	1.10	4.16	1.47	8.31
Average±SE			1.63±0.02	1.09±0.01	4.21±0.05	1.50±0.03	8.31
S1	Non-infected and fresh	CRB Circle, Chittagong	1.61	1.15	4.20	1.40	8.13
S2	Infected		1.67	1.13	4.34	1.48	8.13
S3	Slightly yellowish		1.61	1.15	4.20	1.40	7.29
Average±SE			1.63±0.02	1.15±0.01	4.25±0.05	1.42±0.03	7.85

* S1= Group of leaf sample that were non-infected and fresh, S2 = Group of leaf sample that were infected, S3 = Group of leaf sample that were slightly yellowish.

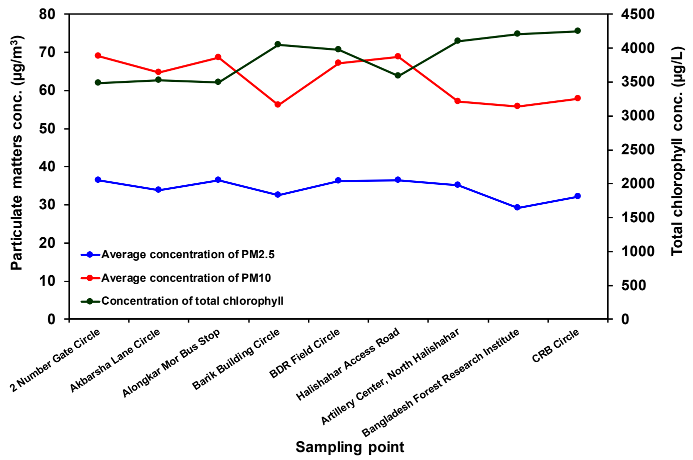

Figure 2. Relationship between airborne particulate matter with chlorophyll concentration in tree leaves on the roadside.

The amount of chlorophyll concentration of the tree leaves was found to be comparatively lower in areas of the high-traffic zone than in areas of the low-traffic zone. The lowest total chlorophyll concentration was found at the 2 no. gate 10.44 mg/L, while the highest concentration was found in tree leaves from the CRB zone area, which was 12.60 mg/L (Table 4). It also shows that the leaf samples from the location of the highly polluted area with particulate matter area have a lower chlorophyll content Figure 2, and the minimum moisture content of the leaves is found at a minimum level of chlorophyll contents. A study revealed that the total chlorophyll content was significantly higher in the leaves of the plant population of the dust-free area, while a lower level was observed in plants exposed to different levels of road dust [33]. Similar results were also achieved in the current study.

In the study, we tried to relate the correlation between the level of pollution and the condition of the trees in the surrounding zone. Total chlorophyll concentration was found to increase with the decrease in the level of particulate matter, sulfur dioxide, nitrogen dioxide, and ozone gas pollution in that particular zone.

4. Conclusions

The results of the current study demonstrate that airborne particles are a serious threat to plant health as they can affect photosynthesis, impede the uptake of nutrients, and make plants more vulnerable to pests and diseases. The vitality and production of plants, as well as the general health of ecosystems, depend on the mitigation of particle pollution.

Acknowledgements

We express our gratitude to the Department of Environment, Chittagong, Bangladesh and Department of Environment, Dhaka, Bangladesh for their help and collaboration. Their cooperation and suggestions have greatly enhanced the caliber and applicability of our study's conclusions. The authors are grateful to EQMS Consulting Limited for lending us the equipment needed for our research and for their technical assistance. Their assistance has been crucial in streamlining our procedures for gathering and analyzing data.

Disclosure statement

Conflict of interest: The authors declare that they have no conflict of interest.
Ethical approval: All ethical guidelines have been adhered.
Sample availability: Samples of the compounds are available from the author.

CRediT authorship contribution statement

Conceptualization: Ahmed Jubaer, Mohammed Khorshed Ali; Methodology: Ahmed Jubaer, Saiyed Mahmud Tanvir Hassan; Software: Ahmed Jubaer, Muhammad Mahabub Alam; Validation: Sajia Islam, Saiyed Mahmud Tanvir Hassan; Formal analysis: Ahmed Jubaer, Mohammed Khorshed Ali; Investigation: Ahmed Jubaer, Md.Shahidul Islam; Resources: Mohammad Zahirul Islam Talukder, Rubayat Tahrim Sourav; Data Curation: Saiyed Mahmud Tanvir Hassan, Md.Shahidul Islam, Muhammad Mahabub Alam; Writing - Original Draft: Ahmed Jubaer, Sajia Islam; Writing - Review and Editing: Mohammed Khorshed Ali, Muhammad Mahabub Alam; Visualization: Mohammad Zahirul Islam Talukder, Rubayat Tahrim Sourav; Supervision: Mohammed Khorshed Ali, Mohammad Zahirul Islam Talukder; Project Administration: Mohammed Khorshed Ali, Mohammad Zahirul Islam Talukder.

ORCID and Email

Ahmed Jubaer
jubaer.ahmed@eqms.com.bd
https://orcid.org/0000-0002-1559-3406
Mohammed Khorshed Ali
khorshed.chem.cse@iiuc.ac.bd
https://orcid.org/0000-0002-1519-3090
Saiyed Mahmud Tanvir Hassan
tanvir.hassan@eqms.com.bd
https://orcid.org/0009-0005-4767-7128
Md.Shahidul Islam
mdshahidulcu@gmail.com
https://orcid.org/0009-0006-8763-5018
Muhammad Mahabub Alam
mahabub.alam@eqms.com.bd
https://orcid.org/0009-0002-6559-8835
Sajia Islam
islamsajia323@gmail.com
https://orcid.org/0000-0002-1518-9411
Mohammad Zahirul Islam Talukder
zisi1000@gmail.com
https://orcid.org/0000-0002-8547-5878
Rubayat Tahrim Sourav
rtsouravdoe@gmail.com
https://orcid.org/0009-0001-2746-0491

References

[1]. Calderón-Garcidueñas, L.; Calderón-Garcidueñas, A.; Torres-Jardón, R.; Avila-Ramírez, J.; Kulesza, R. J.; Angiulli, A. D. Air pollution and your brain: what do you need to know right now. *Prim. Health Care Res. Dev.* **2015**, *16*, 329–345.

[2]. Balali-Mood, M.; Ghorani-Azam, A.; Riahi-Zanjani, B. Effects of air pollution on human health and practical measures for prevention in Iran. *J. Res. Med. Sci.* **2016**, *21*, 65.

[3]. Khoder, M. I. Atmospheric conversion of sulfur dioxide to particulate sulfate and nitrogen dioxide to particulate nitrate and gaseous nitric acid in an urban area. *Chemosphere* **2002**, *49*, 675–684.

[4]. Brown, T. P.; Rushton, L.; Mugglestone, M. A.; Meechan, D. F. Health effects of a sulphur dioxide air pollution episode. *J. Public Health (Oxf.)* **2003**, *25*, 369–371.

[5]. Boningari, T.; Smirniotis, P. G. Impact of nitrogen oxides on the environment and human health: Mn-based materials for the NO x abatement. *Curr. Opin. Chem. Eng.* **2016**, *13*, 133–141.

[6]. Air pollution crippling our nation. https://www.thedailystar.net/opinion/editorial/news/air-pollution-crippling-our-nation-3284316 (accessed January 2, 2024).

[7]. White, P.; Conway, R.; Byrne, D.; O'Riordan, D.; Silke, B. The effects of temperature and humidity on mortality in acute medical admissions. *Eur. J. Environ. Public Health* **2023**, *7*, em0123.

[8]. Sorrentino, M. C.; Capozzi, F.; Amitrano, C.; Giordano, S.; Arena, C.; Spagnuolo, V. Performance of three cardoon cultivars in an industrial heavy metal-contaminated soil: Effects on morphology, cytology and photosynthesis. *J. Hazard. Mater.* **2018**, *351*, 131–137.

[9]. Haagen-Smit, A. J.; Darley, E. F.; Zaitlin, M.; Hull, H.; Noble, W. Investigation on injury to plants from air pollution in the Los Angeles area. *Plant Physiol.* **1952**, *27*, 18–34.

[10]. Honour, S. L.; Bell, J. N. B.; Ashenden, T. W.; Cape, J. N.; Power, S. A. Responses of herbaceous plants to urban air pollution: Effects on growth, phenology and leaf surface characteristics. *Environ. Pollut.* **2009**, *157*, 1279–1286.

[11]. Bignal, K. L.; Ashmore, M. R.; Headley, A. D. Effects of air pollution from road transport on growth and physiology of six transplanted bryophyte species. *Environ. Pollut.* **2008**, *156*, 332–340.

[12]. Felzer, B. S.; Cronin, T.; Reilly, J. M.; Melillo, J. M.; Wang, X. Impacts of ozone on trees and crops. *C. R. Geosci.* **2007**, *339*, 784–798.

[13]. Shabnam, N.; Oh, J.; Park, S.; Kim, H. Impact of particulate matter on primary leaves of Vigna radiata (L.) R. Wilczek. *Ecotoxicol. Environ. Saf.* **2021**, *212*, 111965.

[14]. Pourrut, B.; Shahid, M.; Dumat, C.; Winterton, P.; Pinelli, E. Lead uptake, toxicity, and detoxification in plants. In *Reviews of Environmental Contamination and Toxicology*; Springer New York: New York, NY, 2011; pp. 113–136.

[15]. Azevedo, R.; Rodriguez, E. Phytotoxicity of mercury in plants: A review. *J. Bot.* **2012**, *2012*, 1–6, e848614.

[16]. Varshney, C. K.; Garg, J. K.; Lauenroth, W. K.; Heitschmidt, R. K. Plant responses to sulfur dioxide pollution. *CRC Crit. Rev. Environ. Control* **1979**, *9*, 27–49.

[17]. Swann, A. L. S.; Hoffman, F. M.; Koven, C. D.; Randerson, J. T. Plant responses to increasing CO 2 reduce estimates of climate impacts on drought severity. *Proc. Natl. Acad. Sci. U. S. A.* **2016**, *113*, 10019–10024.

[18]. Sheng, Q.; Zhu, Z. Effects of nitrogen dioxide on biochemical responses in 41 garden plants. *Plants* **2019**, *8*, 45.

[19]. Duque, L.; Poelman, E. H.; Steffan-Dewenter, I. Plant-mediated effects of ozone on herbivores depend on exposure duration and temperature. *Sci. Rep.* **2019**, *9*, 19891.

[20]. Hasanuzzaman, M.; Nahar, K.; Alam, M.; Roychowdhury, R.; Fujita, M. Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants. *Int. J. Mol. Sci.* **2013**, *14*, 9643–9684.

[21]. Trieff, N. M.; Wohlers, H. C.; O'Malley, J. A.; Newstein, H. Appraisal and modification of west-gaeke method for sulfur dioxide determination. *J. Air Pollut. Control Assoc.* **1968**, *18*, 329–331.

[22]. Blacker, J. H.; Brief, R. S. Evaluation of the Jacobs-Hochheiser method for determining ambient nitrogen dioxide concentrations. *Chemosphere* **1972**, *1*, 43–46.

[23]. Cheng, T.; Rivard, B.; Sánchez-Azofeifa, A. G.; Féret, J.-B.; Jacquemoud, S.; Ustin, S. L. Predicting leaf gravimetric water content from foliar reflectance across a range of plant species using continuous wavelet analysis. *J. Plant Physiol.* **2012**, *169*, 1134–1142.

[24]. ZwoŹdziak, A.; Kmieć, G.; Matyniak, Z. Penetration of atmospheric sulphates through cellulose filters. *J. Aerosol Sci.* **1991**, *22*, 395–397.

[25]. Lorenz, R. D.; Clarke, E. S. Influence of the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) on the local atmospheric environment. *Planet. Space Sci.* **2020**, *193*, 105075.

[26]. Jubaer, A.; Khorshed Ali, M.; Mahmud Tanvir Hassan, S.; Zahirul Islam Talukder, M. Urban air pollution caused of particulate matter and lead in the city of Chittagong-Bangladesh. *American Journal of Environmental Science and Engineering* **2022**, *6*, 7.

[27]. Arnon, D. I. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. *Plant Physiol.* **1949**, *24*, 1–15.

[28]. Ahn, J. Y.; Kil, D. Y.; Kong, C.; Kim, B. G. Comparison of oven-drying methods for determination of moisture content in feed ingredients. *Asian-australas. J. Anim. Sci.* **2014**, *27*, 1615–1622.

[29]. Hassan, M. S.; Bhuiyan, M. A. H.; Rahman, M. T. Sources, pattern, and possible health impacts of PM2.5 in the central region of Bangladesh using PMF, SOM, and machine learning techniques. *Case Studies in Chemical and Environmental Engineering* **2023**, *8*, 100366.

[30]. Burr, M.; Gregory, C. Vehicular Exhausts. In *Encyclopedia of Environmental Health*; Elsevier, 2011; pp. 335–343.

[31]. Hossen, M. A.; Pal, S. K.; Hoque, A. Assessment of air quality for selected locations in Chittagong city corporation area, Bangladesh. *Int. J. Innov. Res. Eng. Manag.* **2018**, *5*, 121–128.
[32]. Jamaluddin Ahmed, M.; Jubaer, A.; Ali, M. K.; Ahsan, M. A. Assessment of the status of urban air pollution and its impact on human health in the city of Chittagong. *North American Academic Research* **2020**, *3* (2), 398–417. https://twasp.info/journal/Yx6131D5/assessment-of-the-status-of-urban-air-pollution-and-its-impact-on-human-health-in-the-city-of-chittagong (accessed January 2, 2024).
[33]. Shah, K.; Amin, N. ul; Ahmad, I.; Ara, G. Impact assessment of leaf pigments in selected landscape plants exposed to roadside dust. *Environ. Sci. Pollut. Res. Int.* **2018**, *25*, 23055–23073.