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A Comprehensive Analysis of Ambient Air Quality at Pitalganj Depot of Dhaka Metro Rail Line 1 Project

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Abstract

The Dhaka Metro Rail Line 1, also known as DMRT Line 1, is the first underground metro rail project in Bangladesh, and is currently undergoing depot construction work under contract package-1 (CP 01). The construction of depot work is mainly susceptible to ambient air pollution due to the land development and soil improvement work by continuous sand dumping, filling and compaction activities. This study evaluated ambient air quality in four distinct zones of the depot area from June 2023 to September 2024. There were several pollutants measured in the ambient air including Particulate Matters (PM10 and PM2.5), Ozone (O3), Lead (Pb), Sulfur Dioxide (SO2), Nitrogen Dioxide (NO2), Carbon Monoxide (CO). The air quality monitoring machine Oceanus AQM-09 and Haz-Scanner (HIM, 6000) were used for 8 hours on the site. The power-law equation of Schroeder and Jugloff, 2012 was applied to provide 24-hour and 8-hour averages for the air quality parameters. It is observed that in pre-monsoon period of 2024, there is quite high intensity of particulate matter (PM2.5) present in the air, whereas other air pollutants values were found in all four zones are moderate in the air samples as prescribed by Air Pollution Control Rules, 2022.

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INTRODUCTION

The first underground metro rail project is now underway in Dhaka, Bangladesh, known as Dhaka Mass Rapid Transit Line 1 (Dhaka MRT Line 1). This Line comprises with two sections. One section runs from the Kamalapur Railway Station to Shahjalal International Airport, while the second section begins from the Purbachal at Pitalganj depot and meets the first section close to Natun Bazar. The Airport to Railway Station line will be a completely underground metro whereas the Purbachal Line will be partially elevated and partially subterranean. In Natun Bazar, the Purbachal line will begin its underground journey and it will change to an elevated construction from Kuril. The elevated portion will be ended at Purbachal region onto the Pitalganj depot. (DMTCL,2021) Twelve stations are included below ground and seven stations are above ground along with the total span of 29.8 kilometers. Figure-1 shows the layout of MRT Line-1 stations and the path it will take.

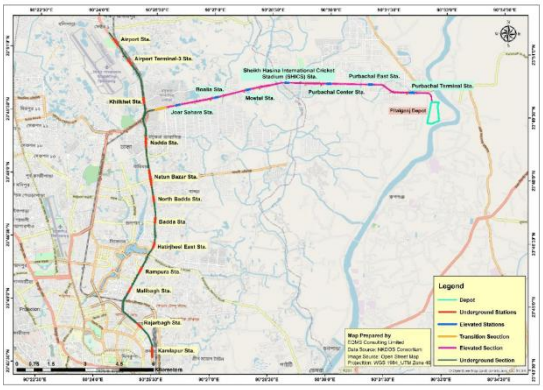

Figure 1. The route alignment and stations layout of MRT Line-1 (DMTCL, 2021)

This Project consists of the following twelve (12) contract packages. The packages are consequently named Contract Package-01(CP-01) to Contract Package-12 (CP-12). This study presents a comprehensive analysis of ambient air quality at the Pitalganj Depot of the Dhaka Metro Rail Line-1 Project, with particular attention to the CP-01 package, which includes civil works for soil improvement, land development, service road construction, and related activities. The depot site is situated on the right bank of the Shitalakshya river, at the eastern edge of Purbachal. The depot site covers a total area of 3,68,450 square meters. The depot ROW is primarily surrounded by rural areas in the north, east, west, and south. The Shitalakshya river is also located in the north, east, and south. Figure 2 illustrates the geographic location of the depot area.

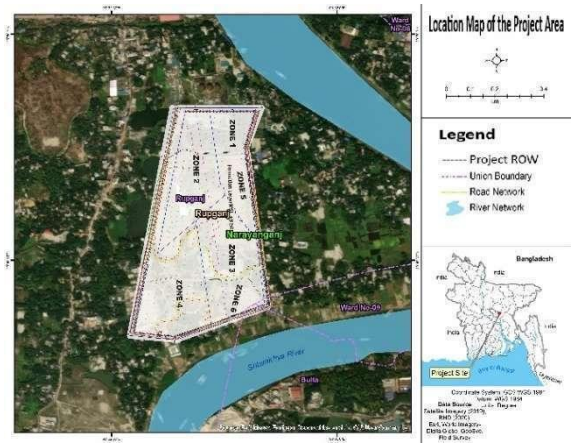

Figure 2. Location Map of the Depot Site (Source: EQMS, Edited by Author, 2023)

The major activities in the depot site are embankment filling, depot U ditch drain construction, box culvert, drainage construction, leveling and compaction, rebar placement, shutter work, concrete casting, curing work, periphery road construction, slope protection work, temporary drainage maintenance work, security chain link fence, light pole installation, geosynthetic reinforcement laying, filling sand dredging at the depot yard. The major sources of air pollution in the project area include project heavy vehicle movement, stack emission, sand dispersion due to wind-blown, the vehicular movement of the Purbachal-Dhaka highway, and Rupshi-Kanchan Road. Also, the project area is sandy, open area, and the local road inside the project area is still open for local vehicle movement. The vehicular movement through this area and wind activity increase the particulate matter concentration in this area. From the environmental aspect, it is evident that this project is mainly susceptible to the ambient air quality and this should be identified and addressed effectively. In 2017, the first Environmental Impact Assessment (EIA) was conducted and the revised EIA was updated in October 2021. The Contractor conducted a baseline survey of environmental monitoring for this project in May 2023. The

ambient air quality monitoring started in June 2023 for CP-01.

The main objectives of this study are given below:

• To assess ambient air quality data in comparison with the national environmental conservation rule set out in Air Pollution Control Rules, 2022, to determine if any deviation occurs during the construction phase activities.

• To recommend effective and efficient control measures for minimizing air pollution impacts during the construction phase of the project.

METHOD

The air quality monitoring machine Oceanus AQM-09 and Haz-Scanner (HIM, 6000) were run for 8 hours on the site. The conversion equation was used to convert the data from a specific time period to expected time period. The sampling rate of air quality data was measured automatically every one to five minutes and directly recorded onsite for measured parameters (SO2, NO2, CO, O3, PM10, PM2.5, and Pb). Different analysis methods are integrated into the instrument, such as Particulates 90° Infrared Light Scattering for particulate matters (PM10, PM2.5), filter for lead analysis, and electrochemical sensors for toxic gases (CO, NO2, SO2, and O3). The particulate and gaseous samples collected during the monitoring have been analyzed as per the procedures specified in Table 1. In order to provide 24-hour and 8-hour averages for the air quality parameters the following power-law equation, as defined in Schroeder and Jugloff, 2012 was applied (Schroeder and Jugloff, 2012). The air quality data has been converted into standard time by using the following equation:

$$C_{long} = C_{short} (t_{short} / t_{long})^p$$

Where,

C_{long} = is the expected value in the standard time

C_{short} = is the measured value at the field level in a specific period

t_{short} = Time period (converted into minutes from hour) in the field level

t_{long} = Standard time period (converted into minutes from hours)

p= is the exponential fact

Table 1. Methodology / Instrument used for ambient air quality monitoring

Parameters	Methodology	Instruments
PM_{10} and $PM_{2.5}$	Both Real time monitoring and Gravimetric method followed by filter sampling	Model HIM-6000, USA.
Ozone (O_3)	Real time monitoring	Air Quality Monitoring System (USEPA approved Air Monitoring System), HORIBA, Japan
Lead (Pb)	ICPMS followed by filter sampling	Air Quality Monitoring System (USEPA approved Air Monitoring System), HORIBA, Japan.
Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon monoxide (CO)	Real time monitoring	Ambient Air Quality Monitoring System, HAZ-SCANNER.

Figure 3. Air Quality Monitoring by AQM-09 (Source: Author, 2024)

Figure 4. Air Quality Monitoring by Haz Scanner, HIM 6000 (Source: Author, 2024)

Monitoring Locations And Dates

The ambient air quality was monitored from June 2023 to September 2024 in four locations of the depot area. Details of the air quality sampling location map is shown in Figure 5.

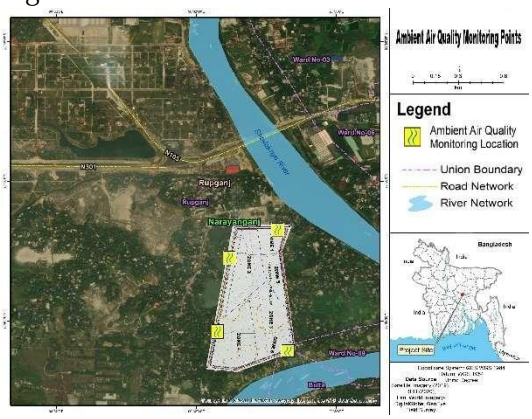

Figure 5. Sampling Points Location (Source: EQMS, Edited by Author, 2024)

The sampling code were determined respectively AAQ1 and AAQ2. The monitoring Locations were selected four zones at the depot area considering the construction work of the monitoring days. These zones were respectively:

- Zone-1 (Northeast Corner, 23°49'49.94"N 90°32'48.82"E)
- Zone 2 (Northwest Corner, 23°49'45"N 90°32'37"E)
- Zone 3 (Southeast corner, 23°49'22.21"N 90°32'46.08"E)
- Zone 4 (Southwest, 23°49'28"N, 90°32'13"E)

Monitoring dates and locations have been given in Table 2 and Table 3.

Table 2. Monitoring Details for 2023 (Jun'23 to Dec'23)

Date	Sampling Code	Location
20/06/2023	AAQ1	Zone-4
	AAQ2	Zone-2
24/07/2023	AAQ1	Zone-4
	AAQ2	Zone-2
22/08/2023	AAQ1	Zone-4
	AAQ2	Zone-2
10/09/2023	AAQ1	Zone-4
	AAQ2	Zone-2
18/10/2023	AAQ1	Zone-4
	AAQ2	Zone-2
25/11/2023	AAQ1	Zone-4
	AAQ2	Zone-2
24/12/2023	AAQ1	Zone-4
	AAQ2	Zone-2

Table 3. Monitoring Details for 2024 (Jan'24 to Jun'24)

Date	Sampling Code	Location
18/01/2024	AAQ1	Zone-1
	AAQ2	Zone-2
25/02/2024	AAQ1	Zone-1
20/02/2024	AAQ2	Zone-2
23/03/2024	AAQ1	Zone-1
24/03/2024	AAQ2	Zone-3
27/04/2024	AAQ1	Zone-1
	AAQ2	Zone-3
22/05/2024	AAQ1	Zone-3
21/05/2024	AAQ2	Zone-4
25/06/2024	AAQ1	Zone-3
	AAQ2	Zone-4

Table 4. Monitoring Details for 2024 (Jul'24 to Sep'24)

Date	Sampling Code	Location
16/07/2024	AAQ1	Zone-3
	AAQ2	Zone-4
28/08/2024	AAQ1	Zone-3
29/08/2024	AAQ2	Zone-4
24/09/2024	AAQ1	Zone-3
23/09/2024	AAQ2	Zone-4

RESULT AND DISCUSSION

This section represents the ambient air quality measurement data to identify trends, fluctuations, and potential sources of air pollution.

To provide a comprehensive understanding, the data is categorized into specific air quality parameters, including Particulate Matter ($PM_{2.5}$ and PM_{10}), Nitrogen oxides (NOx), Sulfur dioxide (SO_2), Carbon monoxide (CO) and Lead (Pb). Each parameter is discussed individually to compare and draw meaningful conclusions about the possible sources of air pollution.

Particulate Matter (PM_{10} & $PM_{2.5}$)

PM_{10} refers to particulate matter that is 10 micrometers or smaller in diameter. These particles are a mixture of solid particles and liquid droplets found in the air. Due to their small size, PM_{10} particles can be inhaled and pose health risks as they can penetrate the respiratory system. (EPA, 2024)

$PM_{2.5}$ refers to particulate matter that is 2.5 micrometers or smaller in diameter. These fine particles are a subset of PM_{10} and are particularly concerning due to their ability to penetrate deep into the lungs and enter the bloodstream. (Yakexi, 2024)

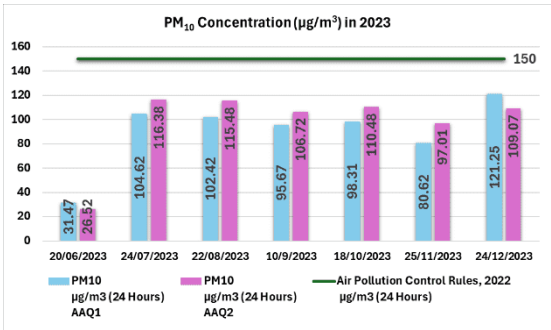

Figure 6. PM_{10} Concentration (µg/m³) in 2023

Fig.6 shows that the concentrations (µg/m3) of air pollutant PM_{10} at AAQ1 and AAQ2 from June 2023 to December 2023 are within the standard level (150 µg/m³) of Air Pollution Control Rules, 2022.

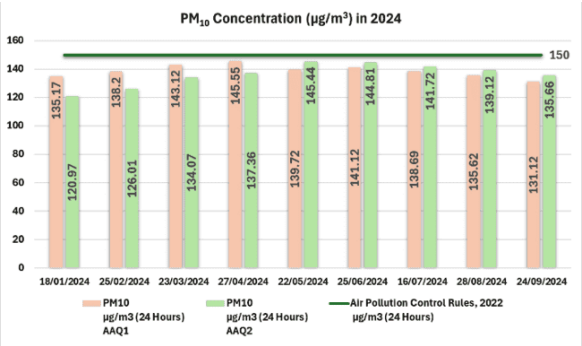

Figure 7. PM_{10} Concentration (µg/m³) in 2024

Fig.7 shows that the concentrations (µg/m³) of air pollutant PM_{10} at AAQ1 and AAQ2 from January 2024 to September 2024 are lower than the standard level (150 µg/m³) of Air Pollution Control Rules, 2022.

Compared to 2023 result (Fig. 6) and 2024 (Fig.7), the graph shows that the concentration of PM10 is much higher in 2024. The possible reason for higher concentration of PM_{10} level in 2024 is due to the peak time of construction activities at the depot including sand compaction pile work and embankment filling work during the night shift.

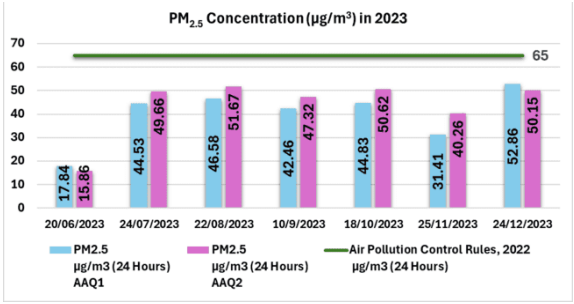

Figure 8. $PM_{2.5}$ Concentration (µg/m³) in 2023

Fig.8 shows that the concentrations (µg/m³) of air pollutant $PM_{2.5}$ at AAQ1 and AAQ2 from June 2023 to December 2023 are lower than the standard level (65 µg/m³) of Air Pollution (Control) Rules, 2022.

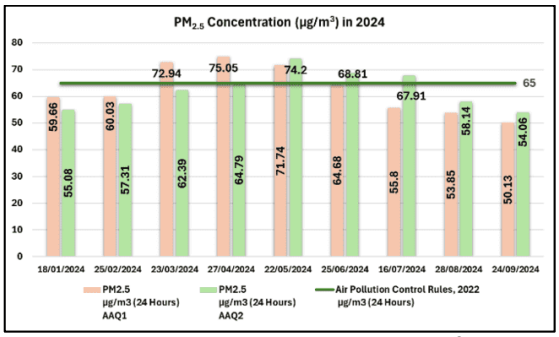

Figure 9. $PM_{2.5}$ Concentration (µg/m³) in 2024

Fig.9 shows that the concentration (µg/m³) of air pollutant $PM_{2.5}$ level (in 2024) at AAQ1 of January to February and June to September was below the standard level of Air Pollution (Control) Rules, 2022. The $PM_{2.5}$ level was also within the limit for AAQ2 (in 2024) for January to April and August to September.

On the other hand, $PM_{2.5}$ level (in 2024) was a concerning scenario at AAQ1 from March to May. Moreover, The $PM_{2.5}$ level at AAQ2 from May to July was also higher than the standard level of Air Pollution (Control) Rules, 2022. This was since the construction activities of those zonal area of depot including the sand compaction pile work, embankment filling work, the local building construction work near the surroundings of depot and several sand yard loading-unloading businesses which might contribute to the high concentration of $PM_{2.5}$ at that time. Furthermore, according to data from the US Embassy archive (aqicn, 2024), $PM_{2.5}$ levels were also elevated in Dhaka city on the monitoring days, which could be the primary reason for higher $PM_{2.5}$ in this area.

Ozone (O_3)

Ozone (O_3) is a gas composed of three oxygen atoms. It exists in two layers of the atmosphere: the stratosphere and the troposphere, with distinct roles and impacts in each (Meng et al, 2022; EPA, 2024).

In construction, ground-level ozone poses health risks to workers, causing airway irritation, asthma attacks, reduced lung function, and increasing the risk of respiratory infections and heart problems.

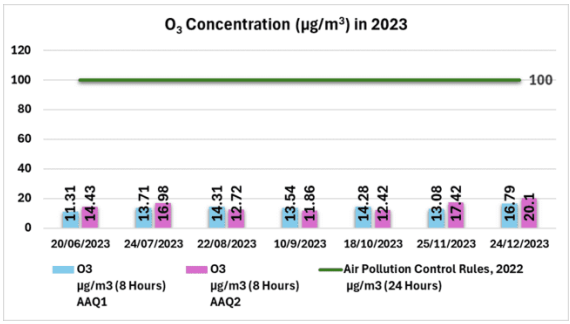

Figure 10. O_3 Concentration (µg/m³) in 2023

Fig.10 reflects that the concentrations (µg/m3) of air pollutant Ozone (O_3) at AAQ1 and AAQ2 from June 2023 to December 2023 are lower than the standard level (100 µg/m³) of Air Pollution Control Rules, 2022.

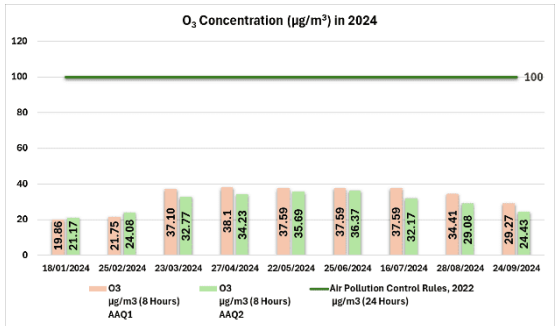

Figure 11. O_3 Concentration (µg/m³) in 2024

Fig.11 shows that the concentrations (µg/m3) of air pollutant Ozone (O_3) at AAQ1 and AAQ2 from January 2024 to September 2024 are lower than the standard level (100 µg/m³) of Air Pollution Control Rules, 2022.

Lead (Pb)

Lead is a dense, soft, malleable metal which can be released into the air through various industrial processes and combustion of lead-containing materials. As an air pollutant, lead poses serious health and environmental risks.

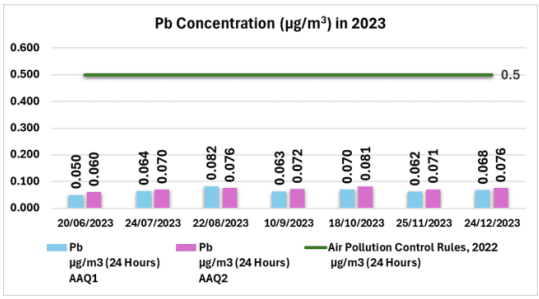

Figure 12. Pb Concentration (µg/m³) in 2023

Fig.12 shows that the concentrations (µg/m³) of air pollutant Lead (Pb) at AAQ1 and AAQ2 from June 2023 to December 2023 are not exceeds the standard level (0.5 µg/m³) of Air Pollution Control Rules, 2022.

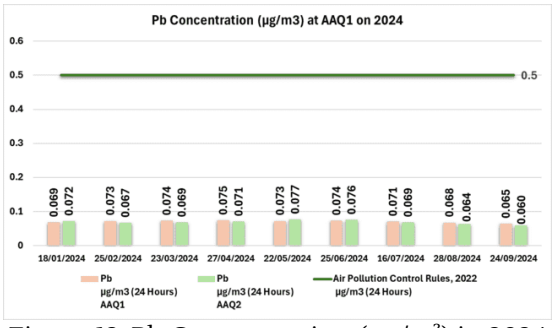

Figure 13. Pb Concentration (µg/m³) in 2024

Fig.13 shows that the concentrations (µg/m³) of air pollutant Lead (Pb) at AAQ1 and AAQ2 from January 2024 to September 2024 are within the standard level (0.5 µg/m³) of Air Pollution Control Rules, 2022.

Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2) is a toxic gas that can be emitted at construction sites primarily through the combustion of sulfur-containing fossil fuels such as diesel in construction machinery and vehicles (Hung & Ashner, 2021).

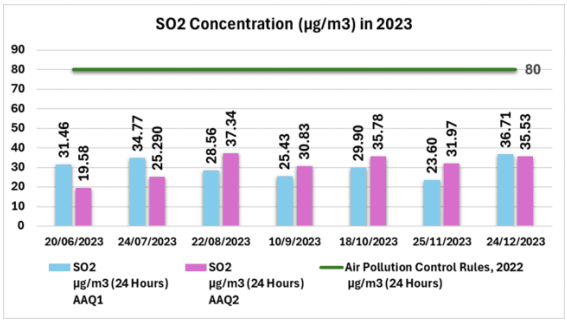

Figure 14. SO_2 Concentration (µg/m³) in 2023

Fig.14 shows that the concentrations (µg/m³) of air pollutant Sulfur Dioxide (SO_2) at AAQ1 and AAQ2 from June 2023 to December 2023 are within the standard level (80 µg/m³) of Air Pollution Control Rules, 2022.

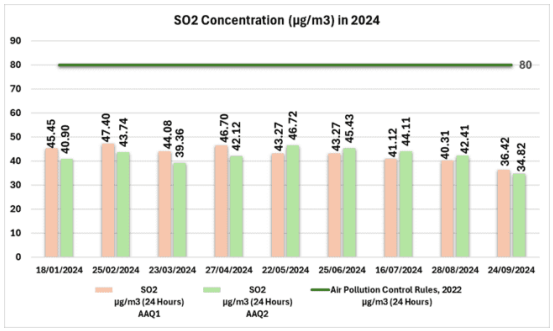

Figure 15. SO_2 Concentration (µg/m³) in 2024

Fig.15 shows that the concentrations (µg/m³) of air pollutant Sulfur Dioxide (SO2) at AAQ1 and AAQ2 from January 2024 to September 2024 are not exceeds the standard level (80 µg/m³) of Air Pollution Control Rules, 2022.

Nitrogen Dioxide (NO_2)

Nitrogen dioxide (NO_2) is a harmful gas produced by the combustion of fossil fuels, commonly emitted by construction machinery and vehicles (Ogunkunle & Ahmed, 2021). At construction sites, NO_2 poses significant health risks, including respiratory issues like coughing, wheezing, and shortness of breath.

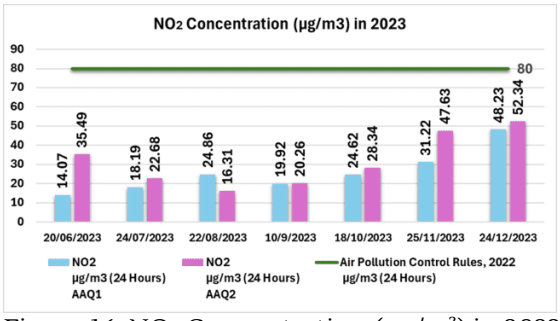

Figure 16. NO_2 Concentration (µg/m³) in 2023

Fig.16 shows that the concentrations (µg/m³) of air pollutant Nitrogen Dioxide (NO_2) at AAQ1 and AAQ2 from June 2023 to December 2023 are lower than the standard level (80 µg/m³) of Air Pollution Control Rules, 2022.

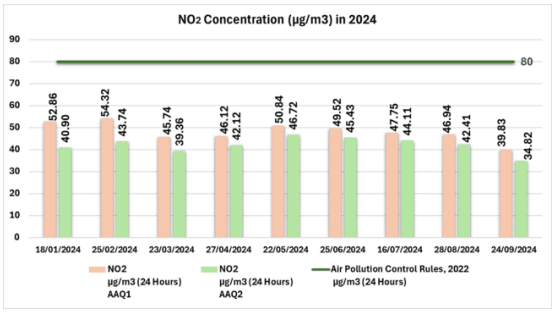

Figure 17. NO_2 Concentration (µg/m³) in 2024

Fig.17 shows that the concentrations (µg/m³) of air pollutant Nitrogen Dioxide (NO_2) at AAQ1 and AAQ2 from January 2024 to September 2024 are lower than the standard level (80 µg/m³) of Air Pollution Control Rules, 2022.

Carbon Monoxide (CO)

Carbon monoxide (CO) is a colorless, odorless gas produced by the incomplete combustion of fossil fuels, commonly emitted by construction machinery, generators, and heaters. On construction sites, carbon monoxide (CO) presents serious health hazards to the workers. It can cause symptoms such as headaches, dizziness, and confusion, and at elevated concentrations, it can result in unconsciousness or even death by inhibiting oxygen delivery to the bloodstream (Raub et al, 2000; MSDH, 2004)

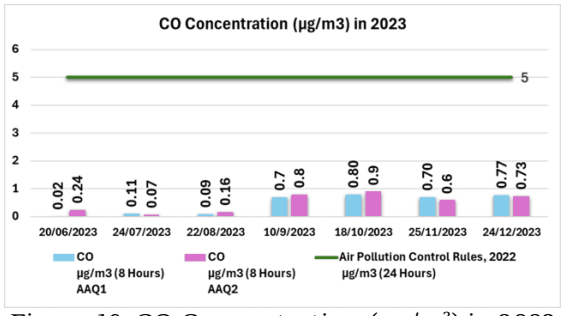

Figure 18. CO Concentration (µg/m³) in 2023

Fig.18 shows that the concentrations (µg/m³) of air pollutant Carbon Monoxide (CO) at AAQ1 and AAQ2 from June 2023 to December 2023 are lower than the standard level (5 µg/m³) of Air Pollution Control Rules, 2022.

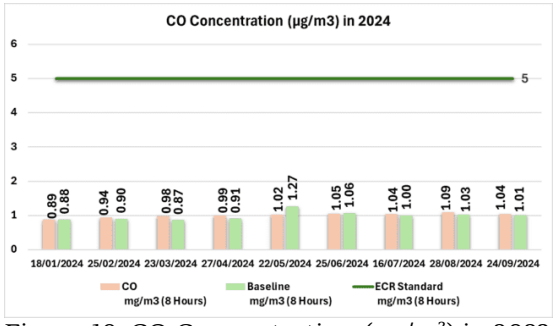

Figure 19. CO Concentration (µg/m³) in 2023

Fig.19 shows that the concentrations (µg/m³) of air pollutant Carbon Monoxide (CO) at AAQ1 and AAQ2 from January 2024 to September 2024 are not exceeds the standard level (5 µg/m³) of Air Pollution Control Rules, 2022.

CONCLUSION

From this study it is found that the overall ambient air quality of the Dhaka Metro Rail Line-1, CP-01 project is at satisfactory level except $PM_{2.5}$ air pollutant compared with Air Pollution Control Rules, 2022. The high concentration of $PM_{2.5}$ which ranged from 67.91 µg/m³ to 75.05 µg/m³ and these high concentrations were found in the pre-monsoon period of March to July 2024.

The probable reasons for these high concentrations of $PM_{2.5}$ are due to the peak construction activities of those months at the depot including the sand dredging work, sand compaction pile work, and embankment filling work. Moreover, near the surroundings of depot, the local building construction work

and several sand yard loading-unloading businesses might contribute to the high concentration of $PM_{2.5}$ at that period of measurement time. Furthermore, according to the data from the US Embassy archive (AQICN, 2024), $PM_{2.5}$ levels were also elevated in Dhaka city on those monitoring days, which could be the transboundary air pollution effect for the higher $PM_{2.5}$ in this project area.

To reduce the overall concentrations of air pollutant including Particulate Matter (PM_{10} and $PM_{2.5}$), Ozone (O_3), Lead (Pb), Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), some mitigation measures are suggested below:

• To reduce the dust generation at site, water should be sprayed on a regular basis at the access road and the required area of the project.

• The vehicular speed should not be more than 10 Km/hr. to control the dust generation from vehicular movement.

• The stackyard of dusty materials should be covered or wetted as required.

• The carrying vehicles should cover the dusty materials with polythene or tarpaulin, and not carry excessive materials beyond its capacity.

• The height of the sand stackyard should be lower to reduce the sand dispersion by windblow.

• The machineries and heavy equipments of the project should be maintained properly on a regular basis to reduce the generation of black smoke from the engine.

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