Proceedings of the 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020), 7~9 February 2020, KUET, Khulna, Bangladesh (ISBN-978-984-34-8764-3)

COMMUTER EXPOSURE TO AIR POLLUTANTS IN KHULNA RAILWAY STATION DUE TO THE INFLUENCE OF LOCOMOTIVES

Prottay Mazumder*[1], Jobaer Ahmed Saju[2] and Q. H. Bari[3]

[1] *Under-graduate student, Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna-9203, BANGLADESH E-Mail: Prottaypm106@gmail.com*
[2] *Post-graduate student, Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna-9203, BANGLADESH E-Mail: jubayerahmed005@gmail.com*
[3] *Professor, Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna-9203, BANGLADESH E-Mail: qhbari@ce.kuet.ac.bd)*

***Corresponding Author**

ABSTRACT

Particulate matter (PM) emitted by the burning of diesel fuel has become an egregious air pollutant. It originates from the engine of the rail transport in available forms. Besides, emissions of SO_2 and NO_2 are the most significant pollutants and the constant exposure of these will lead our way to various chronic diseases. In instances of extended publicity to excessive CO concentrations, obtuseness, scolding, and loss of life would show up. For that reason, a detailed investigation was conducted for 8 hours on three different dates to quantify the exposure to size-segregated particulate matter ($PM_{2.5}$, PM_{10}), total suspended particle (TSP) and gaseous pollutants (SO_2, NO_2, CO) from locomotives in the Khulna Railway Station. The average concentrations of $PM_{2.5}$ and PM_{10} were found 26 μg/m^3 and 50 μg/m^3 respectively. The values of SO_2, NO_2, CO were also measured to be 193 μg/m^3, 44 μg/m^3, 1754 μg/m^3. Furthermore, the current work explores the routine mean degrees of total suspended particles were 77 μg/m^3 in comparison with the standard limiting magnituds. Though it was observed increment of values at the arrival and departure time of the train, the average value lies in the considerable range. Enormous air quality index (AQI) values in the platform suggested that the air around the platform is much more polluted due to the emission of diesel particulate matter (DPM) than Khulna air. According to our investigated data the air quality lies in the moderate zone for Khulna Railway Station. Correlation analysis showed a weak association between the concentration of PM at ground level and background air. It is revealing that the ground PM concentration was less influenced by the ambient air (r^2= 0.45). The study of setting up the Instrument on two different altitudes has found that a smaller value of PM fraction shows that freight rails emit heavier fragments into the wind. It had been observed that commuters were exposed to a noticeably greater degree of $PM_{2.5}$ than PM_{10} when traveling from Khulna railway station. This practice indicates that the volume enhancement of air pollutants linearly associated to the diesel rail visitors concentration and future increment in rail traffic will amplify the rate of PM_{10} and residents residing near the railway station, may additionally experience extraordinary carcinogenic illnesses.

Keywords: *Particulate matter, Gaseous pollutants, Diesel emissions, Air quality, Railway station.*

1. INTRODUCTION

Clean air is a fundamental requirement for human health and environmental resources. However, the air is continuously being contaminated with different types of air pollutants. Every year millions of people are dying due to "air pollution". This act of forcing the air is causing a great change to the standard chemical composition. Short term and long-time period exposure to accelerated degrees of PM have been sharply associated with the enhancement of respiratory and cardiovascular illnesses as well as carcinogenic hassles(Star, March 06, 2019). Particulate matter (PM) or particulates or commonly known as "floating dust" are emitted directly into the atmosphere creating a complex mixture in the air. Sources of particulate matter are commonly associated with anthropogenic or by the air itself. $PM_{2.5}$ (<2.5 microns in diameter) and PM_{10} (2.5 to <10 microns in diameter) are the most hazardous forms of airborne particles having the ability to penetrate deep into the lungs without being unfiltered. Generally, the coarser (PM_{10}) particles tend to settle down quickly due to gravity force making the lighter and finer ($PM_{2.5}$) more dangerous.

Rapid construction activities, combustion of fossil fuel and other biomass directly emitting toxic suspended particles and gaseous pollutants in the air of developing countries (Annadanam & Kota, 2019). Bangladesh, being the most densely-populated nation in the global, has been competing with air pollution for long and country's capital, frequently demands its position among the most polluted cities in global indices. "At a country level, weighted by population, Bangladesh arises as to the most country," stated the 2018 World Air Quality Report (Star, March 06, 2019). To protect human health and environment, all coarse ($PM_{2.5}$) and fine (PM_{10}) particulate sources should be pointed out. In that circumstance, traffic is one of the prime mentioned source categories.

Bangladesh is a developing country, railways serve as the safest and cheapest mode of transport. Most of people prefer to use railways for reaching their destination. However, diesel-powered trains create a momentous blow on air quality. In Khulna, Bangladesh almost all rail locomotives are powered with diesel gas and rail tracks are located in busy city corridors. Thousands of people are traveling daily using this railway to reach their desired destination. Intercity trains, Mail trains, and International trains are moving from the Khulna railway daily. it is essential to put more concern on it. But in this regard, they are unwisely exhausting the diesel particulate matters (DPM) and other pollutants in the air. This is causing a serious threat to the health of commuters. Most of the people in these areas are finding themselves associated with different allergic sinusitis and asthma.

On the other hand, SO_2, NO_2, CO emitted from locomotives are associating with direct radioactive forcing and increasing the overall surface temperature. Emissions of NO_2 and CO are the most significant pollutants contributing to the formation of ground ozone that produces smog to the atmosphere and the constant exposure of these are obvious that we can't see with our open eyes and will lead our way to various chronic diseases.

In Seattle and exclusive urban areas, DPM is the most vital "air toxic" in the metropolitan location and offers greater than 80% of the chance for most cancers from airborne air poisons (Jaffe et al., 2014). In addition to DPM emissions, freight trains carrying different goods and emitting more coarser, finer particles into the air than passenger trains (Jaffe et al., 2014). The emission of air particulates into the air based on abrasion losses of wheels, poorer curving behaviour and, tread brakes (Fridell, Ferm, & Ekberg, 2010). Wear particles cannot be measured easily by just measuring particle concentrations. Airflow during the measurement time should be analysed perfectly to get that answer. But it is impossible to be done without having detailed knowledge of airflow as the air changes the magnitude and direction quite rapidly before, during and after the passage of time.

For that reason, a detailed investigation was conducted to quantify the exposure to size-segregated particulate matter ($PM_{2.5}$, PM_{10}), total suspended particle (TSP) and gaseous pollutants (SO_2, NO_2, CO) from locomotives in the Khulna Railway Station. The main aim was to evaluate the concentration of PM2.5, PM10, and gaseous pollutants to observe the air quality of Khulna railway station through Air Quality Indexing (AQI) and colour scheme. To convey the health implications of air quality and forecasting air pollution level the Site AQI was to find for a specific period to different air pollutants. On the other hand, the study was directed to assess the contribution of the background air upon the Khulna railway air.

2. METHODOLOGY

2.1 Sampling locations

For PM and Gaseous pollutant concentration assessment, The Khulna railway, shown in Fig. 1, was sampled during 24 hours (8 hours/day) sampling period.

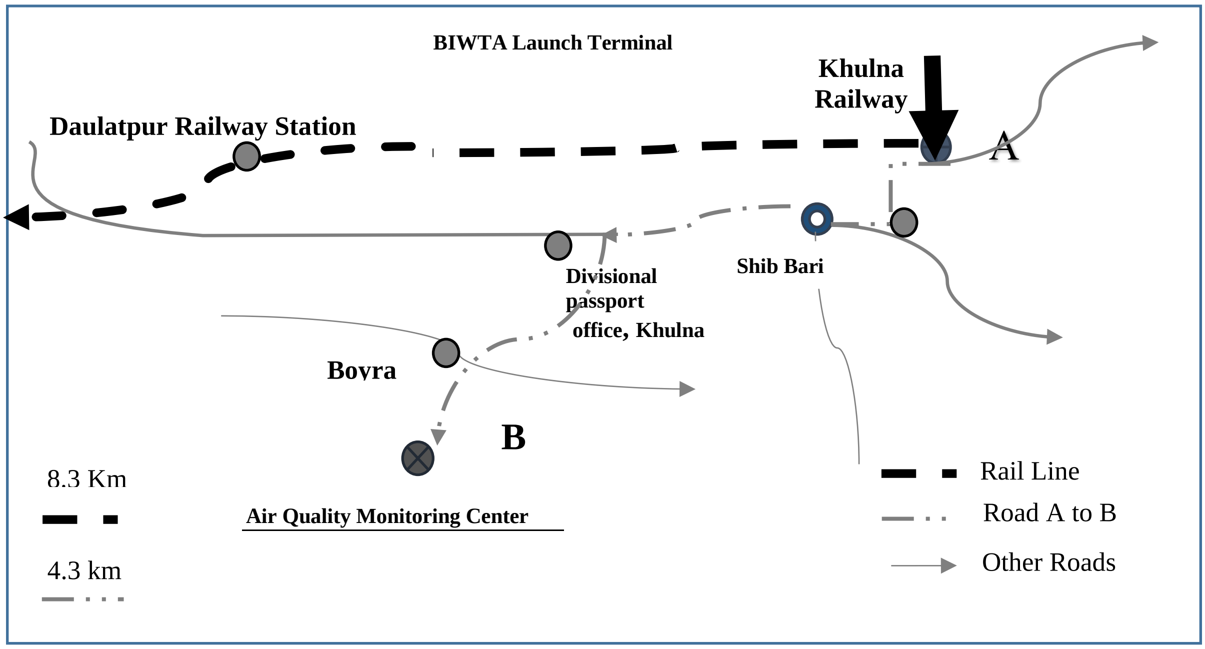

Figure 1: Plan signifying the selected railway station (ground level platform) and adjacent air quality monitoring station where particles were collected for pollutant concentration assessment.

On three specific dates, quantity calculations on train emissions were accomplished at two different sites in Khulna, Bangladesh. The first site was located near the platform of Khulna railway (22.8224ºN, 89.5583ºE) which is the main station of Khulna city and links to Jessore railway station and other different ends of the country. Two distinctive situations are very substantial large concerning railway traffic. On is the scenario in the environment of railway stations, where trains were gradually decreasing speed or accelerating and crossing track switches. The other one is when the train is passing or traveling at a less or more constant speed (Gehrig et al., 2007). In this study, the first situation was covered by the first site. The instruments were set up on the ground platform which is nearly 15 meters from the busy rail tracks. For the different height of the instrument set up the data was measured. The rail tracks are adjoining to the edges of Bhairab River and additionally connected with urban corridors. The second situation is covered by another site about 4 km away from Khulna's main station at Khulna. It is a continuous air monitoring station from where the PM data and gas data are calculated.

2.2 Monitoring Instruments and Sampling campaigns

During this campaign, a laser particle counter (handheld 3016) was used for data sampling of size-segregated PM. It can detect 6 particle sizes simultaneously in the range of 0.3um-25um. This instrument reports PM mass concentration in 6 different sizes of concentrations: 0.3 µg/m^3, 0.5 µg/m^3, 1.0 µg/m^3, 2.5 µg/m^3, 5 µg/m^3, 10 µg/m^3. Then collected data needs to be calibrated using coefficients. Then using an Excel data sheet, it indicates PM mass concentration in 4 different size concentrations: PM_1, $PM_{2.5}$, PM_{10} and Total suspended particle (TSP). The instrument was set to collect six different size-segregated data every minute.

The sampling campaign was carried out on 22 June, 01 and 02 August 2019 from 9 AM to 5 PM. On the ground platform, the sampling introduced to collect both PM_{10} and $PM_{2.5}$ data. Sampling from inside the train was not associated with the study. The instrument was set up at the level of 4 feet from the ground on 22 June. But the elevation was changed and set to 7 feet from the ground level. The fixed air quality station recorded the overall Khulna data at the same time. The fixed air station was located near the Khulna railway. The air station data provided valuable information about the background data of the Khulna railway. Besides, the concentration of gaseous pollutants was collected using the Environmental test meter. The instrument showed the concentration of gaseous data every minute and the data was sampled using two different probes. One was used to collect the SO_2 and another one is used to read NO_2 particles efficiently. This technique of sampling had been effectively performed in many research to inspect the degree of air pollutants in the Urban air.

On the other hand, the fixed air quality station set up their instrument at the elevation of 20 feet to collect the size-segregated particulates and other gaseous pollutants perfectly. XR premium work station V6.4.37 is used to collect the air samples. This also gives readings of every minute both for PM and gaseous pollutants. Besides monitoring of PM, fundamental meteorological data was observed as well, along with temperature (^{0}C), ambient humidity (%RH).

2.3 Quality assurance of PM measurement

It had been seen the difference in measurement values between light scattering assessment scheme, particle counting method and other schemes applied in the air quality fixed monitoring sites (Mohsen, Ahmed, & Zhou, 2018). Therefore, a correction factor was typically ascertained and applied to attain correct measurements from the scattering scheme. To justify the degree of precision for the cumulated data of the specified area of Khulna railway station and from the fixed station a regression model is performed. The main thought was to find the relation between the collected samples from the two sites at the same time. The relation was constructed to find the requirement of any correction factor. The calibration of data samples was done for more accuracy. During the campaign, the collection of data was done in two different elevations for the site so that the PM dust samples that flow with the wind velocity can be detected through the instrument.

2.4 Analytical method

The average concentration of PM standards and the gaseous pollutants were averaged for every hour based on the railway microenvironments alongside with the magnitudes from the fixed monitoring station to illustrate the measurement of the surrounding environment. A regression analysis (based on the least square method) was done to differentiate the values of specified area pollutants concentration to the background pollutant concentration.
For reporting daily air quality of the Khulna station and conveying health implications of the commuters indexing was done. It is known as Air quality index (AQI). The different countries set natural (AQGs) depending upon their technical feasibility, economic consideration, and political & social factors. The pollution level was ascertained using Eq. (1) and consequences were interpreted by the approved Air Quality Index (AQI) for Bangladesh categorization given in table 1.

$$AQI\ pollutant = \frac{Conecentration\ of\ pollutant}{Standard\ concetration\ value} \times 100 \tag{1}$$

Where pollutant data reading was found from hourly average or daily average value in ug/m^3 both for two different sites and standard readings are the corresponding value the air pollutants that are fixed for a specific area location. The highest AQI for any criteria pollutant is known as site AQI or simply AQI of that day of that specific site. So the AQI proportional to health risk. As the AQI increases denote more air pollutants are getting mixed into the air and showing more health risks for sensitive groups.

Table 1: Approved Air Quality Index (AQI) for Bangladesh for making the comparison of pollutants affecting air quality and sorting out site AQI.

Air Quality Index (AQI) Values	**Levels of Health Concern**	**Colors**
When the AQI is in this limit:		
0 to 50	Good	Green
51 to 100	Moderate	Yellow Green
101 to 150	Caution	Yellow
151 to 200	Unhealthy	Orange
201 to 300	Very Unhealthy	Red
301 to 500	Extremely Unhealthy	Purple

3. RESULTS AND DISCUSSION

3.1 PM and gaseous pollutant concentrations at ground level of the rail station

The gaseous pollutant data from the platform were transferred to an Excel sheet and analysed using Excel to determine the average concentration of the pollutants. Pollutant chemicals show a significant change in concentrations with time. The analysed graph displayed that gaseous pollutants undergo a great change in value due to the passage of a train. The data obtained over 24 hours of sampling in three different days are shown in the (figure 2) illustrating average concentration magnitudes of PM_{10}, $PM_{2.5}$, SO_2, CO, NO_2 from railway microenvironments.

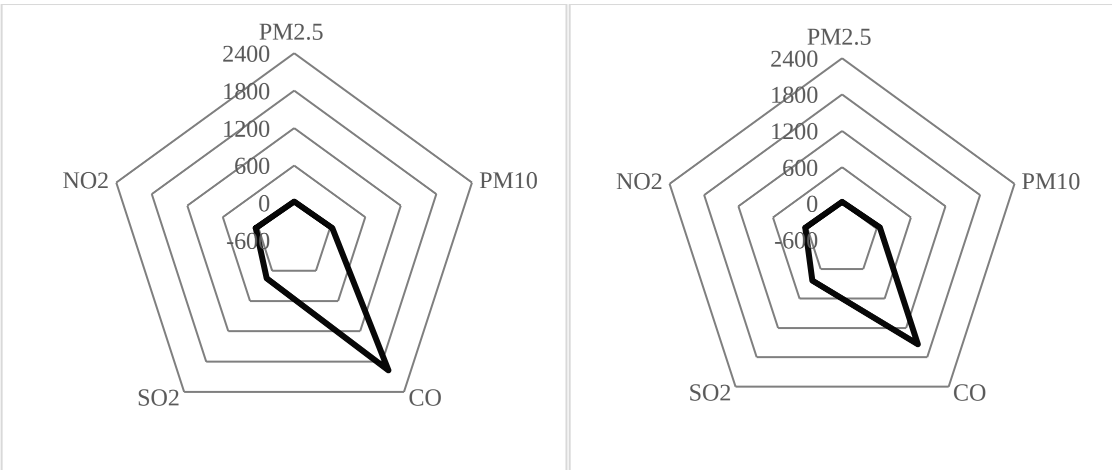

Figure 2: Multi variables ($PM_{2.5}$, PM_{10}, SO_2, NO_2, CO) of radar showing the daily average concentrations of the five criteria pollutants.

Measurements of PM2.5 and PM10 for the first situation shows that the average values are 26 µg/m3 and 50 µg/m3 respectfully of that site. But the value changes every day as it depends on wind blow and other parameters. The readings of PM2.5 vary from 11 µg/m3 to a value of 96 µg/m3. It has been investigated that this maximum value obtains during loading or unloading operation or both occur simultaneously of a passenger train. Due to the movements of the diesel-powered vehicle near the rail lines caused an additional effect on the value (Gangwar & Sharma, 2016). Wind flow at the direct of the instrument to catch more pollutants can be another reason. But as there was not any reading of air magnitude and the direction it couldn't be explained explicitly. The value of PM10 for the site also varied from 18 µg/m3 to 243 µg/m3. The construction site near the railway, abrasion of train wheels with rails were detected to be the probable cause of distributing larger particles or metals into the air and increasing the value of PM10. The average value of SO2, CO, NO2 are 193 µg/m3, 1754 µg/m3, and 44 µg/m3. All the average values of the pollutants lie below the standard limit. But the maximum value for a specific train event went beyond that standard limit. During the rain, the concentrations of the pollutant went down gradually with time. The lesser value of the total suspended particle in the air was the main reason for that.

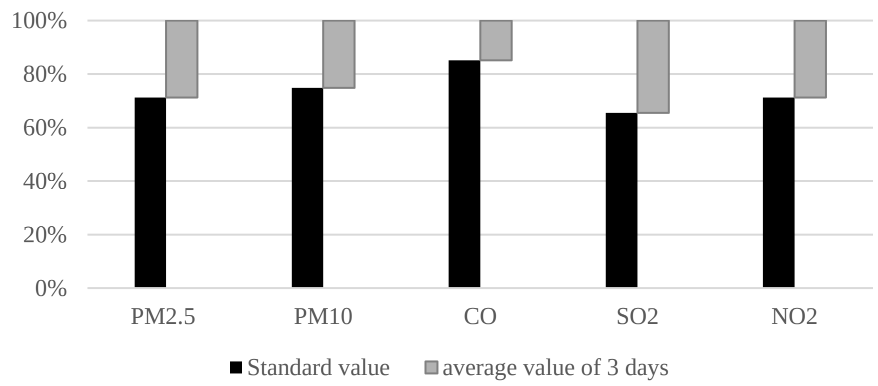

Figure 3: Showing the average concentrations of pollution levels to their standard limits.

Another important investigation was done to measure the fine particle proportion by considering the ratio between $PM_{2.5}$ and PM_{10}. The ratio for the site between $PM_{2.5}$ and PM_{10} was 0.65 where it was 0.50 for the other observation. The enormous portion of the lighter particle is directed towards more health complications.

But inside the train, the fraction or pollutant level of PM works differently. The effects (inside the train) were designated through the Los Angeles research (inside the trains), displaying that commuters were revealed to minor degrees of fine particles while anticipating on the metro systems by a factor of 6% (Cha, Olofsson, Gustafsson, & Johansson, 2018). For considering the degrees of air pollution a character undergoes, accounts that to be taken of how lengthy they are in connection with the microenvironment pollutants. It is essential to build a variety among the term concentration, exposure and respiratory deposition dose (RDDs) (Gupta & Elumalai, 2019). From the 24 hours reading, it has seen that commuters are revealed to an especially greater degree of $PM_{2.5}$ than PM_{10} when traveling from Khulna railway station.

3.2 Site AQI or AQI analysis

The AQI is done for five major criteria pollutants ($PM_{2.5}$, PM_{10}, SO_2, CO, NO_2). The AQI is founded using (equation 1). For a single pollutant, the hourly average concentration was used to find the Hourly AQI. For all the pollutants the hourly AQI is obtained and plotted against time. So total AQI was analysed for every criterion pollutant from 8 hours of data. The highest AQI was found for a single criteria pollutant denoted the site AQI or daily AQI for that specific site (Qiu et al., 2017). From (figure 4) and (figure5) The site AQI for 22 June, 01 August were 72 and 70 respectively. The AQI for August 02 was measured 66. The background site AQI form the air station for 22 June, 01 and 02 were 27, 42 and 48 respectively.

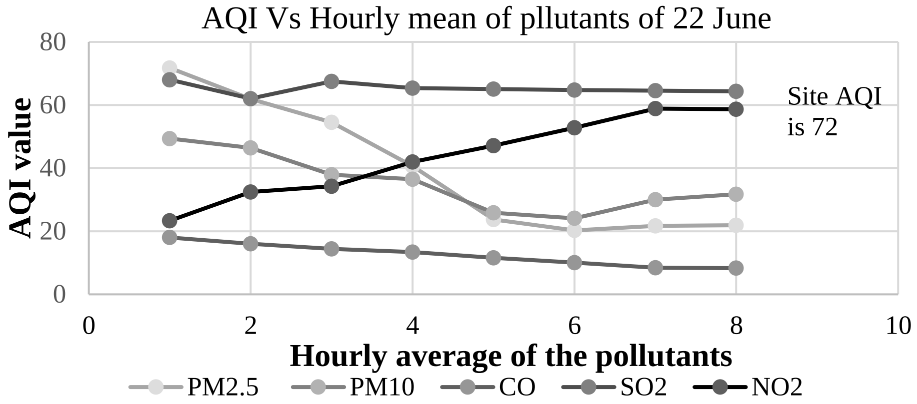

Figure 4: Showing hourly pollution level and the Site AQI of 22 June.

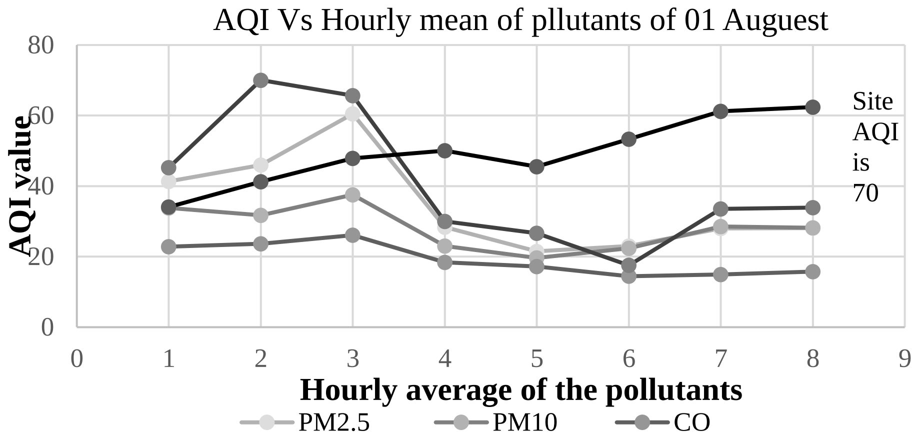

Figure 5: Showing hourly pollution level and the Site AQI of 01 August.

Using (Table 1) and from the AQI, it is noticeable that the railway air is in the moderate zone having a yellow green colour This value is acceptable and can cause moderate health problems for little sensitive people. On the other hand, the air station AQI lies in the Good air quality zone and denoting Green colour. The quality of air is satisfactory with absolutely no health concern.

3.3 Differentiate between PM concentration from Khulna railway and background air

Correlation analysis is carried out to evaluate the impact on the adjacent sources on PM_{10} and $PM_{2.5}$ in the Khulna railway. This impact degree can be several based on adjacent conditions. In (figure6), the PM_{10} data from the platform are plotted against the PM_{10} data from the Air quality station. The correlation showed a weak association as the value of (r^2) = 0.45, exposing little influence from the adjacent air to the railway air. It also signifies that the cause or source of moderate air quality in the rail station lies in the railway station.

Emission from the diesel locomotive is denoted as the primary cause of air pollution in the rail station. But the frisking of the passengers at the last moment of leaving the train from the station created a great change in PM value. It is found that the freshly settled dust is again started floating in the ambient air of the Khulna railway for the hastening of passengers to catch the train. The overflow of air due to the weather itself caused extra particulates to add into the air of that specific situation.

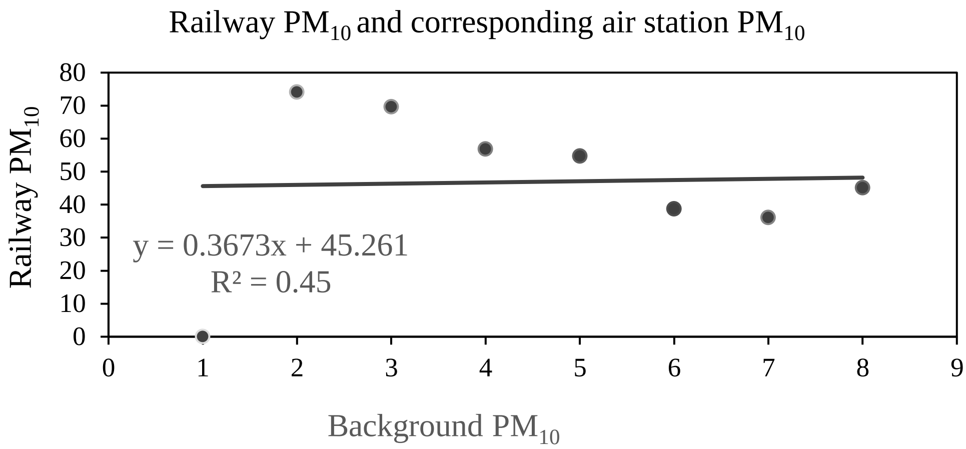

Figure 6: Showing the correlation between railway and background PM_{10}

3.4 Differentiation of PM from Khulna rail with international railway systems

Table 2: Different levels of $PM_{2.5}$ and PM_{10} were obtained from global railway systems.

Location	Measurement environment	PM_{10} Mean	$PM_{2.5}$ Mean	References
Seoul, Korea	On platform/ground level	123.0	115.6	(Park & Ha, 2008)
Prague, Czech Republic	On platform	214.8	115.6	(Cusack et al., 2015)
Sydney, Australia	On platform/ ground level	20.1	16.7	(Mohsen et al., 2018)
Taipei, Taiwan	On platform/ ground level	44.0	33.0	(Cheng, Lin, & Liu, 2008)
Los Angeles, USA	On platform/ ground level	38.0	29.0	Kam, Cheung, Daher, and Sioutas (2011)
Naples, Italy	On platform/ ground level	16.0	10.0	(Cartenì, Cascetta, & Campana, 2015)
Bangladesh	On platform/ ground level	50.3	26.26	Current study

From Table (2) It is acquired that the exposure level of PM in the developed countries lies in a lower magnitude. The main reason is that they use an electric-powered train and ensuring environmentally friendly practices for their transportation mode. Different new systems are adopted by the countries for ensuring the lowest pollution levels.

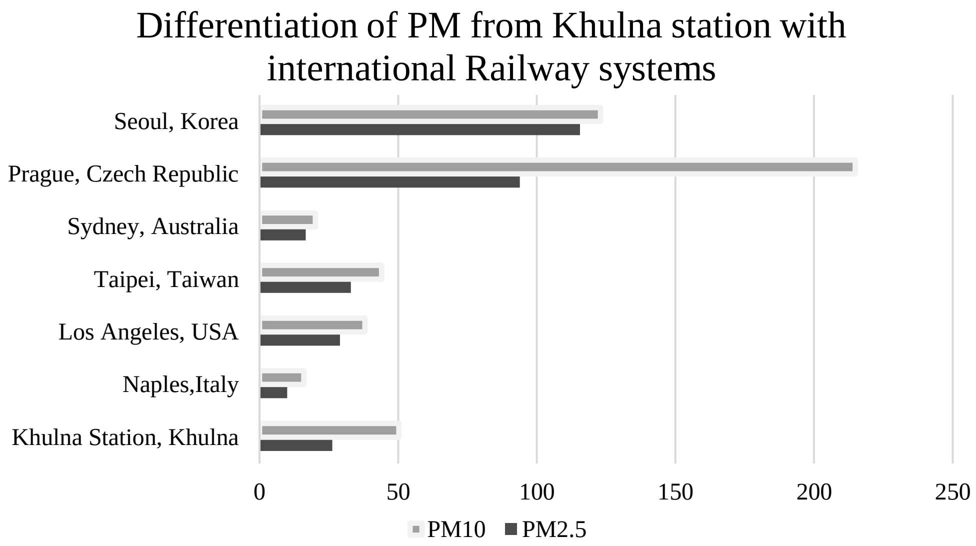

Figure 7: Comparison of various PM fractions in different railways (ground platform)

4. CONCLUSIONS

The concentration of PM and gaseous pollutants were measured both in the platform and background air quality station. The ratio of $PM_{2.5}/PM_{10}$ ratio is greater in the platforms than the background air. This result demonstrates that commuters are revealed to a relatively high amount of $PM_{2.5}$ in the platforms. The increasing values of pollutants concentration with traffic density in the peak hours also showed a linear relationship. On the other hand, the freight train emitted larger particles into the air that caused PM_{10} to reach its maximum value. The Higher AQI values are found from the platforms denoting little health concern to the sensitive groups. But all ground-level PM and gaseous pollutant concentrations are less than the national air quality standards. The lower value of (r^2=0.45) represents that the reason for moderate air quality in the station lies in the station and diesel emission is the main source of it. Based on our PM and gaseous pollutant measurements, It has also found that the value of PM also decreases with increasing the distance from the tracks. So future increments in rail traffic will raise the PM_{10} exposure and residents living close to the railway station, may suffer different carcinogenic diseases. So different new technologies and environmentally friendly practices should be adopted quickly to maintain the Khulna railway overall air quality.

5. ACKNOWLEDGEMENTS

The authors obviously want to thank the Khulna Railway Authority for their special support and Information. We would also like to thank Mr. Bain from Air quality station Khulna for his assistance.

REFERENCES

Annadanam, S. K., & Kota, S. H. (2019). Emission of greenhouse gases and criteria pollutants from railways in India estimated using a modified top-down approach. *Journal of Cleaner Production, 213*, 610-617. doi:10.1016/j.jclepro.2018.12.206

Cartenì, A., Cascetta, F., & Campana, S. (2015). Underground and ground-level particulate matter concentrations in an Italian metro system. *Atmospheric Environment, 101*, 328-337. doi:10.1016/j.atmosenv.2014.11.030

Cha, Y., Olofsson, U., Gustafsson, M., & Johansson, C. (2018). On particulate emissions from moving trains in a tunnel environment. *Transportation Research Part D: Transport and Environment, 59*, 35-45. doi:10.1016/j.trd.2017.12.016

Cheng, Y.-H., Lin, Y.-L., & Liu, C.-C. (2008). Levels of PM10 and PM2.5 in Taipei Rapid Transit System. *Atmospheric Environment, 42*(31), 7242-7249. doi:10.1016/j.atmosenv.2008.07.011

Cusack, M., Talbot, N., Ondráček, J., Minguillón, M. C., Martins, V., Klouda, K., . . . Ždímal, V. (2015). Variability of aerosols and chemical composition of PM 10 , PM 2.5 and PM 1 on a platform of the Prague underground metro. *Atmospheric Environment, 118*, 176-183. doi:10.1016/j.atmosenv.2015.08.013

Fridell, E., Ferm, M., & Ekberg, A. (2010). Emissions of particulate matters from railways – Emission factors and condition monitoring. *Transportation Research Part D: Transport and Environment, 15*(4), 240-245. doi:10.1016/j.trd.2010.02.006

Gangwar, M., & Sharma, S. M. (2016). Risks, determinants, and perspective for creating a railway biodiesel supply chain: case study of India. *Journal of Cleaner Production, 133*, 182-187. doi:10.1016/j.jclepro.2016.05.005

Gehrig, R., Hill, M., Lienemann, P., Zwicky, C. N., Bukowiecki, N., Weingartner, E., . . . Buchmann, B. (2007). Contribution of railway traffic to local PM10 concentrations in Switzerland. *Atmospheric Environment, 41*(5), 923-933. doi:10.1016/j.atmosenv.2006.09.021

Gupta, S. K., & Elumalai, S. P. (2019). Exposure to traffic-related particulate matter and deposition dose to auto rickshaw driver in Dhanbad, India. *Atmospheric Pollution Research, 10*(4), 1128-1139. doi:10.1016/j.apr.2019.01.018

Jaffe, D. A., Hof, G., Malashanka, S., Putz, J., Thayer, J., Fry, J. L., . . . Pierce, J. R. (2014). Diesel particulate matter emission factors and air quality implications from in–service rail in Washington State, USA. *Atmospheric Pollution Research, 5*(2), 344-351. doi:10.5094/apr.2014.040

Kam, W., Cheung, K., Daher, N., & Sioutas, C. (2011). Particulate matter (PM) concentrations in underground and ground-level rail systems of the Los Angeles Metro. *Atmospheric Environment, 45*(8), 1506-1516. doi:10.1016/j.atmosenv.2010.12.049

Mohsen, M., Ahmed, M. B., & Zhou, J. L. (2018). Particulate matter concentrations and heavy metal contamination levels in the railway transport system of Sydney, Australia. *Transportation Research Part D: Transport and Environment, 62*, 112-124. doi:10.1016/j.trd.2018.02.015

Park, D. U., & Ha, K. C. (2008). Characteristics of PM10, PM2.5, CO2 and CO monitored in interiors and platforms of subway train in Seoul, Korea. *Environ Int, 34*(5), 629-634. doi:10.1016/j.envint.2007.12.007

Qiu, Z., Song, J., Xu, X., Luo, Y., Zhao, R., Zhou, W., . . . Hao, Y. (2017). Commuter exposure to particulate matter for different transportation modes in Xi'an, China. *Atmospheric Pollution Research, 8*(5), 940-948. doi:10.1016/j.apr.2017.03.005

Star, T. D. (March 06, 2019). Living in toxic air. Retrieved from https://www.thedailystar.net/frontpage/dhaka-second-most-polluted-air-city-in-world-living-toxic-air-1711213.