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AIR QUALITY ASSESSMENT DURING OPERATION PHASE OF PADMA BRIDGE

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ABSTRACT

Air quality management is essential to ensure clean air. Padma Bridge will be the largest bridge in Bangladesh with enormous traffic volume which may decrease the surrounding air quality due to the air pollutants emission from motor vehicles. The air pollutants such as CO, NO_x, SO_2, VOC_s, PM_{10} emission from motor vehicles are estimated in this study considering the peak operation phase of Padma Bridge. Air quality modeling using HYSPLIT dispersion model is also performed for determining plume movement, air pollutants concentration and deposition having archived meteorological data. This study revealed that the plume of air pollutants during winter season will be mostly towards south-east and south-west direction covering the areas of Shreenagar, Shibchar, Mawa, kobutorkhola, Kawadi and Padma River. Air pollutants such as CO (3.1 ton/yr) and NOx (2.2 ton/yr) emission from motor vehicles were estimated. The maximum increasing concentration due to the motor vehicles emission for CO, NOx, VOCs, SO_2 and PM_{10} were calculated as 3.8 µg/m^3, 2.69 µg/m^3, 0.633 µg/m^3, 0.213 µg/m^3 and 0.192 µg/m^3, respectively. Air Quality Index value (196) indicates unhealthy condition for which general people in addition to the peoples having breathing difficulty can pose at risk due to the long term exposure of air pollutants.

Keywords: *Air quality, Air Pollutants, Dispersion model*

1. INTRODUCTION

Air is an obligatory element in the environment to all living being is vulnerable to degrade in quality affecting human health as well as environment. The Padma Bridge is a multipurpose road-rail bridge across the Padma River under construction in Bangladesh. The bridge will be used as a communication route and motor vehicles are one of the major sources of transportation. The number of vehicles on the Padma bridge will be significant and vehicular emission is also a concern. Air dispersion model can present how air pollutants can disperse in the ambient atmosphere. Models are important tools for air quality management. They are used to estimate the downwind concentration of air pollutants emitted from emission sources. As the motor vehicular emission is increasing the concentration of pollutants, it is necessary to report daily air quality by Air Quality Index (AQI) to determine the air quality to know how clean or unhealthy the air is. For these pollutants, EPA has established national air quality standards to protect public health.

Vehicular emission is one of the most dominating sources of air pollution. Globally vehicular emission from transportation sector is a major source of air pollution and threat to human health and environment. From light-duty, gasoline-powered vehicles, the most important pollutant emissions are volatile organic compounds (VOCs), carbon monoxide (CO), and oxides of nitrogen (NOx), whereas for heavy-duty, diesel vehicles, NOx and fine particulate matter ($PM_{2.5}$) are of the greatest concern. VOCs and NOx react in the presence of sunlight to form ozone and photochemical aerosols. For this understanding the air pollutants emission from vehicle is essential to ensure the clean and healthier air by reducing the air pollutant emission.

The study is aimed at to demonstrate the vehicular emission and its distribution with change the space and time to estimate the air pollutants (CO, SO_2, NO_x & PM_{10}), their concentration and deposition generating from motor vehicles, to perform air quality modeling for evaluating the plume of air pollutants and To determine the air quality index and compare with the standard value.

2. RESEARCH METHODS

The main bridge will be located over the Padma River in the north-south direction starting at Mawa in the Dhaka side under Lauhajang upazila and ending at Janjira in the other side of the River under Shariatpur district where the source location is selected as 90.259534 E, 23.42407 N. The forecasted annual average daily traffic was collected up to year 2044 (Rahman, 2016). Air pollutants emission from motor vehicle was estimated from this equation using emission factor.

E_c= *No. of vehicle x Distance x Emission Factor*. (1)

HYSPLIT dispersion modeling using archived meteorology was developed and the concentration and dispersion of pollutants were simulated and compared with the air quality data to find out the contribution of vehicular emission to the ambient air quality (CASE,2016). The month of January 2016 was selected for the availability of air quality monitoring data of emission from vehicle on Padma Bridge and dispersion modeling was done in this period. This period was selected because of winter season having more stable wind speed with lower velocity than other seasons which can provide maximum pollutant concentration in addition to availability of air quality monitoring data. During this period wind mostly moves towards the south, south-west and south-east direction (ARL,2016)..

AQI index value for this study was calculated for ambient concentration of CO, NO_x, SO_2, VOC_s, PM_{10} to check the ambient air quality for these air pollutants from the vehicular emission in addition with background data (ADB, 2010).The index is derived from the following formula:

AQI= (Pollutants data reading / Standard limit) x 100 (2)

3. RESULTS AND DISCUSSION

3.1 Emission Estimation of Motor Vehicles

The amount of SO_2, NO_x, CO, VOC_s, PM_{10} compounds were calculated from vehicular emission of Padma Bridge using emission estimation technique. Table 1 provides the mass of pollutants released from vehicle due to emission. Emission results show that by the year of 2044 (Rahman, 2016) vehicles will emit around 3168.331 kg/yr of CO, 2240.049 kg/yr of NO_x 527.755kg/yr of VOC_s, 177.659kg/yr of SO_2, 159.987 kg/yr of PM_{10}. The emission of CO is more than NO_x & SO_2. The emission of high CO indicates that the incomplete combustion of fuel. (Alam, 2016). The emitted sulfur dioxide and nitrogen oxides contact with water vapor and form nitric acid and sulfuric acid which can affect human health, animal life and the environment (Alam, 2016).

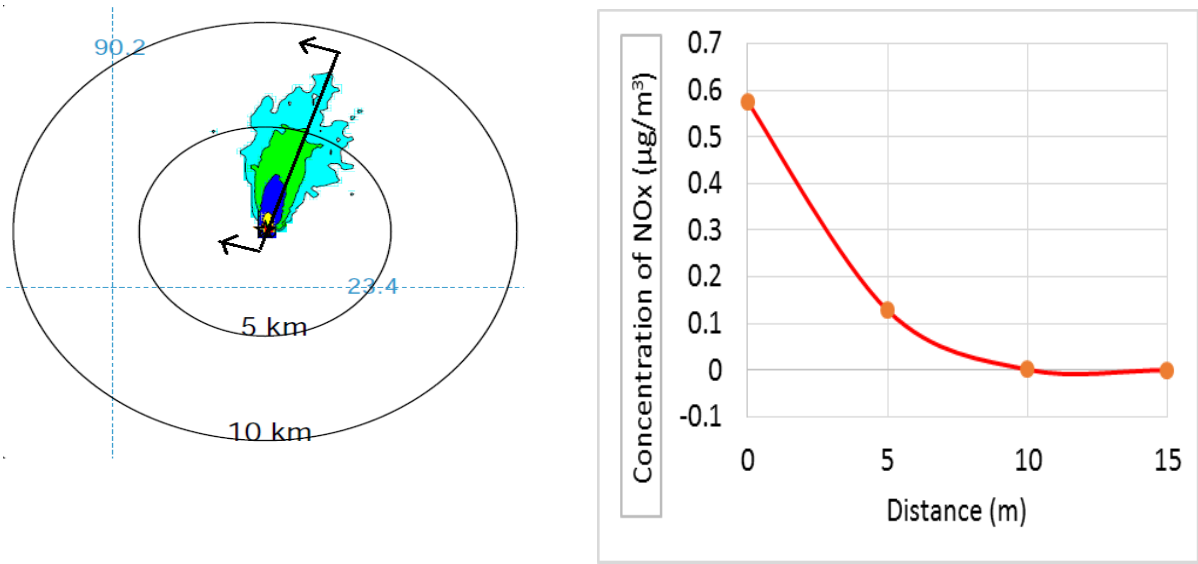
Table 1: Estimated Vehicular Emission

Compounds	Emission (Kg/yr)
CO	3168.3
NO_x	2240.0
VOC_s	527.8
SO_2	177.7
PM_{10}	160.0

3.2 Dispersion Modelling using HYSPLIT

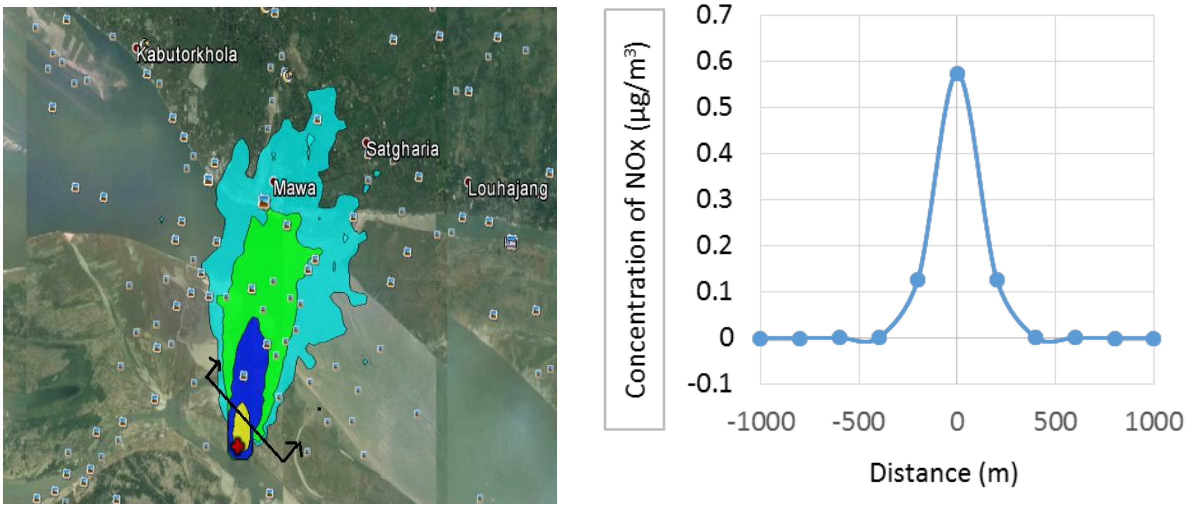
3.2.1 Validation of HYSPLIT Model

For the validation of HYSPLIT dispersion model with Gaussian plume distribution, graph was plotted by the value of pollutant concentrations with distance along the direction of plume distribution, a long section and a cross section transverse to long section of dispersion modeling.



(a) (b)

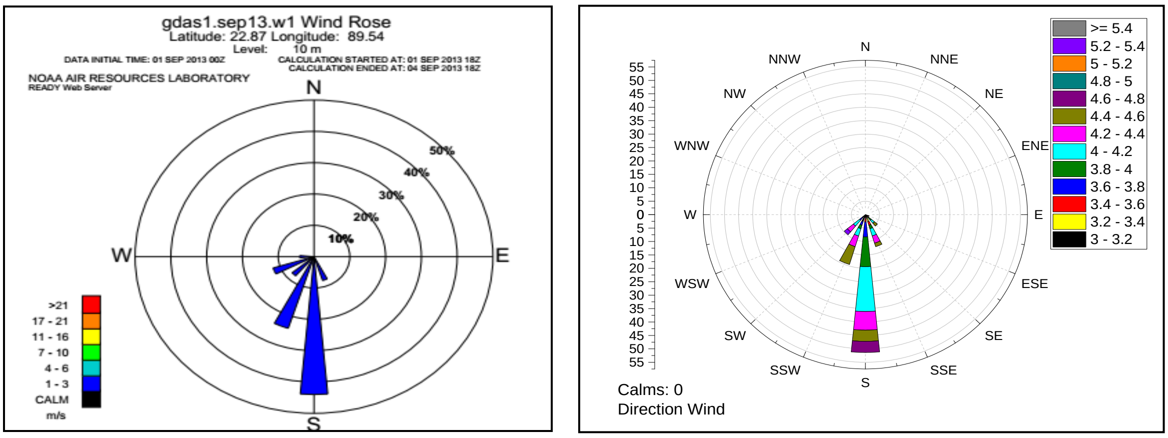
Figure 1: Spatial distribution of plume; (a) Typical dispersion map (b) Plume distribution along distance.



(a) (b)

Figure 2: Gaussian plume distribution; (a) Top view of pollutant dispersion, (b) Cross-section of plume distribution

Figure 1 and 2 showing the pollutant distribution after emission. From the graph, the concentration of NOx is decreasing continuously with the increment of distance. The mass of pollutants get dispersed along with the direction of wind movement. In the meantime, the pollutant mass get deposited on the earth surface. Thus, with the passage of time the covering area of dispersion increase and the pollution concentration decrease. From the HYSPLIT model result, both plume distribution results are similar to the Gaussian plume distributions. HYSPLIT windrose validation was checked with local windrose model on the same date 1st September, 2013 in figure 3 (Alam, 2017).



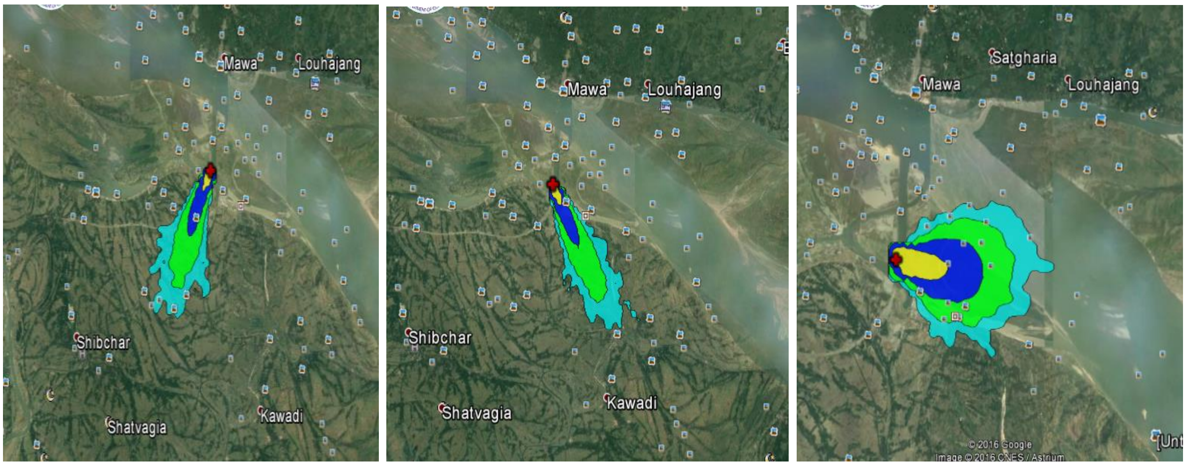
(a) (b)

Figure 3: Windrose for 1st September 2013 to 3rd September 2013; (a) generated by HYSPLIT, (b) windrose with regional air monitoring data

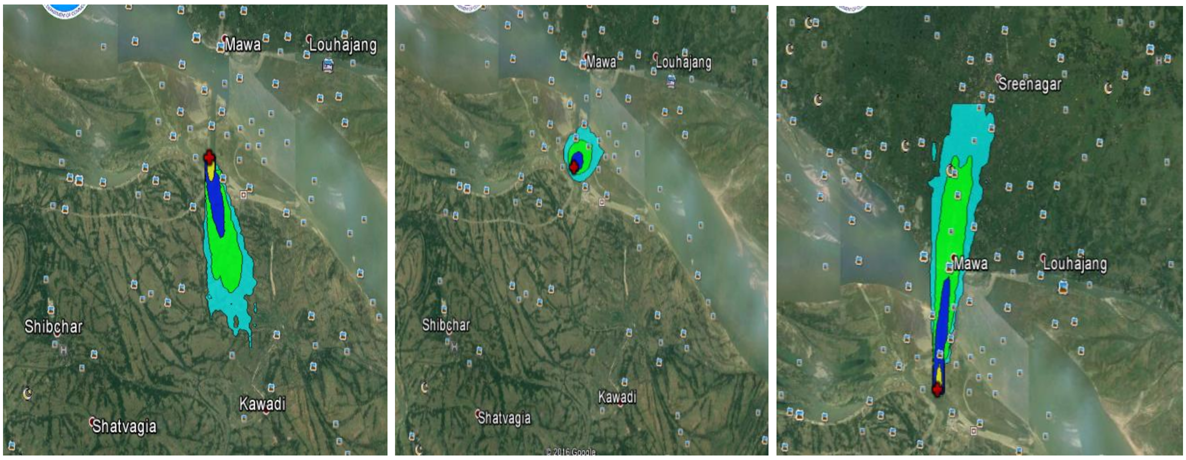
3.2.2 Concentration of Air Pollutants

The plume dispersion for every pollutants in HYSPLIT, is constant under the same meteorology and time as the model run under certain mathematical formula simulated in the model. The generated air pollutants from vehicles, the dispersion models are showing their path of dispersion after emission. The dispersion map in figure 1 showing the plume dispersion is concurrent with the meteorology that is wind speed and wind direction. In this approach, the plumes spread in between 15-20 Km from the source and the time of evolution of the area exposed above a particular concentration limit are considered. With the variation of time and distance, dispersion results from different simulations show variation in plume distribution pattern and concentration. Differences are seen in both plume movement and its aerial spread in each case. The plume travelled mostly in the direction of South-West and South-East direction. The highest concentration was near to the point of interest in all cases within 20 Km of radial distance.

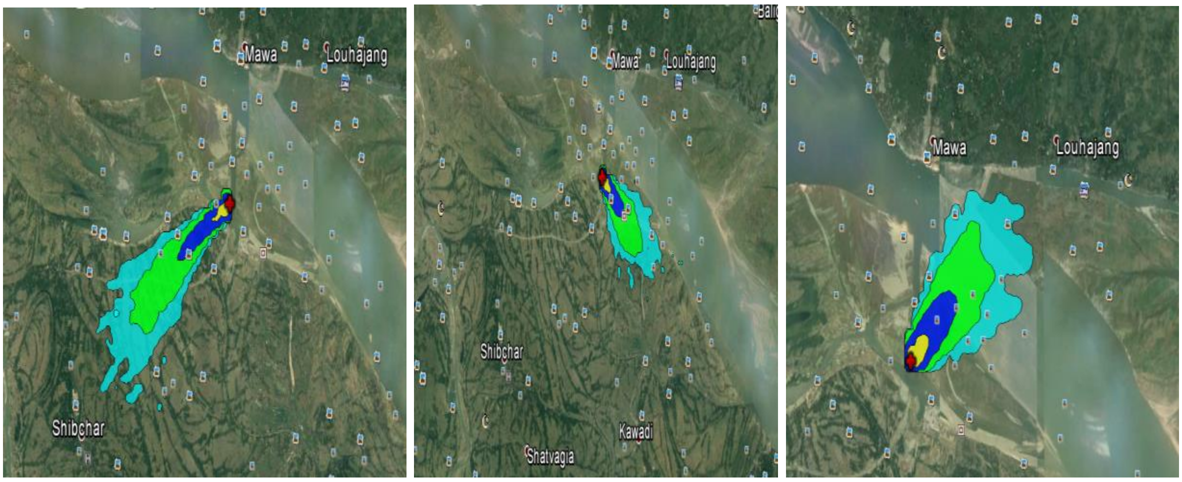
From the analysis of model results, it is seen that for 01 January, the plumes moved towards shibchar 0.958 µg/m^3 and the plume emission dispersed to a distance 10 Km. On January 02, the plumes move towards Kawadi and for 03 and 04 January, towards Padma River.



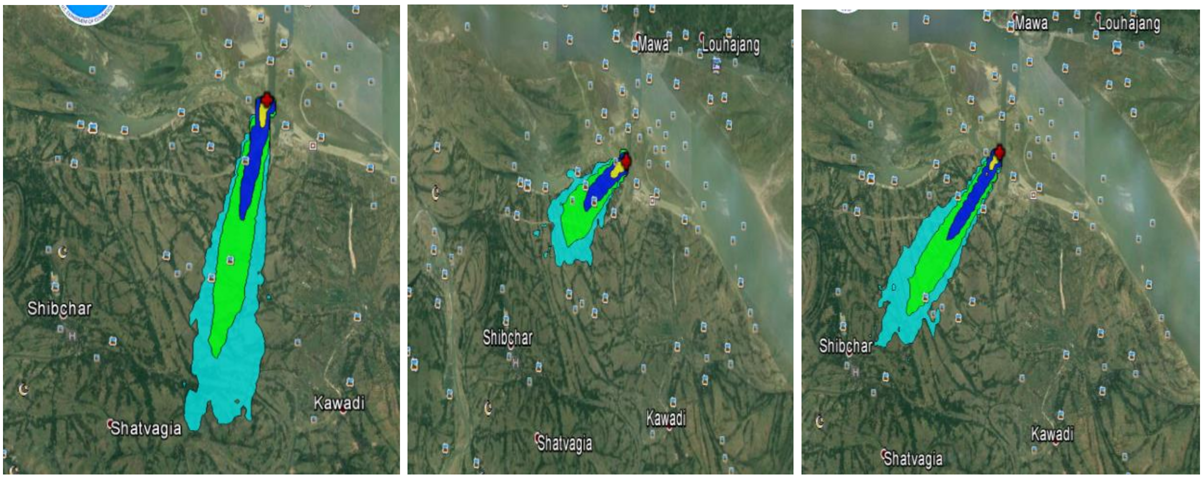
(a) 01 January (b) 02 January (c) 03 January



(d) 05 January (e) 08 January (f) 09 January



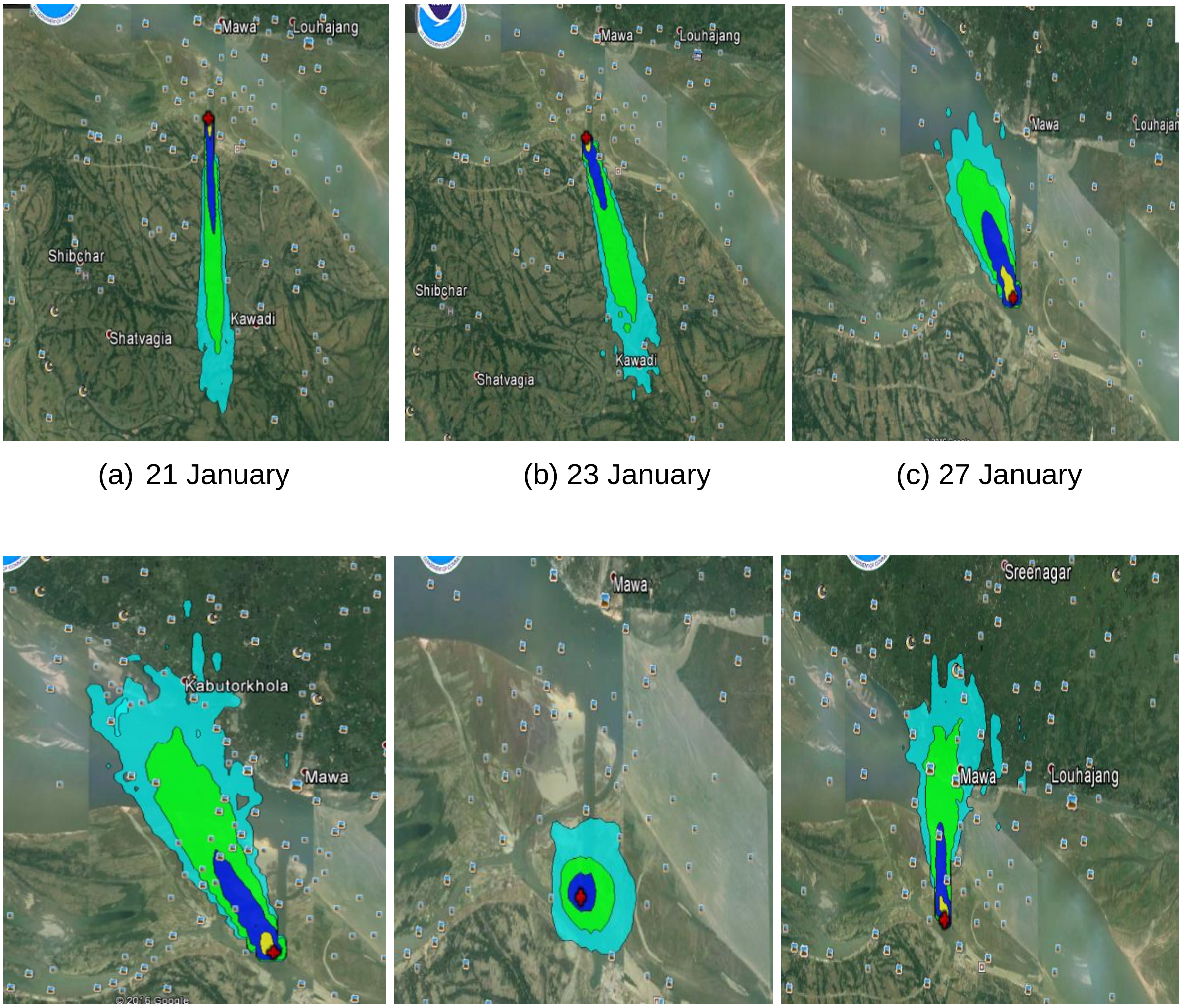
(g) 10 January (h) 12 January (i) 16 January



(e) 17 January (f) 19 January (g) 20 January

Figure 4: HYSPLIT generated air pollutants concentration NOx (µg/m^3) integrated for 1 hour period.

From January 05 to 07 the plume moved towards kawadi and for January 08, the concentration is maximum 2.69 µg/m^3. On january 09, the plume moved towards Sreenagar, 10 km away from the source with concentration 0.345 µg/m^3. 10 and 11 January plumes were in the direction of Shibchar. From 12-15 January plumes were towards the river bank, on 16 January on the river and 17 January was to the Shatvagia with maximum concentration of 0.908 µg/m^3. 19-20 January plumes were towards shibchar 0.832 µg/m^3.



(a) 21 January (b) 23 January (c) 27 January

(d) 28 January (e) 30 January (f) 31 January

Figure 5: HYSPLIT generated air pollutants concentration NOx (µg/m^3) integrated for 1 hour period.

January 21 and 22 showing the plume crossing in between Kawadi and Shatvagia with maximum concentraion 0.868 µg/m^3 with the range 20 km from the point of interest. For 23 to 26 January plumes are moving towards Kawadi. January 27 and January 28 showing that air pollutants are to the river and Kobutorkhola. January 30 having a concentration of 1.81 µg/m^3. For January 31, the concentration is 0.32 µg/m^3 towards Mawa, in the range between 10 km from the source.

3.2.3 Temporal Variation of Concentration

The variation of concentration of the air pollutants with time was obtained by concentration vs time curve by plotting the 31 days concentration of January 2016.

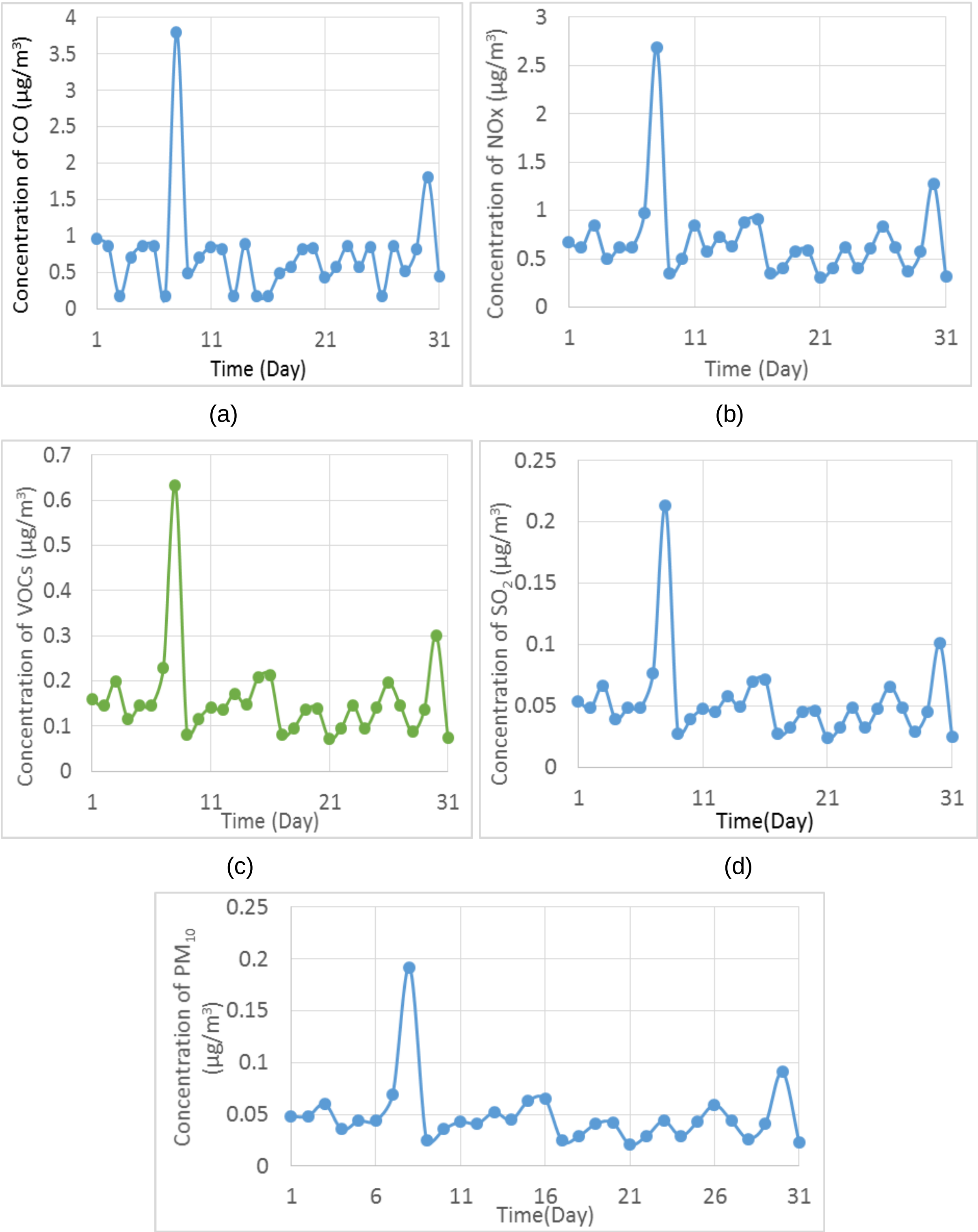


Figure 6: Variation of concentration with time (a) CO (b) NOx (c) VOCs (d) SO_2 (e) PM_{10}

The concentration of CO largely varied in between 0.5 µg/m^3 to 1 µg/m^3 showed in Figure 6 (a). The maximum concentration was found 3.8 µg/m^3 on 8th January, 2016 and the minimum concentration was 0.434 µg/m^3 on 17th and 21st January. The variation of NOx concentration from Figure 6 (b) are from 0.5 µg/m^3 to 1 µg/m^3. On 8th January maximum concentration of that month is 2.69 µg/m^3 and minimum is 0.345 µg/m^3 on 17th and 21st January.

From figure 6 (c), the VOCs concentration changes in between 0.1 µg/m^3 to 0.2 µg/m^3. On January 8 the maximum concentration of VOCs is found 0.633 µg/m^3 and minimum on 17th and 21st January was 0.00813 µg/m^3. In Figure 6 (c) and (d), the maximum concentration of SO_2 and PM_{10} were found 0.213 µg/m^3 and 0.192 µg/m^3 respectively on January 8. Minimum concentrations for SO_2 and PM_{10} were 0.00274 µg/m^3 and 0.00246 µg/m^3 respectively.

3.3 Air Quality Index

Air Quality Index (AQI) provides the understanding of air pollution level at which air can be polluted and the associated health effects that might concern. Background data of criteria air pollutants were obtained from Padma Bridge EIA report (EIA, 2010) was used to calculate the AQI values of CO, NOx, SO_2, and PM_{10} The maximum concentration of PM_{10} was fall in unhealthy condition For NOx, SO_2, CO the AQI values were obtained as good category.

Table 2: Air Quality Index

Air pollutants	Concentration µg/m^3	AQI Index value	Category	Color	Cautionary Statement
PM_{10}	294.1915	196	Unhealthy	Orange	General public at risk; sensitive groups at greater risk
SO_2	54.913	15	Good	Green	Little potential to affect public health
NO_x	26.785	26	Good	Green	Little potential to affect public health
CO	3.789	9.5	Good	Green	Little potential to affect public health

4. CONCLUSIONS

The forecast of estimated emission from the release of pollutants from motor vehicle by the year 2044 when the vehicles will be maximum, was found for CO 3168 kg/yr, NOx 2240 kg/yr, VOCs 527.7 kg/yr, SO_2 177.7 kg/yr, PM_{10} 160 kg/yr. CO and NOx was found higher in amount than the other pollutants. Air dispersion modeling showed that the plumes were heading dominatingly towards South-East and South-West direction and dispersion was within 20 km from the source of interest. The concentration of the pollutants was found maximum on the bridge road. The maximum concentrations for CO, NOx, VOCs, SO2, PM_{10} were found 3.8 µg/m^3, 2.69 µg/m^3, 0.633 µg/m^3, 0.213 µg/m^3 and 0.192 µg/m^3 respectively and the minimum concentrations were 0.434 µg/m^3, 0.345 µg/m^3, 0.00813 µg/m^3, 0.00274 µg/m^3 and 0.00246 µg/m^3 respectively. The Air Quality Index was evaluated for the estimated emission from vehicle in addition with the background data obtained from Padma Bridge EIA report. AQI found unhealthy due to PM_{10} concentration.

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