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Original Research Article

Emission profile of pollutants due to traffic in Lucknow City, India

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The human behaviors over the last few decades have changed the global atmospheric condition. Industrial emissions, transportation, intensification of agricultural practices and urban development have directly elevated the levels of pollutant gases such as CO_2, NO_2, CO and Particulate Matter (PM), which are probably to have inconsiderate climatic implications. Study is based on emissions from 2-Wheelers, 3-Wheelers, 4-Wheelers, Light Commercial Vehicles (LCVs) and Heavy Vehicles (HVs) at Lucknow City, India for three consecutive months; February 1, 2014 to April 30, 2014. The concentration of SO_2, PM, CO and NO_2 of selected location was 0.21 µg/m³, 6.27 µg/m³, 74.28 µg/m³ and 40.64 µg/m³ at Hazaratganj Road where as for Kalidas road it was 0.11 µg/m³, 2.87 µg/m³, 35.78 µg/m³ and 18.77 µg/m³, respectively. The concentrations of above pollutants were more at Hazaratganj Road as compare to Kalidas road. The emissions profile of SO_2, PM, CO and NO_2 were within national ambient air quality standard.

Key words: Vehicle emission, particulate matter, traffic analysis and air modeling

INTRODUCTION

Lucknow city is the capital of Uttar Pradesh; which has a population of 2.82 million (Municipal corporation and Cantonment) as per 2011 census, area of 310 km² and its geographic position is 26°52' N latitude to 80°56' E longitude; 128 meter above the sea level. As a consequence of urban development, along with energy, the transport sector has been the centre of attention during last decade. The transport sector in India consumes about 16.9% that is 36.5 million tons of oil equivalents of total energy. Among different types of motor vehicles, percentage of two wheelers has revealed rapid growth and it constitutes 70% of total motor vehicles of India (Ramchandra et al., 2009).

The main source of particulate air pollution in Lucknow city is vehicular traffic emission. The number of vehicle categories registered in Regional Transport Office (RTO) Lucknow was 14, 24,478 as of March 31, 2013 which is 8.35% higher over the last year. Uttar Pradesh State Road Transport Corporation (UPSRTC) introduced bus services under "Lucknow Mahanagar Parivahan Sewa" on different routes of Lucknow City. Since motor vehicle (traffic) emission are major sources of air pollution (Fujita et al., 1992, Kodama et al., 2002) in the Urban City. Major road present near the Hazaratganj was Nishatganj to Charbag, road which have massive vehicular motion as compare to other roads during entire years. (Figure 1)

Considering the worsening traffic growth and emissions and their impact on human health and urban air quality there is a need for a regulatory framework for the management of traffic, air quality and emissions at local level, regional and national scales (Costabile et al., 2008). The continuous vehicular exhaust inhalation can lead to symptoms of lower respiratory tract such as cough, shortness of breath and pain with inspiration (Dockery et al., 1994, Pope III, 1997). The unpleasant effects of prominent air pollutants on environment and human health are well known. A large number of urban people are at the edge of health risk due to adverse air quality. Among the different sources of air pollutants, tail pipe emission from

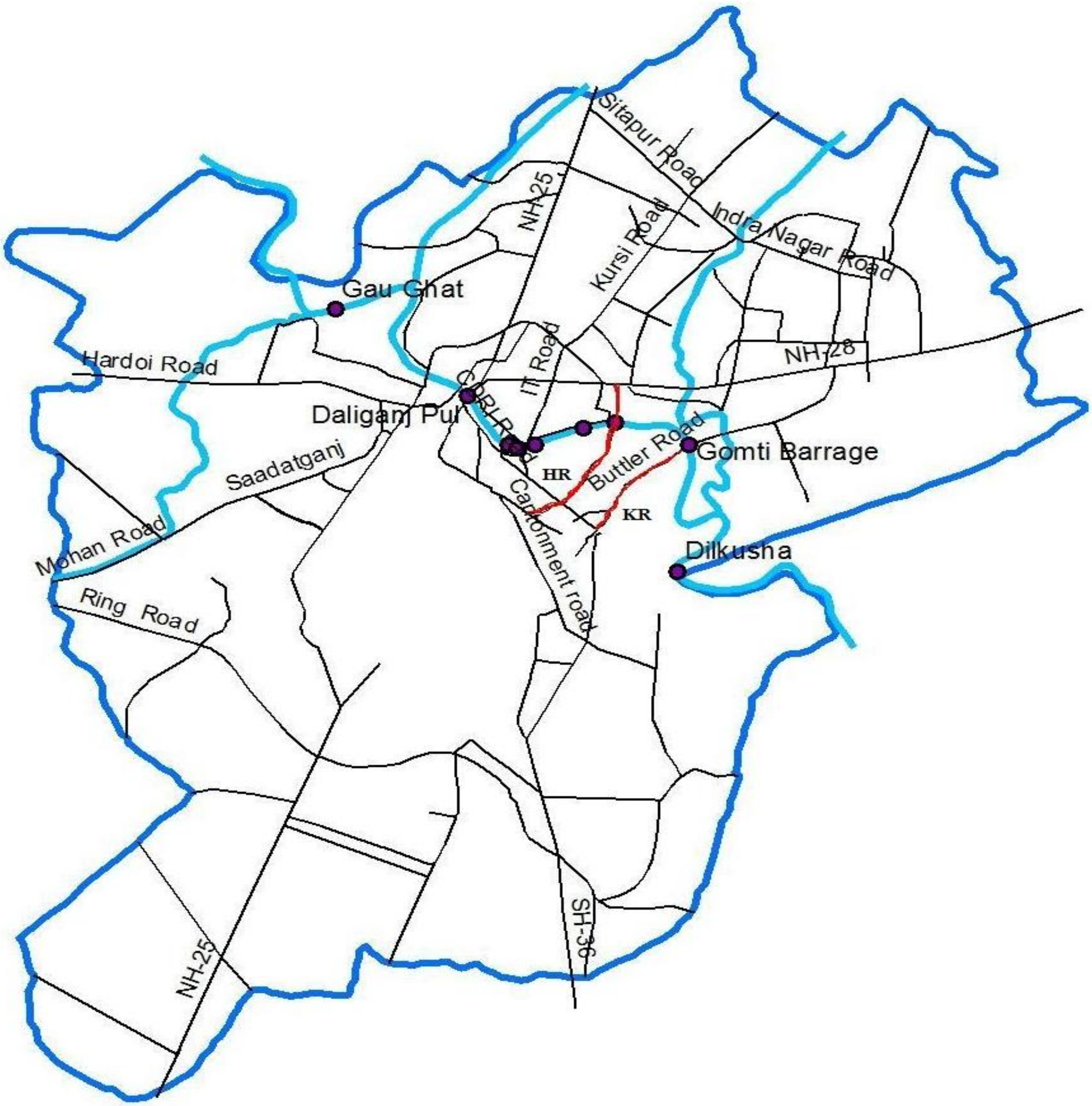

Figure 1: Lucknow city map

the vehicle is one of the main sources of air pollutants. Pollutants like Particulate Matter (PM), Sulphur dioxide (SO_2), Oxide of nitrogen (NO_2), CO (Carbon monoxide), Poly-aromatic hydrocarbon (PAH) and trace elements etc. are also present in the urban air and their levels are on the raise because of vehicular pollution. Due to change of technology and use of different fuels; the composition of the air quality is one of areas of concern.

Association between mortality rate and particulate air pollution has long been studied, but many studies may be limited by a lack of control for confounding factors (Dockery et al., 1993). Various scientific studies are going on in the different parts of the world and in India. Studies revealed that almost all major cities including Lucknow are polluted. Some criteria pollutants are above the prescribed permissible limit, especially the PM_{10}. Several recent studies suggest an association between automobile exhaust and increased respiratory illnesses (Nitta et al., 1993, Oosterlee et al., 1996).

The fine particulate matters are complex mixture of chemical agents of different shapes and sizes. Studies reveal that the effect of PM on human health will depend on the

Table 1: Emission Factor for selected locations

Sr. No.	Particulars of the Traffic	Final Emission Factor (gm/km/vehicle)		
		CO	NO_2	PM
1.	Two Wheeler	1.36	0.315	0.021
2.	Three Wheeler and Auto-rickshaw	1.59	0.577	0.151
3.	Passenger Cars and Jeeps	1.16	0.666	0.114
4.	Light Commercial Vehicle	3.66	2.120	0.475
5.	Heavy Duty vehicle	9.02	9.476	1.075

chemical composition of fine particulate matters, besides its number and mass concentration. At elevated levels, both the categories may increase mortality and morbidity of human population. The effect of SO_2 on ecosystem and human health is well recognized. At eminent level SO_2 can contribute to respiratory illness, particularly to children and elderly people and aggravate existing heart and lung diseases.

The most decisive part of assessment studies is to know the present as well as future air quality levels. The statistical distributional models that are 'non-causal' and based on the historical data overcome the above limitation and calculate the 'extreme' concentrations with logical precision (Jakeman et al., 1988). Hybrid modeling is one of the techniques that estimate the 'entire range' of the distribution of air pollutant concentrations by combining deterministic based models with suitable statistical distributional models. In the past, (Taylor et al., 1985) applied such a technique to envisage the entire range of pollutant concentrations for vehicular exhaust emissions. Recently, Gokhale et al., (2003) have afforded to develop a hybrid model for one of the traffic intersections in Delhi, India, to find out the entire concentration profile of CO.

The paper first, describes the vehicular pollution studies carried out at Hazatarganj and Kalidas road traffic intersections and then predicts the future emission load in that area which is important due to one falls into commercial zone and the latter in silence zone (such as Institutional zone, Hospital zone, VIP residential zone etc.). This paper discusses the current scenario of the transportation sector in terms of air pollution and reviews the air quality modeling studies conducted in Lucknow (U.P.) India. Future scope for air quality modeling is also discussed.

MATERIALS AND METHODS

Traffic survey data of various vehicle on Hazaratganj road and Kalidas Road

Vehicles were counted manually on Hazaratganj Road and Kalidas Road separately. A pre-planned data sheet was prepared to count vehicle. The format of traffic count data sheets was prepared as making fraction of 2W, 3W, 4W, LCV, HV. During counting of vehicle only cross mark sign was used for a vehicle as each per fraction. The vehicle moving toward Charbag was counted by a person and at the same time the vehicle coming from Charbag to Nishatganj was counted by another person.

Length of Nishatganj-Charbag Road was approximately 7 km with width of 28 meters and Lohiya path (Ambedkar park to Kalidas Road) was 2 km with width of 32 meters. It was compared with current year pollution scenario to the projected years due to addition of vehicular movement in subsequent year.

Emission factor

The vehicle emission factors prescribed for Indian Vehicle from CPCB/MOEF (CPCB, 2007) were considered in this study. The composite emission factors indicating fraction of various vehicle categories on the road have been worked out. The emission factor for the selected location is presented in Table 1.

Emission calculation methodology

Emission from the vehicle has been calculated using the following equation 1:

$$Ep = \sum (Veh_i \times D_i) \times EF \qquad \text{Equ. 1}$$

where: Ep is the Pollutant mass emission per day, i is the vehicle category,

Veh is the number of vehicle,

D is the distance traveled in km in one day and

EF is the mass emission factor per km travel.

For estimating SO_2 emissions from vehicle, the following assumptions have been made. Average km run per litre of diesel is taken as: 10 km (for 3W); 15 km (for 4W); 7 km (for LCV) and 5 km (HVs). Sulphur content is in diesel is taken as 50 ppm (wt/wt) (CPCB, 2007). Total road length was estimated by digitizing all the roads and then GIS software was used to calculate road length and therefore, exact road length was obtained. As the next step, information on traffic flow from traffic counts was translated into the vehicle on the roads. Based on road length and number of vehicle on the road, total vehicle kilometer travel (VKT) was estimated for each road. The data of wind direction was procured from Indian Meteorological Division, Pune and validated with the data

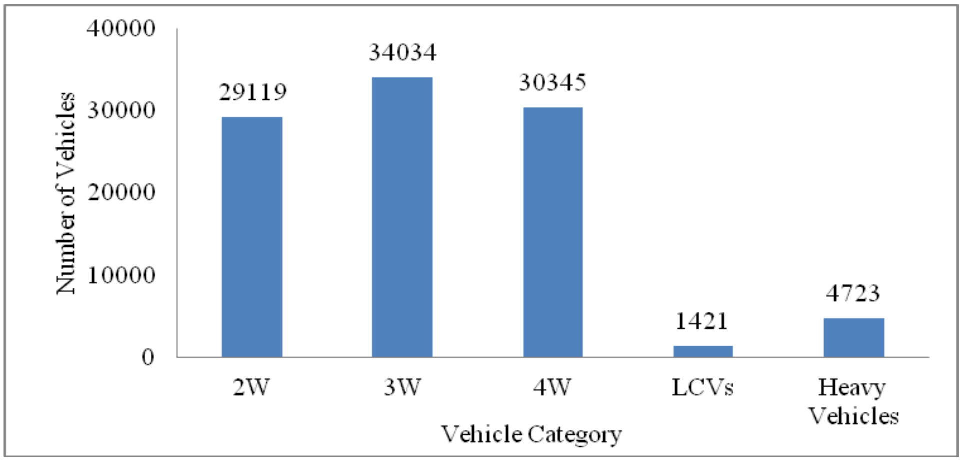

Figure 2: Number of Different Vehicle Category on Hazaratganj road

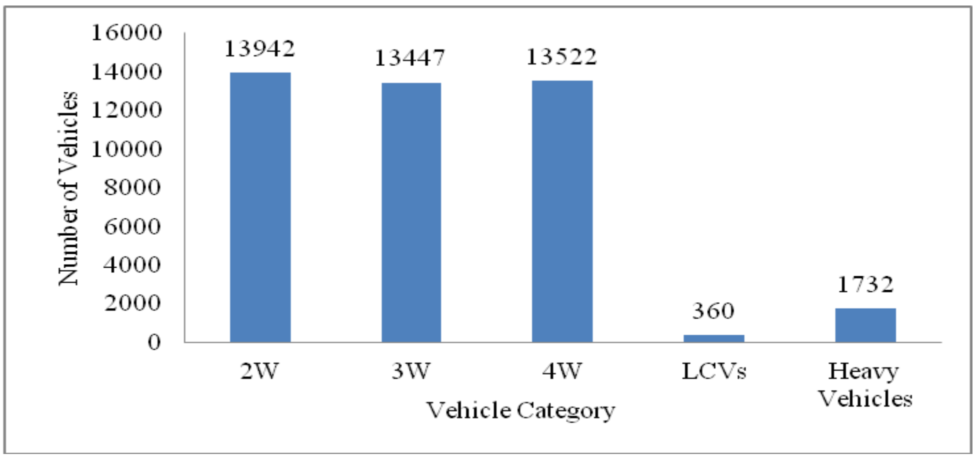

Figure 3: Number of Different Vehicle Category on Kalidas road

reported from literature. Wind rose diagram was prepared by using Lakes Environmental wind rose plot version V.6.5.1.

RESULTS AND DISCUSSION

Traffic survey data of various vehicle on Hazaratganj road

The average daily patterns of flow of 2-Wheelers (2W), 3-Wheelers (3W), 4-Wheelers (4W), LCVs and HVs throughout the day are shown in Figure 2. The number of 3W is high during the day.

Traffic survey data of various vehicle on Kalidas Road

The average daily patterns of flow of 2W, 3W, 4W, LCVs and HVs throughout the day are shown in Figure 3. The number of 2W is high during the day.

The average daily patterns of flow of 2W, 3W, 4W, LCVs and HVs throughout the day are shown in Figure 2 and 3 during Feb 1, 2014 to April 30, 2014. The number of 4W is high during the day. The vehicle count considering both major and minor lanes was found to be 99,642 and 43,003 per day at Hazaratganj road and Kalidas road respectively.

Vehicular emission profile on Hazaratganj Road

The SO_2, PM, CO and NO_2 emissions from different vehicle category are presented in Table 2. The percent contribution of different vehicle category in above pollutants emission is shown in Figure 4.

As from above Figure 4 (i) in case of 2W, the emission of SO_2 was not incorporated as the fuel was petrol in which sulphur content was nil. The movement of 3W was more as the LCV was very less. As it was may be due to the restriction of LCV movement on the Hazaratganj Road. As in case of Figure 4 (iv), the contribution of PM emission was more for 2W, as the movement was more as compare to

Table 2: Pollutants Emission at Hazaratganj Road and Kalidas Road

Pollutants Emission at Different Time Interval		Vehicle Types					
		2W	**3W**	**4W**	**LCV**	**HVs (Buses Total & trucks)**	**Total**
Profile on Hazaratganj Road	SO_2	---	0.14	0.02	0.01	0.04	0.21
	PM_{10}	0.26	2.16	1.44	0.28	2.13	6.27
	CO	16.61	22.82	14.78	2.18	17.88	74.27
	NO_2	3.85	8.24	8.48	1.27	18.79	40.63
Profile on Kalidas Road	SO_2	---	0.07	0.01	0.01	0.02	0.11
	PM_{10}	0.14	0.99	0.75	0.08	0.91	2.87
	CO	9.27	10.52	7.69	0.65	7.65	35.78
	NO_2	2.15	3.80	4.41	0.37	8.04	18.77

All the units are in μg/m³

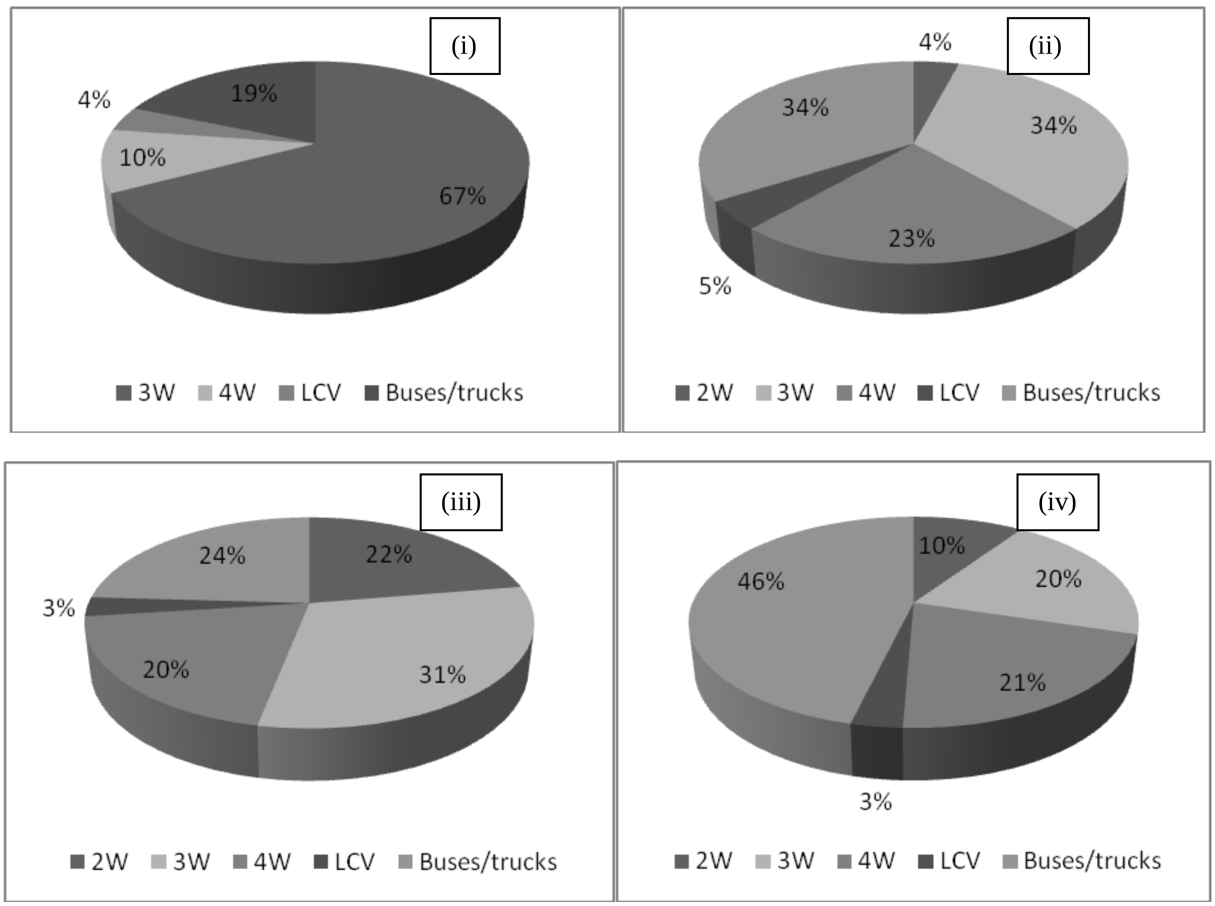

Figure 4: Pollutants Emissions from Vehicle (i) SO_2, (ii) PM, (iii) CO and (iv) NO_2

other vehicle.

Vehicular emission profile on Kalidas Road

The SO_2, PM, CO and NO_2 emissions from different vehicle category are presented in Table 2. The percent contribution of different vehicle category in above pollutants emission is shown in Figure 5.

As from above Figure 5 (v) in case of 2W, the emission of SO_2 was not incorporated as the fuel was petrol in which sulphur content was nil. The number of vehicle was more than twice in case of Hazaratganj Figure 2 and Figure 3 but the emission scenario was approximately same. The movement of 3W was more as the LCV was very less. As it was may be due to the restriction of LCV movement on the Hazaratganj Road. As in case of Figure 5 (viii), the contribution of PM emission was more for 2W, as the movement was more as compare to other vehicle.

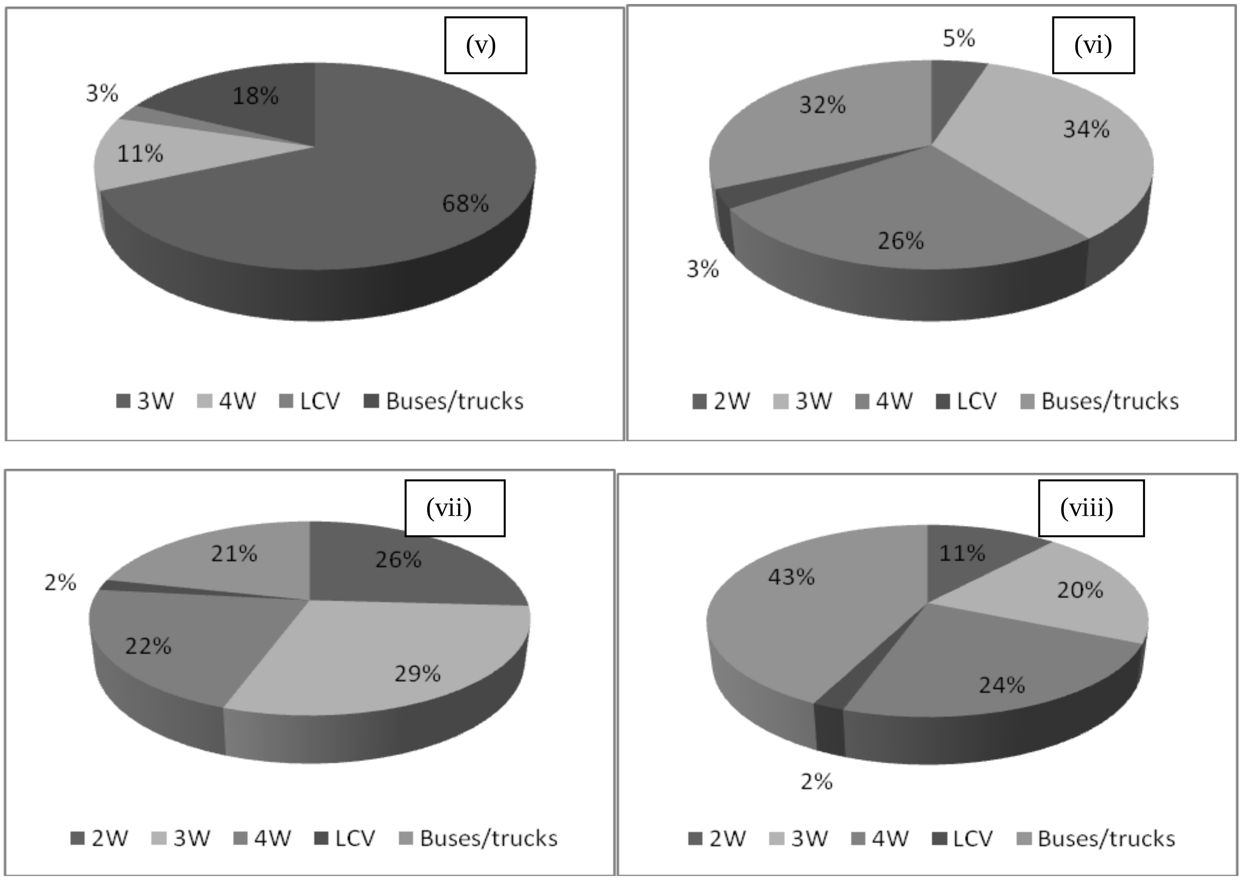

Figure 5: Pollutants Emissions from Vehicle (v) SO_2, (vi) PM, (vii) CO and (viii) NO_2

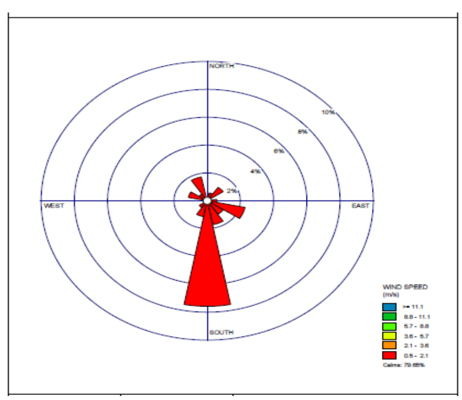

Figure 6: Wind-rose diagram of the Lucknow city

Air quality modeling

The air quality modeling was performed using the dispersion model developed by the United State Environmental Protection Agency (USEPA) in conjunction with American Meteorological Society (AMS). This model is called AMS/USEPA regulatory model, or AERMOD. AERMOD is a complete and powerful air dispersion modeling package which seamlessly incorporates the following popular US EPA air dispersion models into one integrated interface (Tiwari et al., 2014). The emission load was estimated using the AERMOD model of USEPA considering the line sources. Dispersion of air pollutant would depend on wind direction. The wind rose and frequency distribution of the Lucknow city during the study period is given in Figure 6.

Table 3: PM_{10} and NO_2 (24 hour) value for the year of 2014, 2017 and 2022

	2014				2017				2022			
	PM_{10} (μg/m³)		NO_2 (μg/m³)		PM_{10} (μg/m³)		NO_2 (μg/m³)		PM_{10} (μg/m³)		NO_2 (μg/m³)	
	HR	KR	HR	KR	HR	KR	HR	KR	HR	KR	HR	KR
1st	41.76	23.54	41.78	22.69	53.59	29.67	141.91	72.54	69.89	37.76	211.57	109.41
2nd	39.68	22.98	39.65	20.78	52.29	27.31	139.48	74.93	68.23	34.32	204.49	106.56
3rd	34.98	18.67	35.91	18.87	45.07	23.39	199.59	103.49	58.79	28.99	179.87	92.43
Annual	18.21	10.89	17.09	09.23	21.14	1 2.45	59.21	31.65	28.13	15.43	88.42	46.35

HR: Hazaratganj Road, KR: Kalidas Road

PM_{10} and NO_2 concentrations at Hazaratganj Road

Three scenarios were considered in terms of years (2014, 2017 & 2022). The model-computed concentrations for PM_{10} are shown in Table 3. The predicted 1st highest 24 hour concentration for the year 2014 is 41.76 μg/m³ and annual maximum is 17.09 μg/m³. Both 24 hour and annual hour maximum concentrations are well below the NAAQS for PM_{10} (24-hr Standard: 100 μg/m³ and annual standard: 60 μg/m³). For NO_2, highest 24 hour concentration for the year 2014 is 41.78 μg/m³ and annual maximum is 18.21 μg/m³.

PM_{10} and NO_2 concentrations at Kalidas Road

The predicted highest 24 hour concentration for the year 2014 is 23.54 μg/m³ and annual maximum is 10.89 μg/m³ as shown in Table 3. For NO_2, highest 24 hour concentration for the year 2014 is 22.69 μg/m³ and annual maximum is 09.23 μg/m³.

It was predicted from Table 3, on Hazaratganj road that the emission of PM_{10} was 1.3 fold and 1.7 fold more (from 2014 to 2017; and 2014 to 2022), respectively and in case of NO_2, it was 3.4 fold and 5.1 fold (from 2014 to 2017; and 2014 to 2022), respectively. Whereas on Kalidas road, the emission of PM_{10} was 1.3 fold and 1.6 fold more (from 2014 to 2017; and 2014 to 2022), respectively and in case of NO_2, it was 3.2 fold and 4.8 fold (from 2014 to 2017; and 2014 to 2022), respectively.

Traffic-related pollutants affect ambient air quality on a broad variety of spatial scales, ranging from the roadside to the urban and regional background scales. Long term exposure to SO_2, CO, PM and NO_2 cause exacerbation of asthma, cancers, particularly lymphomas, leukemia, and brain cancer.

Characterization of the nature and extent of travel activity is essential for estimating emissions from motor vehicle and for reducing the impact of motor-vehicle emissions on air quality requires a comprehensive strategy that typically includes four key components, that is emissions standards for new vehicle, transportation planning and demand management, specifications for clean fuels and inspection programs to ensure proper vehicle maintenance.

Conclusion

The emission of SO_2, PM_{10}, CO and NO_2 at Hazaratganj road was 0.21 μg/m³, 6.27 μg/m³, 74.27 μg/m³ and 40.63 μg/m³ respectively. While the emission of SO_2, PM_{10}, CO and NO_2 was 0.11 μg/m³, 2.87 μg/m³, 35.78 μg/m³ and 18.77 μg/m³ respectively at Kalidas road. Study revealed that emission profile at Hazaratganj road was more than Kalidas road. As from Air-modeling, the emission of PM_{10} was 1.3 fold and 1.7 fold more (from 2014 to 2017; and 2014 to 2022), respectively and in case of NO_2, it was 3.4 fold and 5.1 fold (from 2014 to 2017; and 2014 to 2022), respectively. Whereas on Kalidas road, the emission of PM_{10} was 1.3 fold and 1.6 fold more (from 2014 to 2017; and 2014 to 2022), respectively and in case of NO_2, it was 3.2 fold and 4.8 fold (from 2014 to 2017; and 2014 to 2022), respectively.

To control vehicle emission, regular checking for fitness and up gradation of fuel quality and tightening of vehicle emission regulations should be adopted. Public transport system must be improve and phasing out of grossly polluting commercial vehicle. Encouraging car pool as well as reduction in value of VKT also reduced the emission profile of vehicle. It is a preliminary prediction which carried out with the ultimate objective of conducting a large-scale source apportionment study for the Lucknow area. Ample long-term measurements of organic and inorganic ambient aerosol components and local source signatures are required in order to gain a more complete result.

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