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ASSESSMENT OF THE IMPACTS OF VEHICULAR EMISSIONS ON AIR QUALITY

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Abstract. *India's several developed regions, still have a fast-increasing automobile population in which deteriorating air quality is a significant environmental issue. Vehicular emission contamination is the presence of toxins in the environment that are anthropogenic (man-made) or typical in proportions that might be harmful to humans, the environment, and animal life. Due to an increase in the number of motor vehicles, growing urbanization, and increased industrialization, it has resulted in worst air quality. This further results in more toxic air discharges. Numerous metropolitan areas have significantly higher airborne toxin concentrations than the national, territorial, or local averages. The main source of air pollution in metropolitan areas is engine vehicles, especially those that are old and poorly maintained. The contaminants carbon monoxide (CO), nitrogen dioxide (NO$_2$), and particulate matter (PM$_{2.5}$) are of particular concern. Fuel combustion or evaporation is the origin of emissions from motor vehicles. India's fuel emission regulations are less stringent than international regulations. Present analysis is related to air quality in context of Kanpur City, India & exploring the aids in strengthening methods to limit exhaust emissions.*

Keywords: Vehicular Emission, Environment Particulate Matter, Contamination, Pollution Towers, Climate.

1. INTRODUCTION

The deterioration in air quality is being caused by vehicle emissions and there are now more health difficulties along with environmental challenges because of the extensive expansion of motor vehicles. In some crossroads and areas with high traffic volumes, the concentration of pollutants is higher than the permitted level. Carbon monoxide (CO), Particulate Matter (PM$_{2.5}$), nitrogen dioxide (NO$_2$), sulphur dioxide (SO$_2$), and ozone (O$_3$) are the principal air pollutants at fault for air pollution brought on by automotive emissions. These contaminants have a negative impact on both the environment and human health. There is only one method to stabilise air pollution, namely PM$_{2.5}$. According to reports, diesel car emissions are substantially more damaging than those from gasoline-powered automobiles. It is a source of atmospheric soot and fine particles, a kind of air pollution linked to heart and lung disease, cancer, and other conditions. When petrol evaporates and burns, it releases poisonous and flammable vapours that contaminate the petrol with CO and NO$_2$ particles and cause air pollution.

Electric cars do not emit any pollutants directly, although they may emit evaporative emissions. The electric energy that drives the motor in all electric cars is stored in a battery. A survey was carried out of Kolkata City – India, to assess the problem caused by vehicle emissions in the study region as well as the state of air pollution at traffic junctions (Ghose *et al.*, 2004). All the major contaminants were found over the allowable limits and threatening levels were reached with the issues. To assess the air pollution stress at various places within the research region, Vulnerable Analysis (VA) has been done. To reduce the amount of air pollution in the city, options for reducing emissions from mobile sources were considered, and a systematic approach to motor vehicle regulation was put forth. Older cars need to be replaced, diesel fuel should be reformulated, LPG and CNG should be introduced, there should be significant infrastructural upgrades, and there should be radical traffic management techniques, among other things.

Arun *et al.* (2017) developed exemplary driving cycles for motorbikes and vehicles that match the actual driving conditions in Chennai – India. To create the driving cycles, second-by-second vehicle speed data from a sample collection of automobiles was collected using an On-Board Diagnostic (OBD) reader and GPS receiver. The driving cycles were built from micro-trips using eleven assessment metrics. The 1,448 and 1,065 second (peak-hour) created cycles for motorbikes and passenger automobiles were compared to the existing driving cycles. The necessity for cycles suited to cities was highlighted by the significant disparities across the cycles.

Jaikumar *et al.* (2017a) discussed the characterization and modelling of passenger automobile exhaust emissions on urban roadways with a variety of traffic patterns. In a populated urban region of India, onboard exhaust emissions measurements were taken along a few chosen routes. According to Vehicle Specific Power (VSP), different driving modes' exhaust emissions were characterized. Results showed that emissions at cruising speeds in VSP modes were 10-12 times lower than those at idle (the mode utilized for emission standard certification), braking, and accelerating speeds. Additionally, it was shown that most roadways had over 20% of the time that cars were idle. Using Artificial Neural Network (ANN) technology, real-time exhaust emission prediction models for diverse traffic circumstances were created. The model was fed information on the vehicle's characteristics, including RPM, speed, acceleration, and VSP. The ANN-based exhaust emission prediction models were trained using the onboard observations of CO, HC, and NO_x concentrations. The results of all driving modes indicated good agreement with onboard measured emissions data (*index of agreement* = 0.9). The emissions calculated using the COPERT model and the emission factors suggested by the Automotive Research Association of India (ARAI) were also compared with those from the ANN model. It was discovered that the ANN model emissions were more advantageous for managing traffic and urban air quality than the ARAI and COPERT model emissions. The behaviour of NO_x, unburned HC, CO, and CO_2 emissions from light-duty diesel automobiles that meet "Euro 6" emissions requirements has been studied through experiments (Chong *et al.*, 2018). The driving path accurately represented a variety of driving scenarios, including urban, rural, and interstate driving. A Portable Emission Measuring System (PEMS) with a Global Positioning System (GPS) was used to measure emissions in real time. The authors calculated the road load coefficients of Vehicle Specific Power (VSP) and the regression coefficient between fuel consumption rate and VSP to explore the features of gaseous emissions and demonstrated the relationship between average fuel usage and each gaseous emission.

An important finding from earlier research (Boulter *et al.*, 2007; Gallus *et al.*, 2017; Myung *et al.*, 2017; Zhang *et al.*, 2014) was that gaseous emissions are strongly correlated with engine speed and load. As a result, gaseous emissions from a vehicle under real-world driving conditions show significant differences in emission quantity and chemical components. Due to the complexity of the diesel exhaust gas characteristic in relation to the operating conditions of the vehicle, researchers typically analyze the emission data collected under well-controlled conditions in laboratories. This is done using a chassis dynamometer to measure various emissions from a vehicle while it is driving over a transient cycle that represents the dynamic operating conditions of the vehicle (Yamada *et al.*, 2016). However, such measurement provides inaccurate data for projecting the actual driving gaseous emissions from vehicles, and the discrepancies can be attributed to several factors, including traffic, ambient conditions, driving patterns, driver's behaviors, and route severities (Fontaras *et al.*, 2014; Fu *et al.*, 2013; Jaikumar *et al.*, 2017b).

Harish (2012) examined vehicle-related petrol emissions in Bangalore – India, to understand urban air pollution and concluded that the Karnataka Pollution Control Board must implement a stringent enforcement and monitoring program to enhance the quality of the air and water. There is also a need for traffic laws; the city needs an effective public transit system, and those who break the law should face harsh penalties and have their vehicles impounded. Environmental education should be made mandatory in schools to raise awareness among the public about how and why it is important to maintain the environment.

Present analysis has been done in context to Kanpur City – India, and in the present work researchers has made an effort to determine the percentage of different air pollutants from vehicular emissions – to analyze statistically air quality parameters at traffics intersections, to understand the nature and causes of vehicular emissions in various traffic intersections along with the impact of vehicular emission on health and environment, and to identify the areas of high concentration of air pollutants in Kanpur.

2. METHODOLOGY

a. Identification of Study of Area
Air pollution in Kanpur City – India is mainly caused by vehicle exhaust emissions at intersections. The concentration of pollutants is higher than the standard values. Especially these pollutants NO_2, SO_2 and $PM_{2.5}$ are of major concern.

b. Data Collection
Air quality data used in this study for year 2015-2019 were obtained from the Uttar Pradesh Pollution Control Board (UPPCB), Kanpur – UP and for January 2020 obtained from Kanpur Smart City Limited. Vehicular population data used in this study were obtained from the Regional Transport Organization (RTO), Kanpur – UP.

c. Data Processing and Standardization
Statistical analysis of air quality data is done by using SPSS software, the package is widely used in social and behavioral sciences. Calculation done for air quality parameters (CO, NO_2, $PM_{2.5}$, SO_2 and O_3) are *i*) *Count*, *ii*) *Average*, *iii*) *Minimum*, *iv*) *Maximum*, *v*) *Median*, *vi*) *Standard-Deviation*, *vii*) *Kurtosis* and *viii*) *Skewness*.

d. Different Methods for finding Air Quality
   i)   Continuous Ambient Air Quality Monitoring;
   ii) Manual Ambient Air Quality Monitoring.

3.   RESULTS AND DISCUSSION

3.1. Statistical analysis of pollutant parameters

A statistical analysis of summary of air quality data is shown in Tables 1-6, for the years of 2015, 2016, 2017, 2018, 2019, and 2020, respectively. During the year of 2015, as can be seen in Table 1, the average annual concentration of $PM_{2.5}$ is 113 μg/m^3 – this value is higher than standard value, *i.e.*, 40 μg/m^3. This is almost thrice the standard value. The average annual concentration of CO and NO_2 is also higher than standard values. The values of O_3 and SO_2 are lower than the standard limits. For the year of 2016 (Table 2), the average annual concentration of $PM_{2.5}$, NO_2 and CO is higher than standard values. The concentration of $PM_{2.5}$ is more than twice of standard value. During 2017 (Table 3), the average annual concentration of $PM_{2.5}$, NO_2 and CO was higher than standard values. The concentration of NO_2 and $PM_{2.5}$ was more than twice of standard value. For the year of 2018, Table 4 shows the average annual concentration of $PM_{2.5}$, NO_2 and CO, which is higher than standard values. The concentration of $PM_{2.5}$ is more than twice of standard value. The concentration of SO_2 and O_3 is also increase in 2018 in comparison to previous years. During 2019, the maximum monthly concentration of $PM_{2.5}$ is 439.37 μg/m^3 for Ghantaghar (place in Kanpur City) (Table 5). This concentration is hazardous for human health and environment. This data is collected from Kanpur Smart City.
Similarly calculated for other locations in Kanpur City, where the concentration of pollutants is very high as compared to standard pollutants concentration.

Table 1. Statistical Analysis of the Air Quality for the year of 2015.

Statistical parameter	CO (mg/m^3)	O_3 (μg/m^3)	SO_2 (μg/m^3)	NO_2 (μg/m^3)	$PM_{2.5}$ (μg/m^3)
Count	12	12	12	12	12
Average	2.320	16.925	11.400	66.160	113
Maximum	4.100	24.500	14.800	99.200	217
Minimum	1.600	11.100	5.900	43.800	33
Median	1.930	14.300	10.950	61.400	96
Standard-Deviation	0.801	5.474	2.730	18.320	66.190
Kurtosis	5.560	0.760	-0.460	-1.010	-1.610
Skewness	1.360	0.374	0.633	-0.564	0.374

Table 2. Statistical Analysis of the Air Quality for the year of 2016.

Statistical parameter	CO (mg/m^3)	O_3 (μg/m^3)	SO_2 (μg/m^3)	NO_2 (μg/m^3)	$PM_{2.5}$ (μg/m^3)
Count	12	12	12	12	12
Average	2.670	15.920	64.375	9.900	109.5
Maximum	1.470	10.200	31.400	4.800	35
Minimum	4.200	31.200	95.700	14.100	226
Median	2.735	14.500	68.450	9.850	82
Standard-Deviation	0.840	5.680	18.780	2.980	66.450
Kurtosis	-0.756	3.730	-0.220	-1.430	-0.940
Skewness	0.157	1.810	-0.870	-0.110	0.808

Table 3. Statistical Analysis of the Air Quality for the year of 2017.

Statistical parameter	CO (mg/m³)	O₃ (µg/m³)	SO₂ (µg/m³)	NO₂ (µg/m³)	PM₂.₅ (µg/m³)
Count	12	12	12	12	12
Average	2.460	13.766	9.066	90.550	103.750
Maximum	3.600	18.700	11.500	42.500	229
Minimum	1.880	9	5.500	161.700	31
Median	2.230	12.900	9.450	90.350	72.500
Standard-Deviation	0.553	2.879	1.706	35.170	66.030
Kurtosis	0.107	-0.830	0.079	-0.193	-0.653
Skewness	1.120	0.090	-0.752	0.411	0.869

Table 4. Statistical Analysis of the Air Quality for the year of 2018.

Statistical parameter	CO (mg/m³)	O₃ (µg/m³)	SO₂ (µg/m³)	NO₂ (µg/m³)	PM₂.₅ (µg/m³)
Count	12	12	12	12	12
Average	2.110	45.030	16.770	60.910	97
Maximum	3.960	80	33.500	26.400	20
Minimum	1.330	20.400	6.300	105.700	218
Median	1.875	41.600	15.050	63.750	68
Standard-Deviation	0.780	17.650	8.860	21.530	68.550
Kurtosis	3.650	-0.670	-0.670	0.180	-0.920
Skewness	1.770	0.540	0.670	0.160	0.770

Table 5. Statistical Analysis of the Air Quality for the year of 2019.

Statistical parameter	CO (mg/m³)	O₃ (µg/m³)	SO₂ (µg/m³)	NO₂ (µg/m³)	PM₂.₅ (µg/m³)
Count	30	30	30	30	30
Average	1.423	10.720	31.168	20.126	92.375
Maximum	0.591	7.370	23.350	12.820	26.690
Minimum	4.148	12.370	39	45.630	439.370
Median	1.264	10.900	30.660	18.840	72.665
Standard-Deviation	0.660	1.120	3.800	6.480	78.820
Kurtosis	2.630	-1.150	0.170	2.540	3.430
Skewness	9.651	1.890	-0.390	8.210	13.550

3.2. Analysis of registered vehicles in Kanpur

In Kanpur City, total registered vehicles were 95,634 in 2015 (Figure 1). Out of which 86,335 (90.27% of total vehicles) registered vehicles were petrol vehicles and 9,178 (9.59% of total vehicles) registered vehicles were diesel vehicles in 2015. But, only 52 (0.054% of total vehicles) electric vehicles and 69 (0.072% of total vehicles) gasoline vehicles were in 2015.

In 2016, the number of total registered vehicles in Kanpur was 100,691 (Figure 1). Out of which 90,292 (89.67% of total vehicles) registered vehicles were petrol vehicles and 9,361 (0.92% of total vehicles) registered vehicles were diesel vehicles. However, only 1,005 (0.99% of total vehicles) electric vehicles and 33 (0.033% of total vehicles) gasoline vehicles were in 2016. According to Figure 1, the numbers of registered vehicles are increased, which causes more traffic and exhaust emissions of gases and particulate.

In 2017, the number of total registered vehicles in Kanpur was 113,202 (Figure 1). Out of which 96,723 (85.44% of total vehicles) registered vehicles were petrol vehicles and 12,381 (10.93% of total vehicles) registered vehicles were diesel vehicles. However, only 1,005 (0.88% of total vehicles) electric vehicles and 75 (0.066% of total vehicles) gasoline vehicles were in 2017.

In 2018, the number of total registered vehicles in Kanpur was 115,950 (Figure 1). Out of which 96,575 (83.29% of total vehicles) registered vehicles were petrol vehicles and 14,198 (12.24% of total vehicles) registered vehicles were

diesel vehicles. Only 5,082 (4.38% of total vehicles) electric vehicles and 95 (0.081% of total vehicles) gasoline vehicles were in 2018.

In 2019, the number of total registered vehicles in Kanpur was 107,709 (Figure 1). Out of which 90,538 (84.05% of total vehicles) registered vehicles were petrol vehicles and 12,334 (11.45% of total vehicles) registered vehicles were diesel vehicles. But, only 4,599 (4.27% of total vehicles) electric vehicles and 238 (0.22% of total vehicles) gasoline vehicles were in 2019.
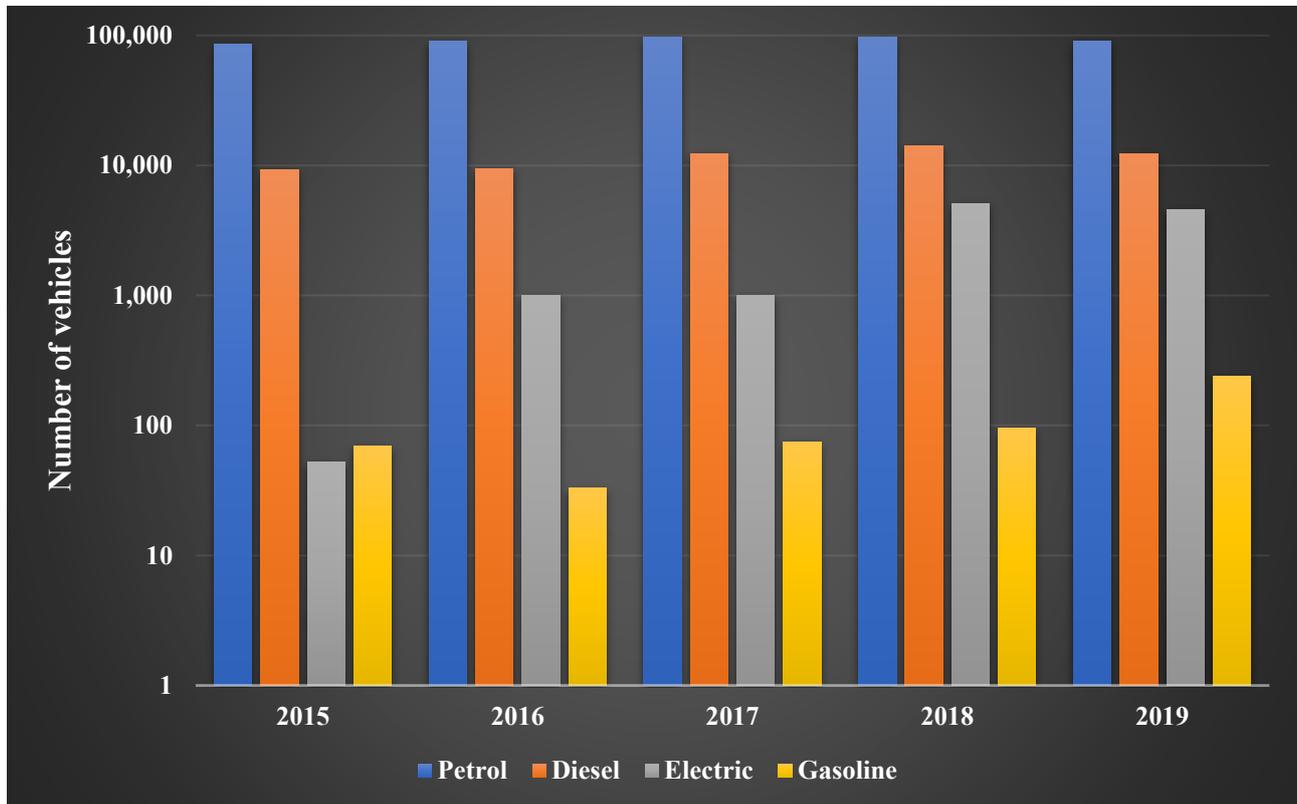
Figure 1. Different fuel vehicles in years of 2015, 2016, 2017, 2018, and 2019.

3.3. Analysis of concentration of pollutants

Figure 2 shows the carbon monoxide (CO) concentration from year of 2015 to year of 2019. The high concentration of CO is harmful for human beings. It reduces the amount of oxygen presents in haemoglobin and exposure over long period can cause risk of heart disease. It is possible to observe that:

- The monthly carbon monoxide (CO) concentration of year 2015, in which the value of CO is lower in July, *i.e.*, 1.60 mg/m^3, in all the months of year 2015 and in December highest value of CO, *i.e.*, 4.10 mg/m^3 followed by November, May, October, April, September, January, March, February, August, and June. The concentration of CO in December, November, May, October, April, and September are above the standard values set by CPCB. This showed that in winter season concentration of CO pollutants increased as compared to summer season;
- The monthly concentration of carbon monoxide (CO) of year 2016, in which the value of CO is lower in July, *i.e.*, 1.47 mg/m^3, in all of the months of the year 2016 and January is the highest value of CO, *i.e.*, 4.20 mg/m^3 followed by November, December, October, April, March, February, May, September, June, August, and July. The concentration of CO in December, November, January, October, February, May, June, August, and September is higher than the standard values;
- The monthly concentration of carbon monoxide (CO) of year 2017, in which the value of CO is lower in March, *i.e.*, 1.88 mg/m^3, in all of the months of the year 2017 and December is the highest value of CO, *i.e.*, 3.60 mg/m^3 followed by November, January, October, February, May, August, June, September, April, and July. The concentration of CO in December, November, January, October, February, May, June, August, and September is higher than the standard values set by CBCP;

- The monthly concentration of carbon monoxide (CO) of year 2018, in which the value of CO is lower in May, *i.e.*, 1.70 mg/m^3, in all of the months of the year 2018, and December is the highest value of CO, *i.e.*, 4.40 mg/m^3 followed by November, January, October, February, March, April, September, July, August, and June. The concentration of CO in all months, except May and June, is higher than the standard values set by CBCP;
- The monthly concentration of carbon monoxide (CO) of year 2019, in which the value of CO is lower in August, *i.e.*, 1.33 mg/m^3, in all of the months of the year 2019 and January is the highest value of CO, *i.e.*, 3.60 mg/m^3 followed by February, April, March, June, and July. The concentration of CO in January, February and April is higher than the standard values set by CBCP and concentration of CO is not available for September, October, November, and December because instrument which monitors the CO concentration is under maintenance.
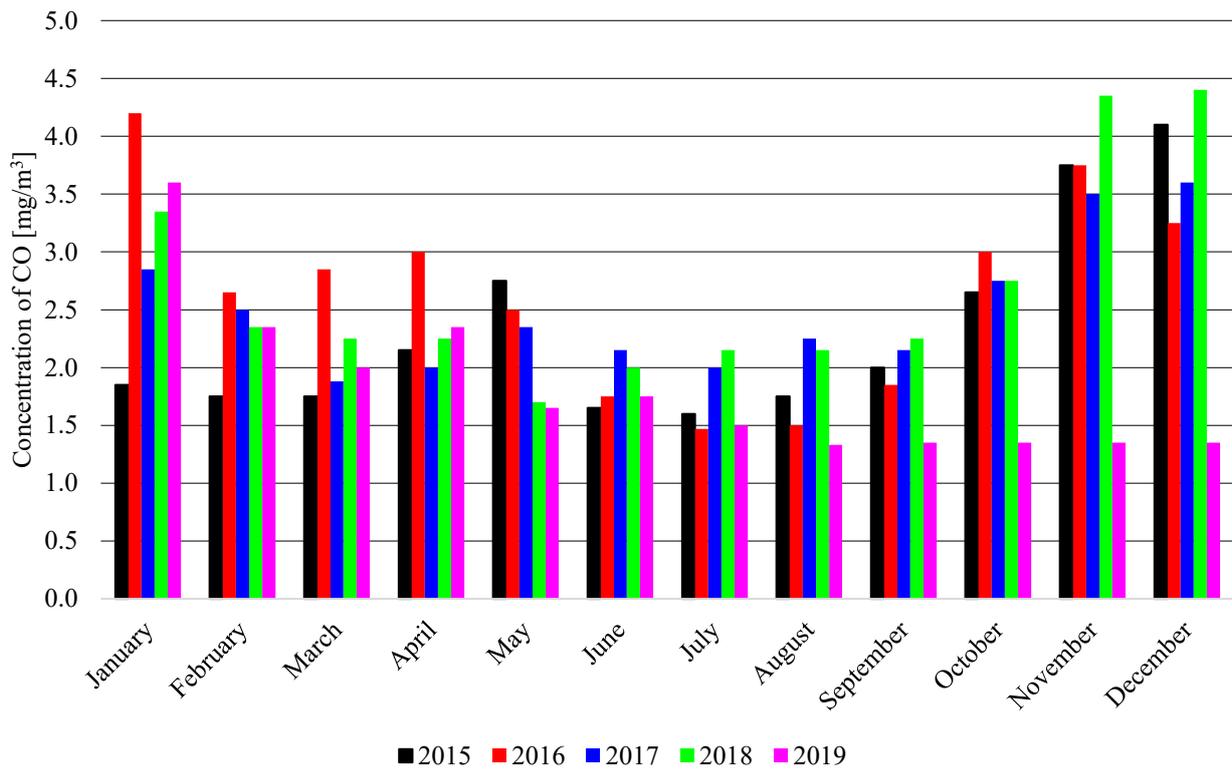

Figure 2. Concentration of CO – Years: From 2015 to 2019. Standard value: 2 mg/m^3.

Figure 3 shows the ozone (O$_3$) concentration from year of 2015 to year of 2019. It is possible to observe that:

- The monthly concentration of ozone (O$_3$) of year 2015, in which the value of O$_3$ in all months, is lower than the standard value. The lowest value is 11 μg/m^3 in August and highest value is 25 μg/m^3 in April;
- The monthly concentration of ozone (O$_3$) of year 2016, in which the value of O$_3$ in all months is lower than the standard value. The lowest value is 10.15 μg/m^3 in January and highest value is 31.23 μg/m^3 in June;
- The monthly concentration of ozone (O$_3$) of year 2017, in which the value of O$_3$ in all months is lower than the standard value. The lowest value is 9.04 μg/m^3 in August and highest value is 18.69 μg/m^3 in May;
- The monthly concentration of ozone (O$_3$) of year 2018, in which the value of O$_3$ in all months is lower than the standard value. The lowest value is 15.31 μg/m^3 in July and highest value is 45.77 μg/m^3 in December;
- The monthly concentration of ozone (O$_3$) of year 2019, in which the value of O$_3$ in all months is lower than the standard value. The lowest value is 20.44 μg/m^3 in September and highest value is 79.97 μg/m^3 in May.
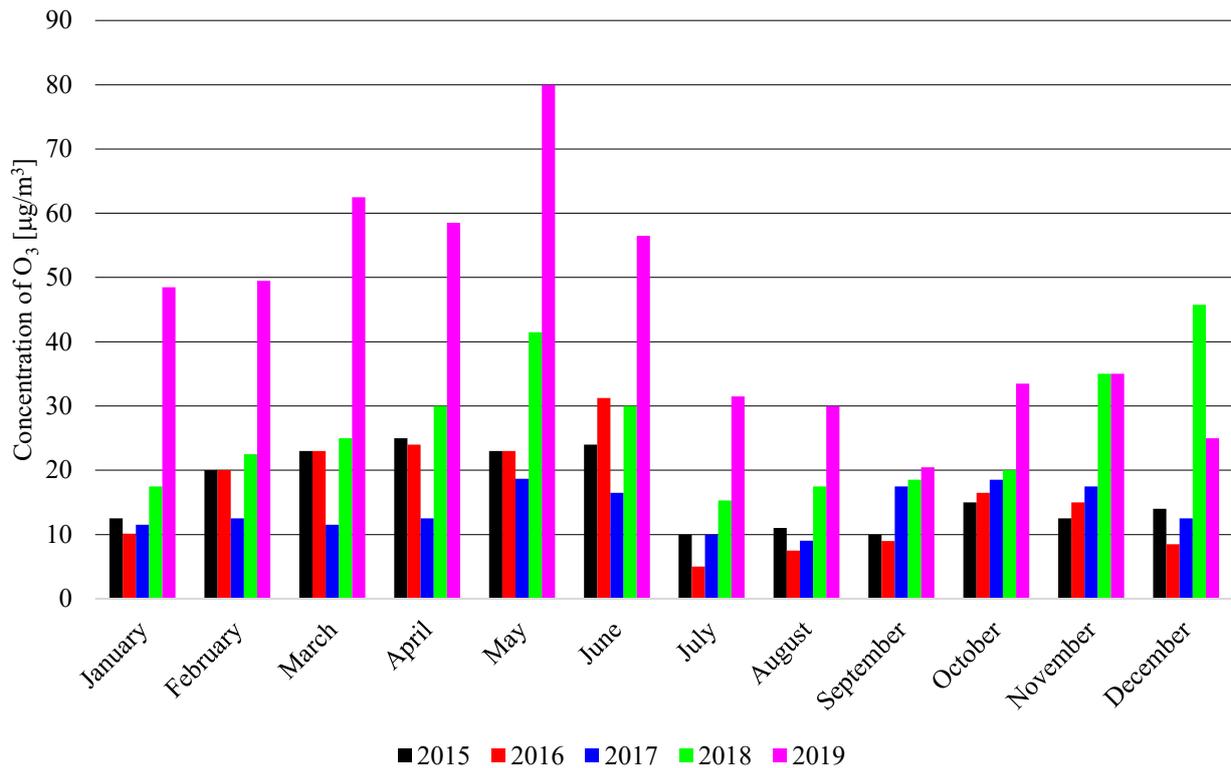
Figure 3. Concentration of O_3 – Years: From 2015 to 2019. Standard value: 100 $\mu g/m^3$.

Figure 4 shows the sulphur dioxide (SO_2) concentration from year of 2015 to year of 2019. It is possible to observe that:

- The monthly concentration of sulphur dioxide (SO_2) of year 2015, in which all of the values are lower than the standard values, set CPCB. In January is lowest value is 5.9 $\mu g/m^3$ and highest is 14.8 $\mu g/m^3$ in April;
- The monthly concentration of sulphur dioxide (SO_2) of year 2016, in which all of the values are lower than the standard values, set CPCB. In July is lowest value is 4.80 $\mu g/m^3$ and highest is 14.07 $\mu g/m^3$ in October;
- The monthly concentration of sulphur dioxide (SO_2) of year 2017, in which all of the values are lower than the standard values set CPCB. In July is lowest value is 5.50 $\mu g/m^3$ and highest is 11.47 $\mu g/m^3$ in October;
- The monthly concentration of sulphur dioxide (SO_2) of year 2018, in which all of the values are lower than the standard values set CPCB. In August is lowest value is 5.80 $\mu g/m^3$ and highest is 24.89 $\mu g/m^3$ in December;
- The monthly concentration of sulphur dioxide (SO_2) of year 2019, in which all of the values are lower than the standard values set CPCB. In September is lowest value is 6.33 $\mu g/m^3$ and highest is 33.52 $\mu g/m^3$ in November.
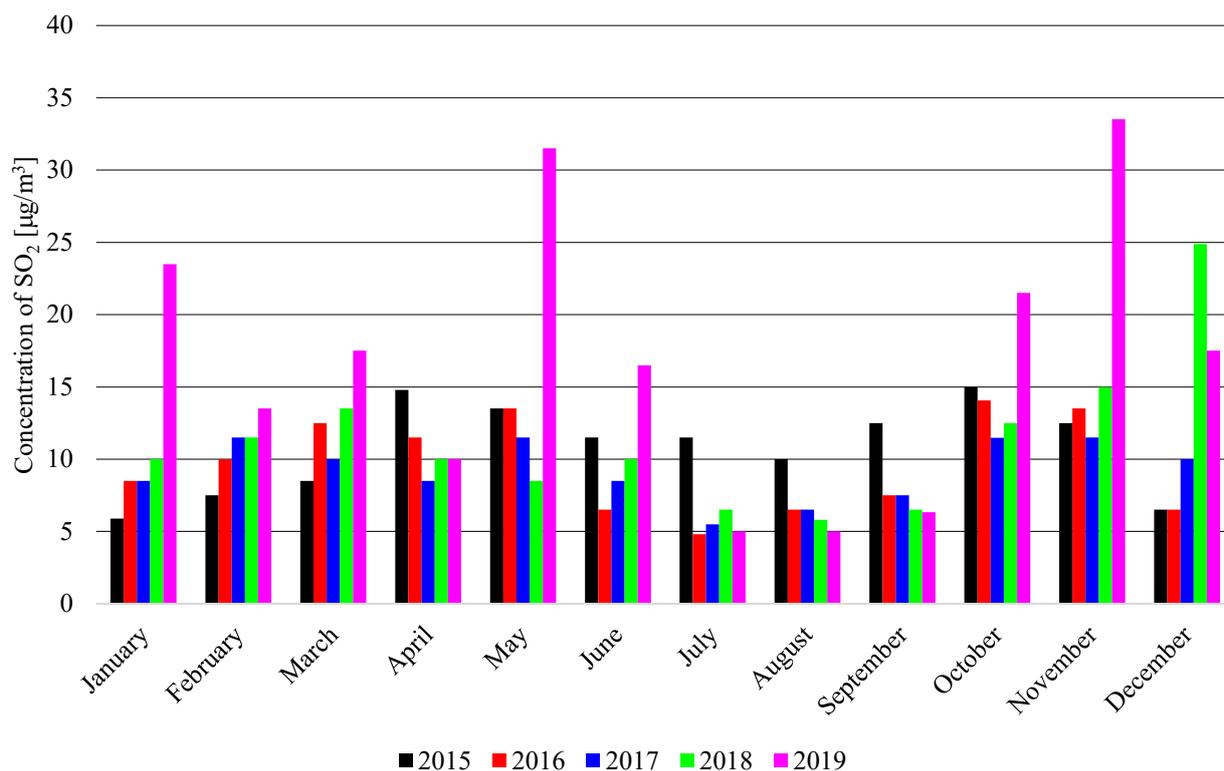
Figure 4. Concentration of SO_2 – Years: From 2015 to 2019. Standard value: 809 μg/m³.

Figure 5 shows the nitrogen dioxide (NO_2) concentration from year of 2015 to year of 2019. It is possible to observe that:

- The monthly concentration of nitrogen dioxide (NO_2) of year 2015, in which the value of NO_2 is lower in July, *i.e.*, 43.8 μg/m³, in all of the months of the year 2015 and December is highest value of NO_2, *i.e.*, 99.2 μg/m³ followed by November, October, May, September, April, June, February, January, March, and August. The concentration of NO_2 in December, November, October, and May is above the standard values set by CPCB. It can cause problem such as coughing, flu, colds etc.;
- The monthly concentration of nitrogen dioxide (NO_2) of year 2016, in which the value of NO_2 is lower in July, *i.e.*, 31.4 μg/m³, in all of the months of the year 2016 and January is highest value of NO_2, *i.e.*, 95.73 μg/m³ followed by February, April, November, March, December, October, May, September, August, and June. The concentration of NO_2 in January is above the standard values set by CPCB. It can cause problem such as coughing, flu, colds etc.;
- The monthly concentration of nitrogen dioxide (NO_2) of year 2017, in which the value of NO_2 is lower in August, *i.e.*, 42.47 μg/m³ in all of the months of the year 2017 and April is highest value of NO_2, *i.e.*, 161.66 μg/m³ followed by May, March, December, November, February, June, October, January, September, and July. The concentration of NO_2 in January, July, August, and September is above the standard values set by CPCB and October is on the mark of limit;
- The monthly concentration of nitrogen dioxide (NO_2) of year 2017, in which the value of NO_2 is lower in July, *i.e.*, 39.95 μg/m³, in all of the months of the year 2017 and November is highest value of NO_2, *i.e.*, 119.89 μg/m³ followed by, December, January, October, February, April, March, May, June, September, and August. The concentration of NO_2 in December, November, January, February, and October is above the standard values set by CPCB;
- The monthly concentration of nitrogen dioxide (NO_2) of year 2019, in which the value of NO_2 is lower in August, *i.e.*, 26.38 μg/m³, in all of the months of the year 2019 and January is highest value of NO_2, *i.e.*, 105.67 μg/m³ followed by November, February, May, October, March, April, December, June, July, and September. The concentration of NO_2 in January is above the standard values set by CPCB.
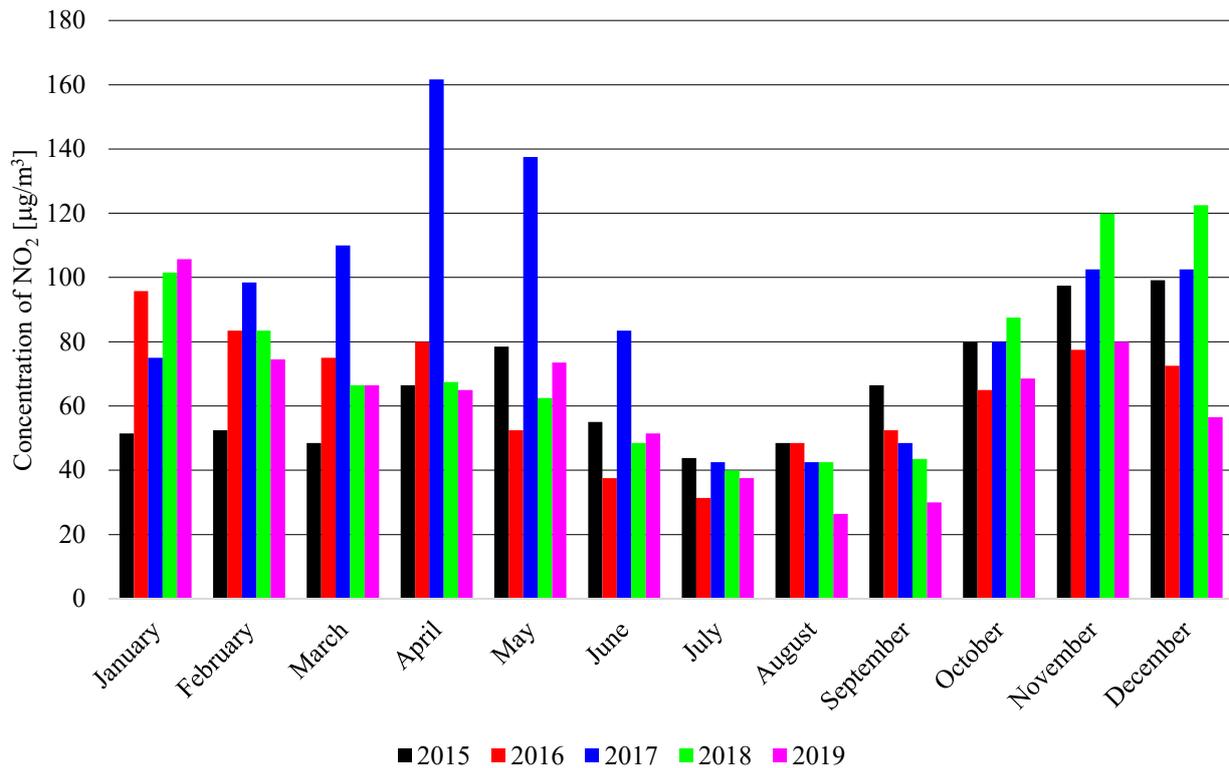
Figure 5. Concentration of NO_2 – Years: From 2015 to 2019. Standard value: 80 $\mu g/m^3$.

Figure 6 shows the Particulate Matter ($PM_{2.5}$) concentration from year of 2015 to year of 2019. It is possible to observe that:

- The monthly concentration of Particulate Matter ($PM_{2.5}$) of year 2015, in which the value of $PM_{2.5}$, is lower in July, *i.e.*, 33 $\mu g/m^3$, in all of the months of the year 2015 and December, highest value of $PM_{2.5}$, *i.e.*, 217 $\mu g/m^3$ followed by January, November, October, May, March, September, June, August, February, and April. The concentration of $PM_{2.5}$ of all months except July and August is above the standard values set by CPCB. The high concentration of $PM_{2.5}$ in November, December and January causes severe health problems such as asthma, respiratory problems, decreased lung functions;
- The monthly concentration of Particulate Matter ($PM_{2.5}$) of year 2016, in which the value of $PM_{2.5}$ is lower in July, *i.e.*, 35 $\mu g/m^3$, in all of the months of the year 2016 and November, is highest value of $PM_{2.5}$, *i.e.*, 226 $\mu g/m^3$ followed by December, January, February, October, March, April, May, September, June, and August. The concentration of $PM_{2.5}$ of all months except July and August is above the standard values set by CPCB;
- The monthly concentration of Particulate Matter ($PM_{2.5}$) of year 2017, in which the value of $PM_{2.5}$ is lower in July, *i.e.*, 31.04 $\mu g/m^3$, in all of the months of the year 2017 and December is highest value of $PM_{2.5}$, *i.e.*, 229.29 $\mu g/m^3$ followed by November, January, October, February, March, April, May, September, June, and August. The concentration of $PM_{2.5}$ of July, August, June and September is lower than the standard values set by CPCB;
- The monthly concentration of Particulate matter ($PM_{2.5}$) of year 2018, in which the value of $PM_{2.5}$ is lower in July, *i.e.*, 32.28 $\mu g/m^3$, in all of the months of the year 2018 and December is highest value of $PM_{2.5}$, *i.e.*, 220.13 $\mu g/m^3$ followed by January, November, October, February, May, March, April, June, September, and August. The concentration of $PM_{2.5}$ of December, November, October, January, February, March, and May is above the standard values set by CPCB;
- The monthly concentration of Particulate Matter ($PM_{2.5}$) of year 2019, in which the value of $PM_{2.5}$ is lower in August, *i.e.*, 20.21 $\mu g/m^3$, in all of the months of the year 2019 and January is highest value of $PM_{2.5}$, *i.e.*, 218.32 $\mu g/m^3$ followed by November, December, February October, March, May, April, June, September, and July. The concentration of $PM_{2.5}$ of January, November, December, October, February, March, April, and May is above the standard values set by CPCB.
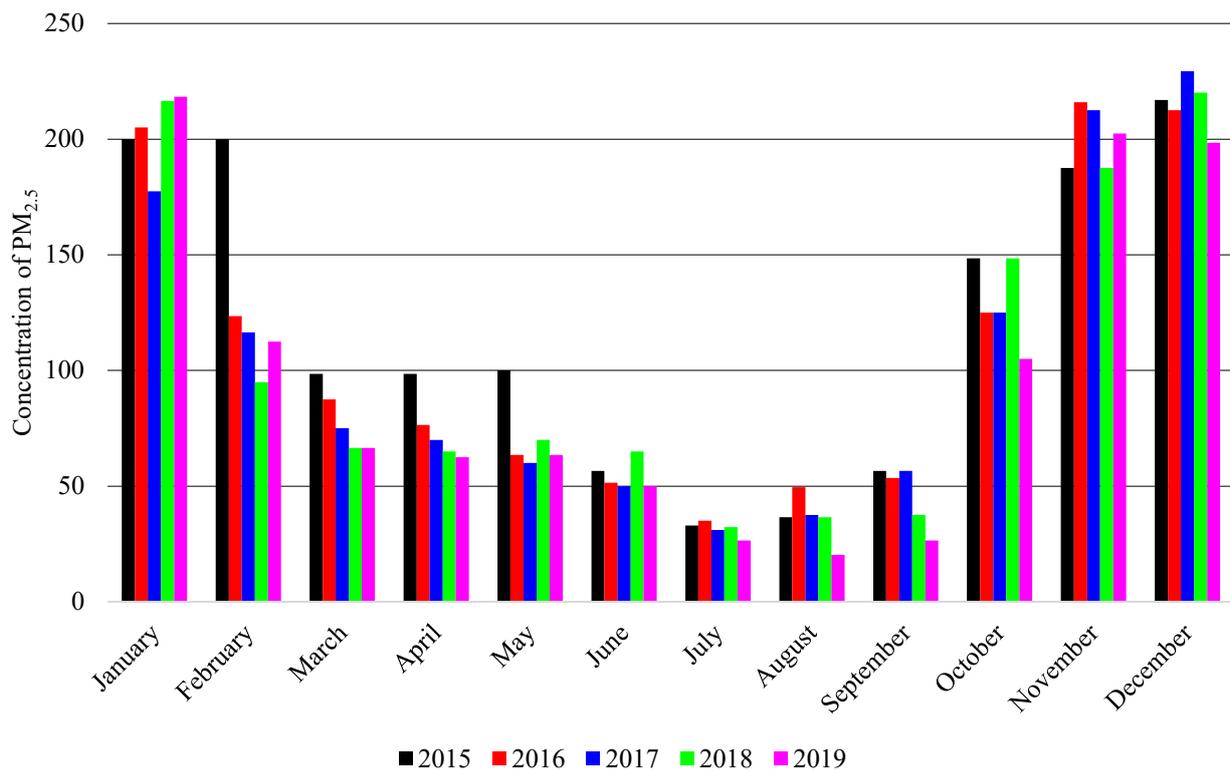
Figure 5. Concentration of PM$_{2.5}$ – Years: From 2015 to 2019. Standard value: 60 μg/m^3.

These high concentrations of particulate matter were most probably caused by vehicular exhausts because no other combustion sources were observed. In general, high concentration levels of particulate matter in winter were expected and can be allocated to more stable atmospheric conditions which may lead to bad dispersion of pollutants. Increased levels in winters can be attributed to foggy conditions which lead to settling of coarse particles. As a result, the concentration of the pollutants is found higher than the NAAQS (National Ambient Air Quality Standards). The pollutants are emitted into the atmosphere in high concentrations to increase the natural turbidity of the environment.

3.4. Human Health Problems

- Adverse effects of air pollution are of two types, one is acute effect and other is incessant impacts. Intense impacts show when show up quickly upon momentary introduction to air poisons in high focuses;
- The incessant impacts are very tough to demonstrate and are consequentially less obvious. The air pollution disaster in 1952, London case study, low temperature inversion of particulates (4,500 μg/m^3) and SO$_2$ causes approximately 4,000 deaths, thousands hospitalized for respiratory and heart diseases. Another case in London 1956 similar to 1952 case extended fog conditions.

3.5. Environmental Problems

- An increased level of pollutants may impair visibility, damage vegetation, a worldwide temperature alteration, acid rain and depletion of ozone layer;
- The concentration of CO emissions, mostly of burning fossil fuels, accounts for about 50% of global warming. The impacts of vehicle discharge contamination are far reaching, influencing the quality of air, building structures, water, and soil;
- Nitrous oxide adds to the consumption of the ozone layer, which protects the Earth from hurtful bright radiation from the sun. SO$_2$ and NO$_2$ blend in with water to make corrosive downpour, which harms yields, backwoods and other crops and structures;
- Oil and fuel spills from vehicles and trucks saturate the dirt close to expressways and disposed of fuel and particulates from vehicle emanations defile lakes, waterways and other wet paths.

4. CONCLUSIONS

Following are the major findings in present analysis of the impacts of vehicular emissions on air quality Kanpur City – India:

(1) Air pollution is caused by the following major pollutants, *i.e.*, Particulate Matter ($PM_{2.5}$), nitrogen dioxide (NO_2) and Carbon monoxide (CO);

(2) The gradual growth in registered diesel vehicles caused a higher concentration of major pollutants in comparison to registered electric vehicles;

(3) The average annual concentration of $PM_{2.5}$ is more than two times the standard value for all years;

(4) Average annual concentration of CO is higher than standard value for all years;

(5) Average annual concentration of NO_2 is higher than standard value whereas year 2017 concentration is more than two times;

(6) The average annual concentration of O_3 and SO_2 is lower than standard values for all years;

(7) For January 2020, the concentration of $PM_{2.5}$ of all traffic station is too higher than standard value.

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6. RESPONSIBILITY NOTICE

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