3

Assessment of Effect of Vehicular Emissions on Kanpur City Using Vulnerability Analysis

Varun Yadav*, Rajiv Ganguly

Department of Civil Engineering, Harcourt Butler Technical University, Kanpur, Uttar Pradesh, India.

*Corresponding Author Email: rganguly@hbtu.ac.in

Abstract

Emerging economies have improved due to rapid urbanization and industrialization, often causing environmental issues. Air Pollution is one of the major environmental problems experienced due to this phenomenon. The problem is further compounded due to increase in number of vehicles leading to increase in air pollutants concentrations. This study examines the effects of vehicular emissions on urban air quality and public health focusing on the impacts of the air pollution. In particular, a vulnerable analysis (VA) has been presented for Kanpur city. The VA was conducted for the study period of five months for the year 2021 wherein the data was collected from eight sites in Kanpur City. The pollutants considered for the study was PM_{10}, SO_2 and NO_2. It was observed from the study that the average concentrations of PM_{10} exceeded the NAAQS standards at all of the sites. However, the average concentrations SO_2 were found to be well within the prescribed standards. The average concentrations of NO_2 were exceeded at 5 of the 8 selected locations. The pollutant PM_{10} was primarily responsible for raising the vulnerability index of Kanpur city.

Keywords

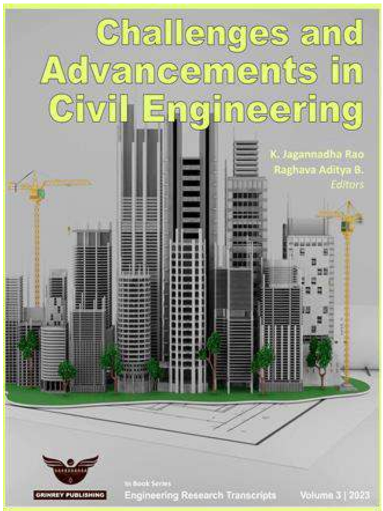
Kanpur; NO_2; PM_{10}; Vehicular Emissions; Vulnerability Index.

Received: 31 May 2023 | Accepted: 20 Sep 2023 | Online: 28 Sep 2023

Cite this article

Varun Yadav and Rajiv Ganguly (2023). Assessment of Effect of Vehicular Emissions on Kanpur City Using Vulnerability Analysis. *Engineering Research Transcripts*, 3, 25–31.

DOI: https://doi.org/10.55084/grinrey/ERT/978-81-964105-0-6_3



1. Introduction

India is one of the most developing countries in the world, outpacing the development of many developed countries. This rapid development of the country has been bought about by increased industrialization and urbanization processes [1]. However, such rapid pace of industrialization and urbanization, places a great strain on the existing natural resources. Due to such increased anthropogenic activities of industrial and vehicular emissions leads to significant deterioration of ambient air quality. With improved regulatory guidelines and interventions, there has been a significant reduction in air pollutants arising from industries; however with increased urbanization, a huge surge has been observed in use of personal motor vehicles [2]. This has led to substantial increase in air pollution due to emissions from vehicular exhausts. These pollutants emitted from vehicular emissions undergoing secondary reactions in the ambient air have significant effects on human health [3-5]. In this context, vehicles plying on the road following stricter emission norms could significantly reduce the pollutant concentrations. However, the increased number of vehicles on the road could offset the potential environmental benefits [6-7]. Hence, the potential effect of pollutants on the ambient air needs to be assessed. There exist different techniques for determination of exposure of air pollutants including implementation of large scale monitoring systems and Air Quality (AQ) modelling techniques for assessments. Both the methods have their own advantages and disadvantages, for example while monitoring data fails to represent spatial variation in data, the accuracy of the Air Quality (AQ) dispersion models are highly dependent on the quality of the input parameters [8]. The Vulnerability Index is another indices used to represent the effect of air pollutants on human health [9-10]. Reported studies conducted at megacity of Delhi showed that the vulnerability indexes (VI) were *low* at residential areas and *medium to high* on intersections and highways [10]. In similar manner, a study conducted in the traffic intersections of major areas in Kolkata scored *high* on the vulnerability index (VI) for all of the selected study intersections [9].

In the above context, the main objectives of the study were (a) to observe the variation in monitored concentrations of air pollutants from selected sites of Kanpur city for five months of 2021 and (b) to evaluate the VI at the selected sites covering the same study periods. The selected method of analysis has not been applied before at the study area and is another possible way of representing air quality scenario in Kanpur city.

2. Material and methods

2.1 Secondary Air Quality Data Collection

India has a wide network of air quality monitoring stations that are used for recording data. In Kanpur, the National Ambient Monitoring Program (NAMP) currently operates eight manual monitoring stations as shown in Table 1. This study compiles the data from the website of the Uttar Pradesh Pollution Control Board (UPPCB) on the five-month air quality trend for the three primary pollutants PM_{10}, SO_2, and NO_2. The major sources of air pollution in Kanpur city can be attributed to five different categories namely fugitive dust sources, domestic, transport (motor vehicles and railways), commercial, and industrial activities.

2.2 Vulnerability Analysis (VA)

Vulnerability analysis is carried out to determine the effects of air pollutants on human health at the selected study locations [9-10]. The information arising out of the VA is to help in planning and implementation of suitable mitigation measures for air pollution. A total vulnerable score (VST) can be obtained from the following expression:

$$\mathrm{VST} = \sum_{i=1}^{n} Xi\,Ti \qquad (1)$$

where *Xi* is the concentration of i^{th} air pollutant, *Ti* the toxicity weighing factors for i^{th} air pollutant, and *n* the number of air pollutants. The toxicity weighing factors in this analysis are from World Bank (1992) as given below in Table 2.

Table 1: List of monitoring stations in Kanpur city (http://www.uppcb.com/ambient_quality.htm)

Location	Monitoring station number	Type of station
Kidwai Nagar	S1	Residential
Jareeb Chowki	S2	Commercial
Panki Site 1	S3	Industrial
Shashtri Nagar	S4	Residential
Awas Vikas Kalyanpur	S5	Residential
Dada Nagar	S6	Residential
IIT Campus	S7	Residential
Ramadevi	S8	Commercial

Table 2: Pollutants and their relative weights [9-10]

Sr. No.	Pollutant	Relative weight
1.	NO_x	4.5
2.	PM_{10}	2.3
3.	SO_2	1.4

The Vulnerability index (VI) has been calculated based on VTr of threshold concentrations for residential and sensitive areas and is summarized in Table 3.

Table 3: Rating Scale for Vulnerability Index [9-10]

Sr. No.	Total vulnerability score (VST)	Vulnerability index (VI)
1	>4420	Very high
2	4420–3315	Medium high
3	3315–2210	High
4	2210–1661	Medium high
5	1661–1113	Medium
6	1113–517	Low
7	<517	Very Low

3. Results

3.1 Air Quality Data Analysis

Table 4 summarizes the average concentration of PM_{10} ($\mu g/m^3$) for the first five months of the year 2021. It was observed from Table 4 that sites S2, S6 and S8 experienced the maximum concentrations of PM_{10} due to large flow of diesel vehicles passing through these monitoring regions. Further, high concentrations of the pollutant were observed in the month of January at all of the sites during winter season. This may be attributed to inversion effects during winter season. The average concentration of the pollutants varying at the different monitoring sites over the five-month study period has been summarized in Fig. 1.

Table 4: Average concentrations of PM_{10} ($\mu g/m^3$) for the study period

STATION/MONTHS	JANUARY	FEBRUARY	MARCH	APRIL	MAY	AVERAGE
S1	250.53	223.46	163.18	151.2	115.41	180.75
S2	328.61	198.45	184.05	177.65	122.44	**202.24**
S3	308.24	169.37	202.87	177.42	136.83	198.94
S4	299.93	147.96	134.28	135.96	100.62	163.75
S5	290.28	176.21	146.7	122.63	94.32	166.02
S6	380	429.8	569.2	305	0	**336.8**
S7	175	182.1	126.1	175.8	0	131.8
S8	329.8	328	316	339.6	0	**262.68**

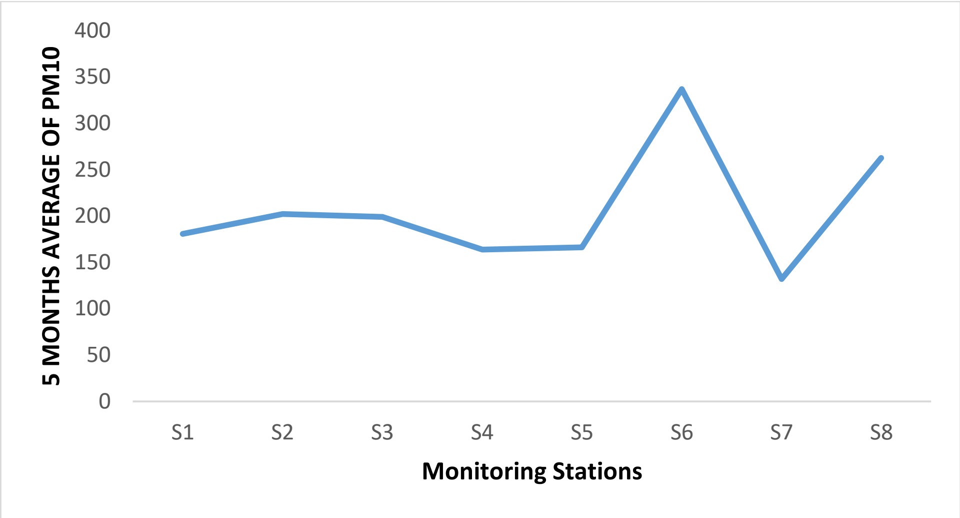


Fig. 1. Average concentrations of PM_{10} at the monitoring locations.

Table 5 presents the average concentrations of SO_2 for the study period in the year 2021. It was observed from Table 5 that the average concentrations SO_2 at all the monitoring stations were less than the prescribed NAAQS standards. This suggests that the SO_2 concentrations recorded at the monitoring sites may be attributed to existing background concentrations without the influence of any sufficient anthropogenic activities. The average concentration of the pollutant varying at the different monitoring sites over the five-month study period has been summarized in Fig. 2.

Table 5: Average concentrations of SO_2 ($\mu g/m^3$) for the study period

STATION/MONTHS	JANUARY	FEBRUARY	MARCH	APRIL	MAY	AVERAGE
S1	16.89	20.34	8.66	8.5	7.76	12.43
S2	14.62	15.58	9.84	9.08	7.68	11.36
S3	18.44	17.73	9.89	10.59	9.27	**13.184**
S4	16.61	12.71	11.49	9.28	7.53	11.524
S5	13.92	14.41	9.8	12.96	7.43	11.704
S6	5.4	2	2	4.4	0	2.76
S7	2	2	2	2	0	1.6
S8	2	4.2	4.1	2	0	2.46

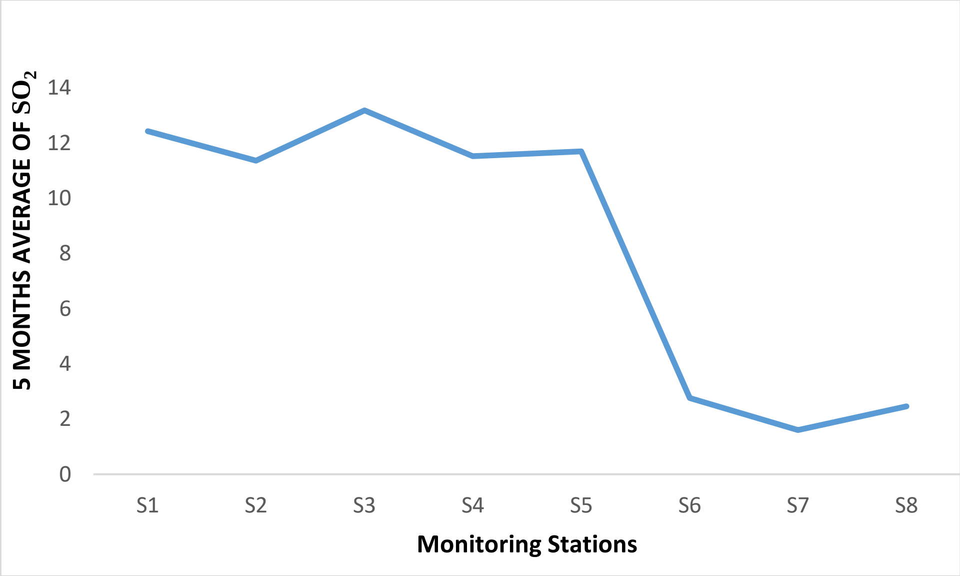


Fig. 2. Average concentrations of SO_2 at the monitoring locations

Table 6 presents the average concentrations of NO_2 for the study period in the year 2021. This study shows the number of locations exceeding the NAAQS standards (40 µg/m3) with respect to NO_2 which may be due to the Industrial and Commercial activities. The average concentration of the pollutant varying at the different monitoring sites over the five-month study period has been summarized in Fig. 3.

Table 6: Average concentrations of NO_2 (µg/m^3) for the study period

STATION/MONTHS	JANUARY	FEBRUARY	MARCH	APRIL	MAY	AVERAGE
S1	68.77	87.35	51.85	48.95	39.5	**59.284**
S2	71	78.91	55.04	55.16	40.65	**60.152**
S3	85.5	86.94	58.01	64.37	40.65	**67.094**
S4	76.13	72.52	50.21	35.53	35.99	**54.076**
S5	66.25	76.31	53.85	53	34.06	**56.694**
S6	39.3	30.5	32.1	43.2	0	29.02
S7	9.5	9.4	10.8	8.6	0	7.66
S8	30.6	39.9	39.9	35.5	0	29.18

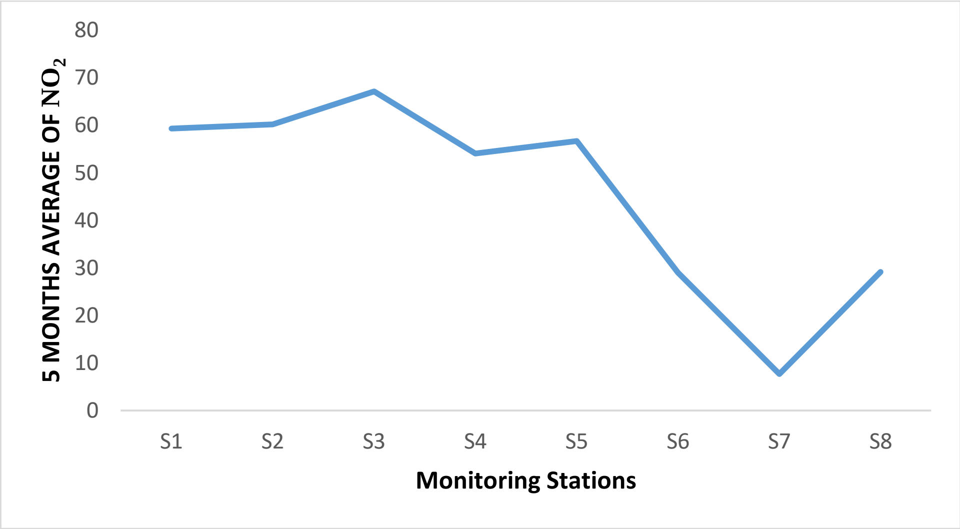


Fig. 3. Average concentrations of NO_2 at the monitoring locations

3.2 Vulnerability Analysis (VA)

From the Table 8, it can be analyzed that the Vulnerability index (VI) is rated low at almost all locations. The maximum VI is observed at Station 6 and minimum at Station 7. The VI was carried out on the basis of 3 monitored parameters in Kanpur city. However, studies conducted in Kolkata [9] and Delhi [10] was based on a total of 6 monitored parameters. The present study did not include the parameters like CO, Pb, etc. for Kanpur sites due to unavailability of monitoring data. To further study this effect, a revised table (Table 7) is presented for Delhi location wherein the VI was recalculated on the basis of the same parameters as observed for Kanpur city. It was observed from the revised VI that there was a change in grading by one scale at a minimum at the sites in Delhi. In some locations, the change in scale was observed to by two scales also. This implies that based on the results presented in Table 7, the results obtained for Kanpur city needs to be upscaled by at least one scale to represent the actual ambient air quality. This is presented in Table 8 as revised VI scale.

Table 7: Example Set of Data from the Case of Delhi

		CO	NO_2	SO 2	RSP M	SPM	Pb	VS_T	VI (Jain and Khare, 2008)	Revised VS_T [VS_T-(CO+Pb +RSPM)]	Revised VI
2003	ITO	124	743.2	14.6	632.5	330.4	3.14	**1848**	Mh	**1088.36**	Low
	Sirifort	88	281.4	5.8	391	276.5	1.95	**1045**	Low	**564.05**	Low
	Nizamuddin	95.5	194.9	17.1	299	283.5	1.61	**892**	Low	**495.89**	Very low
	Ashok Vihar	55.3	144.9	8.5	303.6	320.4	2.21	**835**	Low	**473.89**	Very low
	Janakpuri	68.4	198.9	16.4	315.1	261.9	1.36	**862**	Low	**477.14**	Very low
	Netaji Nagar	90.4	208.8	10.1	349.6	316.8	2.46	**978**	Low	**535.54**	Low
	Townhall	98.6	265.1	16.1	522.1	430.2	3.57	**1336**	Medium	**711.73**	Low
2004	Ito	103.4	836.1	15.5	572.7	289.3	4.16	**1821**	Mh	**1140.74**	Medium
	Sirifort	57.6	358.7	7.1	349.6	258.4	2.55	**1034**	Low	**624.25**	Low
	Nizamuddin	80.5	194.9	17.1	269.1	283.5	2.72	**848**	Low	**495.68**	Very low
	Ashok Vihar	49.6	144.9	8.5	223.1	320.4	2.89	**749**	Low	**473.41**	Very low
	Janakpuri	53.7	198.9	16.4	257.6	261.9	1.19	**790**	Low	**477.51**	Very low
	Netaji Nagar	78.2	208.8	10.1	292.1	316.8	3.31	**909**	Low	**535.39**	Low
	Townhall	85.4	265.1	16.1	455.4	430.2	3.65	**1256**	Medium	**711.55**	Low

Source: https://doi.org/10.1007/s10661-007-9681-7 [10]

Table 8: Total Vulnerability Score (VS_T)

STATIONS	Vulnerability Scores (VS)			VS_T	VI	Revised VI
	PM_{10}	SO_2	NO_2			
S1	180.756	12.43	59.284	699.92	Low	Medium
S2	202.24	11.36	60.152	751.74	Low	Medium
S3	198.946	13.184	67.094	777.96	Low	Medium
S4	163.75	11.524	54.076	636.10	Low	Medium
S5	166.028	11.704	56.694	653.37	Low	Medium
S6	336.8	2.76	29.02	909.09	Low	Medium
S7	131.8	1.6	7.66	339.85	Very Low	Low
S8	262.68	2.46	29.18	738.92	Low	Medium

4. Conclusion

This study reveals that air pollution is a significant problem in Kanpur city. The increased levels of air pollution at different monitoring stations in the city, which are primarily caused by vehicular sources, are a serious reason for concern. Further, high concentration of Particulate matter show plying of large number of diesel vehicles within the city premises make it unhealthy for the residents. This suggests that a comprehensive emission inventory for these pollutants needs to be prepared for developing successful air quality management strategy for the city. It is important to maintain a detailed record of all vehicles (particularly diesel vehicles) so that they can be phased out at the end of their life span thereby reducing pollutant emissions.

References

[1] EEA (European Environmental Agency). 2013. “Air quality in Europe 2013 report.” Accessed June 25, 2019. https://www.eea.europa.eu.

[2] Ganguly, R., Sharma, D., Kumar, P., & Gurjar, B. R. (2021). Dispersion modeling of air pollutants in a hilly city in India. *Journal of Hazardous, Toxic, and Radioactive Waste*, *25*(2), 04020073. https://doi.org/10.1061/(ASCE)HZ.2153-5515.0000574

[3] Montone, R. A., Camilli, M., Russo, M., Termite, C., La Vecchia, G., Iannaccone, G., ... & Niccoli, G. (2022). Air pollution and coronary plaque vulnerability and instability: an optical coherence tomography study. *Cardiovascular Imaging*, *15*(2), 325-342. https://doi.org/10.1016/j.jcmg.2021.09.008.

[4] Ganguly, R., and B. M. Broderick. 2008. “Performance evaluation and sensitivity analysis of the general finite line source model for CO concentrations for motorways in Ireland: A note.” Transp. Res. 13 (3): 198–205. https://doi.org/10.1016/j.trd.2008.01.006

[5] Guttikunda, S. K., and R. Goel. 2013. “Health impacts of particulate pollution in a megacity-Delhi, India.” Environ. Dev. 6: 8–20. https://doi.org/10.1016/j.envdev.2012.12.002

[6] Brusselaers, N., Macharis, C., & Mommens, K. (2023). The health impact of freight transport-related air pollution on vulnerable population groups. *Environmental Pollution*, *329*, 121555. https://doi.org/10.1016/j.envpol.2023.121555.

[7] Hama, S. M. L., P. Kumar, R. M. Harrison, W. J. Bloss, M. Khare, S.Mishra, A. Namdeo, R. Sokhi, P. Goodman, and C. Sharma. 2020.“Four-year assessment of ambient particulate matter and trace gasesin the Delhi-NCR region of India.” Sustainable Cities Soc. 54:102003. https://doi.org/10.1016/j.scs.2019.102003.

[8] Ganguly, R., S. Batterman, V. Isakov, M. Snyder, M. Breen, J. Burke,and W. Brakefield-Caldwell. 2015. “Effects of geocoding errors on traffic related air pollutant exposure and concentration estimates.” J. Exposure Sci. Environ. Epidemiol. 25 (5): 490–498. https://doi.org/10.1038/jes.2015 .1

[9] Ghose Mrinal, K., R. Paul, and S. K. Banerjee. "Assessment of the impacts of vehicular emissions on urban air quality and its management in Indian context: the case of Kolkata." *Environ Sci Policy* 7.4 (2004): 345-351. https://doi.org/10.1016/j.envsci.2004.05.004

[10] Jain, Suresh, and Mukesh Khare. "Urban air quality in mega cities: a case study of Delhi City using vulnerability analysis." Environmental monitoring and assessment 136.1 (2008): 257-265. https://doi.org/10.1007/s10661-007-9681-7