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Air Quality Status of Central and Southern Regions of Lucknow City, India

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Transport has become the lifeline of our social and industrial progress. In the pursuit of accelerated industrialization and urbanization, the mushrooming of vehicles started on the city roads and highways in the last two decades, chocking the major cities of our country. As of today, there are more than 300 million passenger cars, trucks and buses in the world and their number is increasing rapidly keeping pace with the industrial and social progress. It has been estimated that in all the big cities of our country, about 800 to 1000 tons of pollutants are being ejected into the atmosphere every day (Rangarajan et al. 1995). Surprisingly, in Asian countries, the highest growth in motor vehicle population has been reported since 1979 (UNEP 1987). In India alone, there are over 5 crore vehicles plying on the roads. Due to boom increase in automobile number in recent years on Indian roads, air pollution has reached to alarming proportions in major cities.

In a study carried out by Joshi et al. (1997), it was noted that there are 1,68,520 registered vehicles plying on the road of Indore city, whereas in Calcutta, the number of registered vehicles reported by Samanta et al. (1998) were 0.5 million. In Lucknow alone, the vehicle number has augmented many folds (presently over 6 lakhs) during past 10 years. This city has more population of two-wheelers than three and four-wheelers, which being largely 2-stroke emit more pollutants than the 4-wheelers. Because of their mobility and wide distribution, automobiles often cause more serious health hazards to city dwellers than those caused by stationary sources (Raaschou-Nielsen et al. 2002). The levels of auto-exhaust pollution are generally higher close to the traffic signals where the vehicles have to stop with engines running for a short period (Salagre and Throat 1995). To meet the transportation need of vast population of the U.P. state, a network of roads has now been widened around tourist places, hill resort and rural areas. Thus, environmental problem, which was earlier restricted to 10-20 metropolitan cities and a few pockets of high industrial activities, has now spread far and wide, both urban and rural areas. Consequently, the city dwellers have been gasping for fresh air. In metros, fresh air centers have been opened where people are put on O_2 supply for a short period for fresh lease of life. Due to continuous exposure to auto pollution, many are suffering from many diseases like bronchitis, blood pressure, heart diseases, lung cancer, etc.

Modern life has also given rise to a new form of pollution, called noise pollution. Noise is a physical pollutant and it differs from chemical, air and water pollution in that it disappears fast and thus does not remain in atmosphere for long. Crowded cities

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or towns, mechanized means of transport, new devices of recreation and entertainment are charging the atmosphere with their continuous noise (Sarangi et al. 1997). Noise is a part of our normal life and is deemed to be one of the most effective alarm systems in main's physical environment. It is continuously disturbing human peace and tranquility (Tiwari and Ali 1988). The so-called noise has now become a serious threat to the quality of our atmosphere.

To monitor the quality of air in different cities of India, a network of air quality monitoring stations has been established by National Environmental Engineering Research Institute (NEERI), Nagpur in cities where its zonal labs are present. However, there is no air monitoring station of NEERI in Lucknow city. Therefore, an air monitoring study of the central and southern areas of Lucknow city was taken up to know its present status of the air quality as a part of investigation on air quality status of the entire city area. The status of air quality of trans-Gomti area of the Lucknow city has already been published in the previous issue of Bulletin of Environmental Contamination and Toxicology (Verma et al. 2003).

The Lucknow city is situated between 26°52'N latitude and 80°56' E longitude and 120 m above sea level in the central plain of the Indian sub-continent. It is the capital of Uttar Pradesh, one of the largest and most populous states of India. The city is spread over an area of 79 km^2 and has a population of more than 1.7 million. It has distinct tropical climate with a marked monsoonal effect. The year is divided into three distinct seasons i.e. summer (March to June), rainy (July to October) and winter (November to February). The temperature ranges from 5°C in winter to 45°C in summer. The mean average relative humidity is 60% and rain fall 1006.8 mm. During last decade, the number of vehicles has increased tremendously to keep pace with public demand and hence contributed significantly to the air pollution problem of Lucknow city. In order to assess the air quality status of the city environment, air monitoring was carried out in the central and southern regions in the different seasons in the second phase of investigation.

In the central region, for the pollution monitoring, ten road intersections were selected as, National Botanical Garden, Jopling road intersection, Aishbagh crossing, Aminabad crossing, Medical college crossing, Charbagh crossing, Kaiserbagh crossing, Hussainganj crossing, Hazaratganj crossing, and Parivartan square and identified as C1, C2, C3, C4, C5, C6, C7, C8, C9 and C10, respectively. Likewise, Ashiyana intersection, Sadar crossing, Anand nagar crossing, Telibagh crossing, Cantt road intersection and Alambagh crossing were selected in southern region for air pollution monitoring. These sites were further designed as S1, S2, S3, S4, S5 and S6. These sites reflected lean to high traffic density areas in respective zones.

MATERIALS AND METHODS

A dichotomous high volume sampler (Envirotech make – APM460), especially designed to cut-off coarser particles (larger than 10 μ size) from air stream before filtering it on 0.5 micron pore size whatman GF/A filter paper, was used for monitoring of Suspended Paticulate Matter (SPM). For gaseous pollutants, an attachment device (make APM 411) with the high volume sampler was used to bubble air in glass impingers filled with different absorbing solutions for monitoring of gaseous pollutants like SO_2, NO_2 and O_3.

During air monitoring, air stream was drawn in the impingers during moderate traffic hour (11 AM – 1 PM) on the roadside from the respirable zone i.e. a height of 1.5 meter above the ground. The gaseous samples were collected by bubbling air in glass impingers separately filled with 25 ml of different absorbing solutions for various pollutants i.e. potassium tetra chloro mercurate (TCM) for SO_2, sodium hydroxide – sodium arsenite solution for NO_2 and potassium iodide solution for O_3 at the flow rate of 1.5 L/min. The samples were brought to the laboratory and analysed within reasonable time, following the standard methods i.e. West and Gaeke (1956) method for SO_2, Jacobs and Hochheiser (1958) for NO_2 and Byers and Saltzman (1958) for ozone. Noise level was determined, using a handy sound level meter (Lutron SL 4001) at the height of 1.5 meter above the ground level at each site.

Air quality index was calculated, following the method of Tiwari and Ali (1987) and on the basis of AQI, quality of ambient air in different localities was adjudged (Mudri 1990). The detailed methodology of AQI calculation has been earlier described by Verma et al. (2003).

A relationship between the concentration of different pollutants and traffic density was calculated statistically with the help of coefficient of correlation (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

In order to assess the air quality status of Lucknow city, monitoring of ambient air at different intersections in two selected regions viz. central and southern, for different gaseous (SO_2, NO_2 and O_3) and particulate pollutants (SPM), was carried out in different seasons and the data of ambient air quality in central region of Lucknow city have been presented in Table 1. When the concentration of gaseous and particulate pollutants (SO_2, NO_2, O_3 and SPM) was calculated and it was noted that in central region of Lucknow city, the level of pollutants followed a mixed trend; at site C9, the concentrations of SO_2 and SPM were recorded as 73.32 and 900.55 $\mu g/m^3$, respectively, which were found to be maximum; while at site C10, the NO_2 and O_3 levels were maximum with the concentrations of 38.37 and 23.32 $\mu g/m^3$, respectively. The minimum levels of SO_2 and SPM were observed at site C1 (7.11 and 155.07 $\mu g/m^3$ respectively) and of NO_2 at site C2 (i.e. 9.15 $\mu g/m^3$), whereas minimum concentration of O_3 was recorded at site C3 (4.07 $\mu g/m^3$). In the central region of Lucknow city, a positive correlation was observed between the traffic density of both diesel and petrol driven vehicles and concentration of different gaseous and particulate pollutants as reflected in Tables 1. Likewise, Table 2 reflects the ambient air quality levels in southern region of Lucknow city. Site S6, which is a commercial-cum-residential area of the southern region was highly polluted with the maximum traffic load. The concentrations of SO_2, NO_2 and SPM at this site were 34.15, 23.88 and 532.26 $\mu g/m^3$, respectively; while at minimum polluted site S1, concentrations of SO_2, NO_2 and SPM were measured as 17.60, 14.55 and 147.30 $\mu g/m^3$, respectively. However, O_3 concentration followed a non-specific pattern and ranged between a minimum of 3.97 $\mu g/m^3$ at site S3 to a maximum of 24.11 $\mu g/m^3$ at site S5. Like central region of the city, in the southern region also, the levels of all the automobile exhaust pollutants showed a positive correlation with the traffic density of both petrol and diesel driven vehicles as reflected in Table 2.

SPM levels at most sites were above the permissible limit (200 $\mu g/m^3$), while gaseous pollutants were always noted below the threshold limit (80 $\mu g/m^3$) as per national air quality standard shown in Table 3. This indicates that SPM level in the city environ is only of serious concern and so demands immediate attention for amelioration to save people from health hazards.

Although pollution monitoring data indicated a wide variation in their concentrations at different sites and regions, an over-all-view emerged that the central region of the Lucknow city was maximally polluted, while the Southern region was found to be least polluted. The concentration of primary pollutants showed a positive correlation with the traffic density at most sites, indicating that the traffic population is the main culprit for urban pollution. In earlier studies also, automobiles were correlated to air pollution along the roadsides (Rangarajan et al. 1995). Emission from major high ways, based on an hourly vehicular count, was estimated using vehicle-specific emission factors. The vehicular density, the type of vehicles plying on the road, the road conditions, diffusion of the pollutants as affected by the topography of high rise buildings on the either side etc. are some of the major factors, affecting pollutant ambient concentration on the roadside (Joshi 1998).

At some sites, it was also observed that although the vehicular traffic was low, but the pollution load was high. This was probably due to the poor road conditions and the high-rise buildings along the roadside, which impeded the dispersion of pollutants into the environment.

Air quality index (AQI) is an indexing system developed to assess the air quality in different localities. AQI is calculated by dividing the observed value of a particular pollutant with its standard values and then by taking geometric mean of these obtained values.

Assessment of air quality category of different localities of central region of Lucknow city, based on AQI, indicated that sites C1 and C2 were under clean category; C3, C4 and C5 sites were under fairly clean category; sites C6, C7 and C8 were kept under moderately polluted category and sites C9 and C10 were placed under polluted class (Table 4). The AQI value ranged between a minimum of 19.77 at site C1 to a maximum of 85.00 at site C10. At rest of the sites of central region, index value ranged between these two extremes. In order to find out a relationship between AQI and the traffic density at central region, a coefficient of correlation was calculated which showed a significant relationship (R^2=0.91).

Similarly, adjudgement of air quality category of different localities of the southern region was also done, which reflected that sites S1, S2 and S3 were under clean category; sites S4 and S5 were kept under fairly clean category, whereas, site S6 was under moderately polluted category. The index value in this region ranged between a minimum of 21.30 at site S1 and a maximum of 51.36 at site S6 (Table 5). In order to evaluate the relationship between the air quality index and vehicular traffic volume in southern region, a coefficient of correlation was calculated which also indicated a highly significant relationship (R^2=0.96).

In fact, AQI was developed by Tiwari and Ali (1987) to maintain consistency in reporting air quality within a city, state or through out the country. The AQI is

Table 1. Vehicular pollution levels of SPM, SO_2, NO_2 and O_3 at different sites of central region of Lucknow city and correlation of diesel and petrol driven vehicles with different air pollutants.

Sites	Traffic density (vehicles/hour)			SPM	SO_2	NO_2	O_3
	Diesel	Petrol	Total	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)
C1	NA	NA	NA	155.07	7.11	10.11	14.02
C2	437±20	67±6	505±26	284.34	9.63	9.15	14.20
C3	1483±47	54±5	1598±52	363.19	34.51	10.83	4.07
C4	720±26	338±14	1059±40	317.03	23.17	17.63	5.17
C5	995±26	433±30	1428±56	560.46	44.66	14.30	6.72
C6	730±24	767±39	1497±63	781.18	38.15	28.60	13.28
C7	3926±61	620±30	4547±91	735.82	57.12	19.02	15.29
C8	3298±81	778±28	4076±109	566.88	60.57	30.39	18.80
C9	4935±94	1228±38	6163±132	900.55	73.32	32.71	18.75
C10	7486±109	1462±67	8948±176	839.31	71.20	38.37	23.32

Vehicles	**SO_2**	**NO_2**	**O_3**	**SPM**
Petrol	0.863808^a	0.765751^a	0.787126^b	0.713404^b
Diesel	0.864461^a	0.958202^a	0.806169^a	0.889281^a
Total	0.881647^a	0.812396^a	0.804154^a	0.75638^b

NA = Not available

a=significant at 1% level, b=significant at 5% level

Table 2. Vehicular pollution levels of SPM, SO_2, NO_2 and O_3 at different sites of southern region of Lucknow city and correlation of diesel and petrol driven vehicles with different air pollutants.

Sites	Traffic density (vehicles/hour)			SPM	SO_2	NO_2	O_3
	Diesel	Petrol	Total	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)
S1	331±11	28±2	359±13	147.30	17.60	14.55	5.59
S2	286±19	37±3	323±22	156.18	20.23	16.77	5.81
S3	828±23	55±5	883±28	215.82	21.04	18.26	3.97
S4	1302±57	162±18	1464±75	346.88	26.57	20.31	12.35
S5	1515±63	187±14	1702±77	385.46	32.86	20.87	24.11
S6	1693±58	312±22	2005±80	532.26	34.15	23.88	16.41

Vehicles	**SO_2**	**NO_2**	**O_3**	**SPM**
Petrol	0.951889^a	0.949079^a	0.82149^a	0.959373^a
Diesel	0.947548^a	0.955176^a	0.763357^a	0.995334^a
Total	0.960161^a	0.958965^a	0.820077^a	0.974053^a

a=significant at 1% level

Table 3. National ambient air/noise quality standard.

Pollutant	Industrial area	Residential/commercial area	Sensitive area
SO_2 ($\mu g/m^3$)	120	80	30
NO_2 ($\mu g/m^3$)	120	80	30
SPM ($\mu g/m^3$)	500	200	100
O_3 ($\mu g/m^3$)	120	80	30
Noise (dB)	75	65	50

designed to make it easier to understand air quality from region to region. This system pays maximum emphasis on protecting the public health from air pollution.

Hence, this tool is used to inform the residents of air pollution levels in a particular location and about its associated health effects and to advise precautionary steps to be taken when air pollution reaches alarming levels. Based on the principle that 'prevention is better than the cure', it is possible to avoid pollution-related health hazards with the help of AQI data.

The AQI scale ranges from 0 to 125. The most important number of this scale is 50. An AQI value in excess of 50 means that the ambient air concentration is reaching an alarming level in a locality. AQI levels above 100 may trigger immediate remedial actions by state and local officials to bring down pollution levels to save life. This could include health advisories to advice citizens or susceptible individuals to limit their certain activities.

The most irritating in the city area is the noise pollution. A persistently high decibel intolerable noise created by the heavy vehicles on the highways and by industrial operations with in the city may impair the hearing permanently and also lead to tension, blood pressure and even heart attack. Measurement of noise level at selected sites in different zones during three seasons was carried out and data are presented in Figures 1 A&B.

The noise levels at different sites in central region have been presented in Figure 1A. It was observed that the noise level varied between a lowest of 51.0 dB at site C1 and a highest of 106.0 dB at site C9 with a traffic load of 6163 vehicles/h. When noise levels in the southern region were measured, it was found that it varied between a minimum of 59.9 dB at site S1 with a traffic load of 359 vehicles/h and a maximum of 94.1 dB at site S6 with traffic volume of 205 vehicles/h (Figure 1B).

It is a matter of serious concern that the noise levels at all the sites except C1 was much higher than the permissible limit of 65 dB.

To evaluate the role of traffic density in regulation of noise level in a particular region, coefficient of correlation was calculated between the total traffic density and the noise level during different seasons and a positive correlation was found between these two. In the central region, the correlation value was R^2= 0.76, whereas in the southern region, a correlation value of R^2= 0.76 was observed.

Vehicular noise arises from various sources like horn, tyre, engine, exhaust, aerodynamic noise or vibration noise due to road surface. Because of heavy and heterogeneous type of traffic on the Indian roads, horns are used very liberally in contrast to the other parts of world, which contributes significantly to noise pollution (Mohan et al. 2000). According to Prakash (2000), in most vehicles, exhaust noise constitutes the predominant source of noise at normal operation below 55 km/h. Although tyre noise is much less of a problem in cars than in trucks, it is the dominant noise source at speed above 80 km/h. While not as noisy as truck, the total contribution of cars to the noise environment is significant because of their large numbers. Diesel trucks are 8 to 10 dB noisier than gasoline-powered ones. In trucks, at speed above 80 km/h, tyre noise often becomes the dominant noise source.

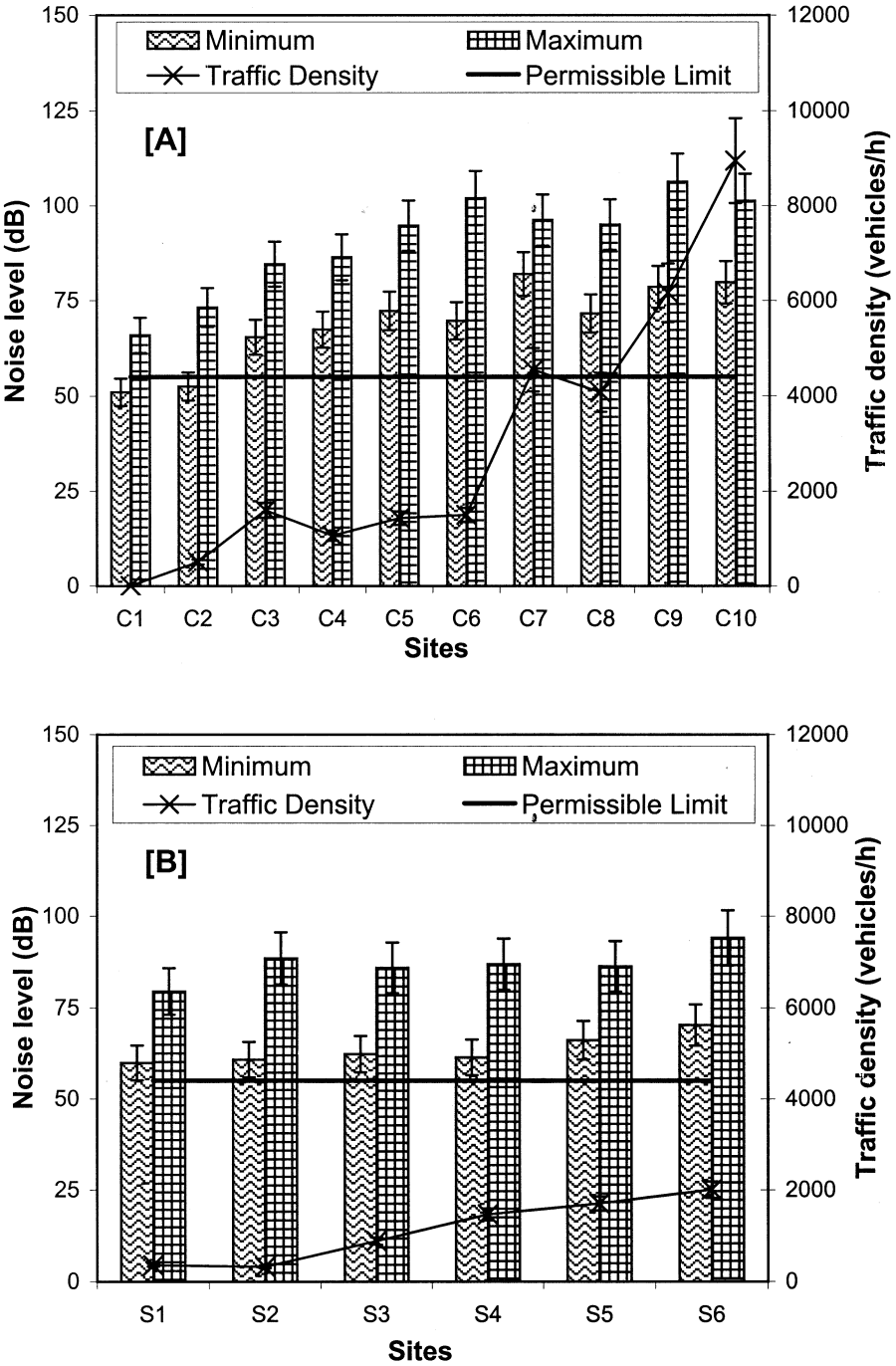

Figure 1. Noise levels in different localities of Central [A] and Southern [B] regions of Lucknow city

Table 4. Category of air quality in central region of Lucknow city estimated on the basis of air quality index.

Sites	Quality rating				Air quality index	Air quality category
	SPM	SO_2	NO_2	O_3		
C1	78	9	13	18	19.77	Clean
C2	142	12	11	18	24.29	Clean
C3	182	43	14	5	27.10	Fairly clean
C4	159	29	22	6	28.44	Fairly clean
C5	280	56	18	8	39.15	Fairly clean
C6	390	48	36	17	57.66	Moderately polluted
C7	368	71	24	19	58.78	Moderately polluted
C8	283	76	38	24	66.16	Moderately polluted
C9	450	92	41	23	79.30	Polluted
C10	420	89	48	29	85.00	Polluted

AQI≤10, very clean; 10-25, clean; 25-50, fairly clean; 50-75, moderately polluted; 75-100, polluted; 100-125 heavily polluted and ≥125, severely polluted (Mudri 1999).

Table 5. Category of air quality in southern region of Lucknow city estimated on the basis of air quality index.

Sites	Quality rating				Air quality index	Air quality category
	SPM	SO_2	NO_2	O_3		
S1	74	22	18	7	21.30	Clean
S2	78	25	21	7	23.42	Clean
S3	108	26	23	5	23.81	Clean
S4	173	33	25	15	38.77	Fairly clean
S5	193	41	26	30	49.95	Fairly clean
S6	266	43	30	21	51.36	Moderately polluted

AQI≤10, very clean; 10-25, clean; 25-50, fairly clean; 50-75, moderately polluted; 75-100, polluted; 100-125 heavily polluted and ≥125, severely polluted (Mudri 1999).

On the basis of air quality index, the sites C6 (Charbagh crossing), C7 (Kaiserbagh crossing) and C8 (Hussainganj crossing) of the Central region and S6 (Alambagh crossing) of the southern region of Lucknow city are moderately polluted, while C9 (Hazaratganj crossing) and C10 (Parivartan square) of central region are highly polluted mainly with auto-generated SPM. However, the pollution level in other localities has not reached to alarming proportions. Further, the average noise level was recorded much higher than the threshold limit (65 dB for day time) in all the localities of central and southern regions, except national Botanical Garden, where noise level was monitored in daytime. Hence, remedial measures like expansion of roads, traffic regulation, proper tuning of vehicles, use of catalytic converters, deroading of out-dated vehicles and raising of avenue trees, banning of horn or hooter blows etc. have to be taken by the concerned officials to ameliorate the pollution levels to save the city dwellers from morbidity and mortality.

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