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Air Quality of the Trans-Gomti Area of Lucknow City, India

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Automobiles contribute significantly to the air pollution problem in urban areas. Their emissions account for approximately 60% of total pollution in developed countries and about 80% in the developing countries (Pundir and Das, 1985). About the vehicular pollution, the expert committee's report of WHO (1969) had specially mentioned the case of India and observed "while the vehicular population in India may be small as compared to those in more advanced western nations, the environmental pollution problem is quite formidable due to a predominance of old and poorly maintained vehicles, narrow roads, poor technology and high weight and H.P. ratio". Due to a boom increase in automobile number in recent years on Indian roads, the air pollution has reached to alarming proportions in major cities. In Lucknow city alone, the vehicle number has augmented many folds (presently over 0.4 million) during past 10 years against a total population of 4 million of vehicles. This city has more population of two wheelers (about 70%) than 3- and 4-wheelers which being largely 2-stroke, emit more pollutants than the 4-wheelers. Also because of their mobility and wide distribution, automobiles often cause more serious health hazards to city dwellers than those caused by stationary sources. To meet the transportation needs of vast population, a network of roads has now even been widened to tourist places, hill resorts 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.

There are mainly two types of pollutants emitted by motor vehicles viz. primary and secondary (Dochinger, 1988). Primary pollutants are those whose concentrations are dependent on number of vehicle, traffic density, quality and driving speed of vehicles and climatic factors of urban areas (Ghauri et al., 1994; Joshi, 1998; Samanta et al., 1998). On the other hand, secondary pollutants are formed due to photochemical reactions among the primary pollutants in the lower layer of urban environment (Freedman, 1995; Chan and Nien, 1996; Derwent et al., 1996; Wennberg et al., 1998; Kley et al., 1999; Postiglione et al., 2000). Most common air pollutants in urban environment with high level of vehicular traffic are hydrocarbons, carbon monoxide, respirable suspended particulate matter (RSPM), sulphur dioxide, nitrogen dioxide and ozone (D`Amato, 1999). Out of which, RSPM is one of the greatest concerns as it contributes 50% to total urban air pollution load (Fuller, 1974) and also causes respiratory disorders in human beings.

Motor vehicles are also the main source of noise pollution. Unfortunately, till very recently, in India, sound pollution has not been given proper attention (Goodfriend and Kesseler, 1973). But now, it is gaining more importance due to its harmful effect as a silent killer (Bhutada, 1993; Dhembare et al., 1999; Mohan et al., 2000). A survey conducted in Indian metropolitan cities has shown that the average noise level in Delhi,

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Mumbai and Calcutta is as high as 90 dB (decibel). Inhabitants of the major cities, subjected continuously to this level of noise, run the risk of losing their working ability. People, residing in central area of large and overcrowded cities have to go to sleep only after midnight when traffic on the roads becomes thin (Prakash, 2000). Main sources of vehicular noise are – horn, hooter, tyre, engine, exhaust and aerodynamic noise or vibration noise (on road surface). Out of these, hooter, horn and exhaust noise levels are of very high decibel. Because of heavy and other heterogeneous types of traffic on the Indian roads, horns are used very frequently and liberally in contrast to other parts of world, which is very irritating, and a major cause for road accidents. Noise causes auditory (Bhutada, 1993) and physiological effects on human beings. It may lead to permanent hearing loss, in case we are exposed to higher decibel for longer time.

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 (NEERI, 1980, 1983, 1988). However, there is no air monitoring station of NEERI in Lucknow city. Therefore, an air monitoring study of the trans-Gomti area 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.

Lucknow 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 subcontinent. It is the capital of Uttar Pradesh, one of the largest states of India. The city is spread over an area of 79 km^2 and has a population of more than 0.17 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 few years, number of two wheelers (presently approximately 0.4 million), four wheelers (presently approximately 50000) and 3 wheelers (presently approximately 20000) has increased tremendously and 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 trans-Gomti area in the different seasons in the first phase. Air monitoring will be done in remaining two zones viz. Central and Southern, in the subsequent years.

Trans-Gomti region of Lucknow city is newly developed as residential cum commercial area, wherein 12 sites were identified and designated as HAL Crossing (S1), Picup Bhawan (S2), Badshah Nagar (S3), IT Crossing (S4), Chhanilal Crossing (S5), Purania Crossing (S6), Kukrail Picnic Spot (S7), Engineering College Crossing (S8), Vikas Nagar (S9), Gomti Nagar Police Station (S10), Sitapur Road (S11) and Indira Nagar (S12), for air monitoring of SO_2, NO_2, O_3, RSPM and noise levels as shown in Figure 1. These sites reflect lean to high traffic density areas.

MATERIALS AND METHODS

A dichotomous respirable dust 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 Respirable Suspended Paticulate Matter (RSPM). For gaseous pollutants, an attachment device (make APM 411) with the high volume sampler was used to bubble air in glass impingers filled with 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

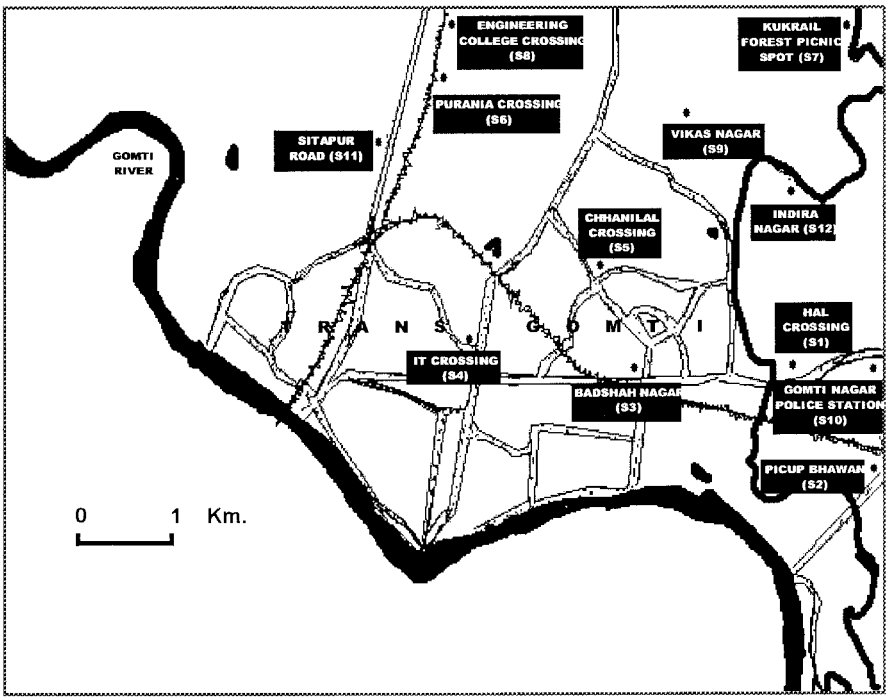

Figure 1. Location of sampling sites in trans-Gomti area of Lucknow.

height of 1.5 meter above the ground. The gaseous samples were collected by bubbling air in glass impingers filled with 25 ml 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 hand 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). Firstly, air quality rating of each parameter used for monitoring is calculated separately by the formula as under:

$$q = 100 \times V/V_s$$

Where q stands for quality rating, V stands for observed value of the parameter and V_s for standard value recommended for that parameter.

If total `n` no of parameters were considered for air monitoring, geometric mean of these `n` number of quality ratings is calculated in the following way:

$$g = \text{anti}^{-}\log \frac{(\log_a + \log_b + \log_c + \text{------} \log_x)}{n}$$

where g = geometric mean, a, b, c, d, x = different values of quality rating, n = numbers of values of quality rating, log = logarithm.

Table 1. Air quality categories based on air quality index (AQI)

Category	AQI of ambient air	Description of ambient air quality
I	Below 10	Very clean
II	Between 10-25	Clean
III	Between 25-50	Fairly clean
IV	Between 50-75	Moderately polluted
V	Between 75-100	Polluted
VI	Between 100-125	Heavily polluted
VII	Above 125	Severely polluted

The geometric mean is considered as Air Quality Index (AQI) and on the basis of AQI, quality of ambient air in different localities was adjudged, as described in the Table 1 (Mudri, 1999).

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). Its formula is:

$$r = \Sigma xy / \sqrt{\Sigma x^2 \times \Sigma y^2}$$

where x and y = deviation from the actual mean, Σxy = sum of product of x-deviations and y-deviations, Σx^2 = sum of the squared deviations of x-scores from mean, Σy^2 = sum of the squared deviations of y scores from mean.

RESULTS AND DISCUSSION

Air monitoring data contained in Table 2 indicate a wide variation in the levels of gaseous pollutants in different localities of Lucknow city. At IT Crossing (S4), the air was contaminated maximum with both gaseous and particulate pollutants, while at Kukrail Picnic Spot (S7), the air was least polluted. At other sites, the pollution levels varied between these two extremes, depending upon the traffic density. It was observed that the RSPM level was higher than the permissible limit of 140 $\mu g/m^3$ at all the sites and ranged between 150-995 $\mu g/m^3$ (Table 2 and 3). The highest RSPM level (995 $\mu g/m^3$) was recorded at IT Crossing (S4) with maximum traffic density (6723 vehicles/h) and least (150 $\mu g/m^3$) at Kukrail Picnic Spot (S7) with a minimum traffic load (52 vehicles/h). It is obvious that RSPM level has come down significantly with respect to earlier estimated RSPM level in the city environment with the government's decision to ban Vikram tempos (diesel driven) on certain main routes. In an earlier study carried out by Singh et al. (1995), the RSPM level at HAL crossing, for examples was recorded 974 $\mu g/m^3$, which has now decreased to 438.8 $\mu g/m^3$ with ban on tempos.

As far as the atmospheric concentrations of primary gaseous pollutants were concerned, SO_2 and NO_2 levels were also recorded maximum i.e. 41.92 and 38.24 $\mu g/m^3$, respectively, at IT Crossing and minimum (SO_2, ND, NO_2, 4.29 $\mu g/m^3$) at Kukrail Picnic Spot. The levels of all the automobile pollutants showed a trend of positive correlation with the traffic density of petrol and diesel driven vehicles, as evident from the correlation Table 4. Since these pollutants are discharged at the ground level, their accumulation occurs in the lower atmosphere. However, O_3 being a secondary pollutant did not show any linear correlation with the traffic density. As its formation takes place due to the photochemical reactions of NO_2 and HC, its concentration does not build up in the immediate vicinity of the source. Hence, except O_3, maximum levels of RSPM, SO_2 and NO_2 were recorded at IT Crossing (S4) due to high traffic flow including gasoline and diesel driven vehicles. It was also observed that the levels of RSPM and SO_2 came down significantly with respect to earlier estimates as the tempos, which were the major source

Table 2. Vehicular pollution levels of RSPM, SO_2, NO_2 and O_3 at different sites of trans-Gomti area in Lucknow city

Sites	Traffic density (vehicles/hour)			RSPM	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	1437±59	390±31	1827±90	438.80	26.32	25.08	4.87
S2	2289±72	363±22	2652±94	427.70	38.48	21.66	27.56
S3	2657±60	321±30	2978±90	458.00	34.52	16.57	4.87
S4	4552±190	2171±89	6723±279	995.30	41.92	38.24	13.90
S5	1639±64	160±31	1799±95	444.40	26.50	14.03	4.39
S6	1730±62	166±27	1896±89	643.50	26.39	23.50	18.78
S7	42±6	10±1	52±7	150.00	Nd	4.29	20.00
S8	497±33	321±37	818±70	671.29	20.00	26.73	14.14
S9	546±31	177±19	723±50	495.37	26.51	18.50	22.93
S10	656±44	97±11	753±55	287.03	24.58	16.66	9.79
S11	1369±63	703±46	2072±109	550.92	35.46	26.13	23.68
S12	917±50	440±33	1357±83	430.54	34.42	29.38	20.75

Nd = Not detected

Table 3. National Ambient Quality Standard

Pollutant	Annual average concentration in ambient air ($\mu g/m^3$)		
	Industrial area	Residential area	Sensitive area
SO_2	80	60	15
NO_2	80	60	15
RSPM	360	140	70
O_3	80	60	18

Table 4. Correlation of diesel and petrol driven vehicles with different air pollutants

Category	AQI of ambient air	Description of ambient air quality
RSPM	0.80^a	0.70^a
SO_2	0.58^b	0.73^a
NO_2	0.76^a	0.57^b
O_3	0.01^{NS}	-0.18^{NS}

a = significant at 1% level, b = significant at 5% level NS = not significant

for the both the pollutants were banned on the main routes of the city. However, at certain site where the vehicle number may not be as high as at the other site, but the ambient concentrations of gaseous pollutants might build up due to restricted open space because of high-rise buildings on either side of the roads.

Table 5 shows air quality index and air quality category of different monitored sites (S1-S12) of trans-Gomti region of Lucknow city. As reflected in the Table 5, the site S7 (Kukrail Picnic Spot), where traffic density is the lowest and which is under thick forest cover, is of 'very clean' category, sites S1, S3, S5, S8, S9, S10 come under 'fairly clean category, while sites S2, S4, S6, S11, S12 are 'moderately polluted'. Among these 'moderately polluted' sites, IT Crossing (S4) shows the greatest value of AQI i.e. 68.42 which is near to the value of 'polluted' category (75-100), and hence requires a proper attention.

The most irritating in the city area is the noise pollution. A persistently high decibel may impair the hearing permanently and also lead to tension, blood pressure and even heart attack, as the heavy vehicles used to make intolerable noise on the highways.

Table 5. Category of air quality in trans-Gomti region of Lucknow city estimated on the basis of Air Quality Index.

Sites	Quality rating				Air quality index	Air quality category
	RSPM	SO_2	NO_2	O_3		
S1	219	33	31	6	33.52	Fairly clean
S2	214	48	27	34	55.59	Moderately polluted
S3	229	43	21	6	33.51	Fairly clean
S4	498	52	48	17	68.42	Moderately polluted
S5	222	33	18	5	28.52	Fairly clean
S6	322	33	29	23	51.89	Moderately polluted
S7	75	Nd	5	25	9.89	Very clean
S8	336	25	33	18	47.35	Fairly clean
S9	248	33	23	29	48.46	Fairly clean
S10	144	31	21	12	32.74	Fairly clean
S11	275	44	33	30	58.25	Moderately polluted
S12	215	43	37	26	58.26	Moderately polluted

Nd = Not detected

Figure 2 shows that the maximum noise level (105 dB) was recorded at Sitapur Road (S12), where the frequency of trucks and buses is very high. Not only at Sitapur Road, but also at all the other sites except Kukrail Picnic Spot (S7), the noise level was much higher than the permissible limit of 50 dB as reflected in the Table 6.

On comparing the average noise level of different sites with the data in Table 7 containing permissible duration of exposure of different sound levels (h/day); it is found that residents of Engineering College Crossing (S8) and Sitapur Road (S11) areas are the main sufferers of sound pollution because they are exposed to invariable high traffic noise for longer duration which is much more than the permissible duration of exposure.

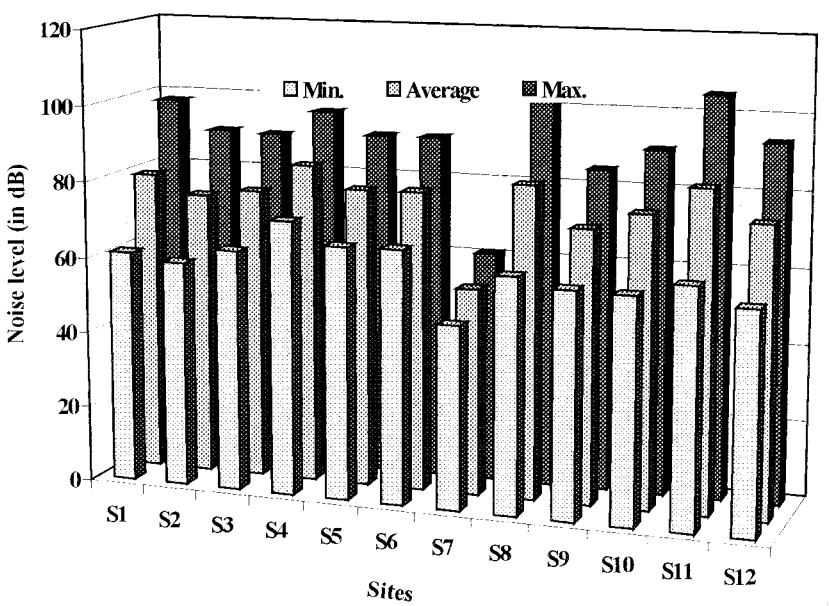

Figure 2. Noise level in different localities of trans-Gomti area in Lucknow city.

Table 6. Recommended noise level for various land use (MCGB, 1981).

No.	Land used	Time	Noise level
1.	Exclusively residential area	6AM-8AM	40
		8AM-7PM	45
		7PM-11PM	40
		11PM-6AM	40
2.	Residential area	6AM-8AM	45
		8AM-7PM	50
		7PM-11PM	45
		11PM-6AM	45
3.	Commercial area and partially industrial area	6AM-8AM	55
		8AM-8PM	60
		8PM-11PM	55
		11PM-6AM	50
4.	Industrial area	6AM-8AM	60
		8AM-8PM	70
		8PM-11PM	60
		11PM-6AM	65

Table 7. Permissible exposure limits to various noise levels.

No.	Noise levels (dBA)	Permissible duration of exposure (hour/day)
1.	90	8
2.	95	4
3.	100	2
4.	105	1
5.	110	½
6.	115	¼

On the basis of this investigation, the Lucknow environment of the trans-Gomti area is mainly contaminated with Respirable Suspended Particulate Matter, which is much more than the permissible limit even after the government's decision to ban the diesel driven tempos on the main thoroughfare of the city. The levels of gaseous pollutant mainly SO_2, NO_2 and O_3 are still under the permissible limits of residential and commercial categories. In view of this scenario, the diesel driven vehicles should be banned in the city areas to bring down the RSPM level within the permissible limit.

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