ENVIRONMENTAL STATUS OF LUCKNOW

A PRE-MONSOON SURVEY REPORT
on
WORLD ENVIRONMENT DAY-2006

INDUSTRIAL TOXICOLOGY RESEARCH CENTRE
(Council of Scientific & Industrial Research)
Post Box 80, Mahatma Gandhi Marg,
Lucknow-226001

5th June 2006

CONTENTS

Select Features of the Study Area

- **Geographical Position** : 26^{o} 52' N Latitude
  80^{o} 56' E Longitude
  128 m above Sea Level
- **Area** : 310 sq. km
- **Population** : 22.45 lakhs as per 2001 Census
- **Total Vehicle Population as on 31/03/2006** : 8,24,003
- **Growth of Vehicle over 2005-2006** : 9.89%
- **Road Transportation** : Two Wheelers (9.70%)
  Three Wheelers (42.86%)
  Car (10.45%)
  Bus (8.16%)
- **Total Number of Petrol Pumps** : 125
- **Consumption of Petrol** : 96009 kl
- **Consumption of Diesel** : 115480 kl
- **Major Source of Pollution** : Vehicular Emissions, Diesel Generating (D. G.) Sets, Burning of Street Garbage
- **Parameters Monitored**
  Air : SPM, RSPM, $PM_{2.5}$, SO_2, NO_X, HCHO, Pb, Noise and
  Water : Bacteriological Quality of Water
- **Study Conducted by** : Environmental Monitoring and Aquatic Toxicology Section
  ITRC, Lucknow

1.0 AIR POLLUTION

1.1 INTRODUCTION

The atmosphere being the largest and most vital part of the biosphere needs to be free from impurities viz. gaseous and particulate matter for the healthy life human being. Other limitations with the atmosphere are its untreatability and the inability of human being to avoid it or to arrange any other alternate source like in case of water and soil.

Natural composition of the atmosphere has been disturbed because of various sources of pollution both natural and anthropogenic where natural sources are also stimulated by the human activities. Rapid and unplanned urbanization and industrialization leads to the deterioration of air quality in urban and sub urban areas. Moreover the increasing number of vehicles in the cities makes the situation more worsen.

In urban areas major sources of air pollution is gasoline and diesel powered engine exhausts consists of particulate matter, SO_2, NO_x, CO, HC, aldehyde etc. The International Agency for Research on Cancer (IARC) has classified diesel exhaust emission elements as *probable carcinogens*. Because of their fine particle size they can penetrate into lungs and causes both acute and chronic lung injuries. The particles emitted by the motor vehicles are mostly black carbon soot. They range in size from 0.002 to 0.13 micrometer from diesel engines and 0.004 to 0.06 micrometer from petrol engines. While most light motor vehicles operate on petrol, whereas, heavy motor vehicles such as buses trucks and other transport and construction sector vehicles use diesel fuel.

Although diesel engine emits less organic compound then petrol engines, they are high emitters of particulate matter. Through fundamental improvements in engine design and the introduction of catalytic converters and unleaded fuels, technological advances in recent years have lead to a marked reduction in gaseous and particulate mass vehicular emissions. However, these advances have not resulted in a decrease in emission rates of ultra fine particles. The increased trend of emissions of ultra fine particles by vehicular traffic is additionally compounded by the increase in vehicle numbers, road condition and congestion.

Gasoline and diesel powered engine exhausts consists of particulate matter, SO_2, NOx, CO, HC, aldehydes etc. All the pollutants from auto exhaust are potentially harmful to human at elevated concentrations.

According to the Society of Indian Automobile Manufacturers (SIAM) the details of sector wise automobile sales are given in **Table-1** for the country.

Table-1: Domestic sales of Automobiles during 2004-05 and 2005-06 in India

Sl. No.	Segment	2004-05	2005-06	Per cent change
1	Passenger Car	8,20,179	8,82,094	7.5
2	Commercial Vehicle	3,18,438	3,50,683	10.1
3	Scooter	9,22,428	9,08,159	-1.5
4	Motorcycle	49,64,753	58,15,417	17.1
5	Three Wheelers	3,07,862	3,60,,187	17.0

Source: Business Line, April 14, 2006

The overall growth of automobile sales in domestic market grew by 12.8% during 2005-06 over the previous year.

The reason for double-digit growth of automobile-population especially the motorcycle and passenger car segments are that people are gradually becoming attached towards personal means of conveyance and the cities are becoming automobile dependent. This automobile dependence creates several environmental, problems e.g.

- Oil Vulnerability
- Photochemical smog
- High green house gas contribution
- Increase in the fine and ultra fine particles in the ambient air
- Urban sprawl

In view of above facts, it is need of the hour to have a look at our city Lucknow the capital of Uttar Pradesh with a population of 22,45,509 (municipal corporation + Cantonment) as per 2001 census and an area of 310 sq. km.

Total vehicle registered with RTO, Lucknow during 2005-2006 were 8,24,003 as against 7,49,830 during 2004-2005. The overall growth registered is 9.89 % during 2005-2006.

Number of registered vehicles with RTO Lucknow in different categories during last two years is given in **Table-2** and details of vehicles plying as public transport (non government) on different routes in Lucknow are shown in **Table-3**.

Table -2: Registered Vehicles with R.T.O. Lucknow during 2004-05 and 2005-06

Sl. No.	Type of Vehicle	Number of Vehicles		% Rise
		On 31st March, 2005	On 31st March, 2006	
1	Multi Axial	567	917	61.73
2	Medium and Heavy weight Vehicles	7925	8014	1.12
3	Light Commercial Vehicles (Three Wheelers)	2525	2930	16.04
4	Light commercial Vehicles (Four wheeler)	4994	5365	7.43
5	Buses	3678	3978	8.16
6	Taxi	5477	5979	9.17
7	Three Wheelers and Auto Rickshaw	8751	12502	42.86
8	Two wheelers	601737	660093	9.70
9	Car	85309	94222	10.45
10	Jeep	11959	12428	3.92
11	Tractor	12821	13385	4.40
12	Trailers	914	991	8.42
13	Others	3173	3199	0.82
	Total	**7,49,830**	**8,24,003**	**9.89**

Source: RTO, Lucknow

Table-3: Present Status of Public Transport Available on Different Routes as on 31-03-06

Sl. No.	Routes	Number
Buses on Different Routes		
1	Sarojini Nagar to Chinhat	113
2	Charbagh to Tehripulia via Munshipulia	53
3	Rajajipuram to PGI	48
4	Gomtinagar to Dubagga	73
5	Power House LDA Colony to Engineering College	2
6	Ramram Bank Chowraha to Charbagh	14
	Total	**303**
Maxi cabs on Different Routes		
1	Rajajipuram to PGI	34
2	Gomtinagar to Dubagga	38
3	Power House LDA Colony to Engineering College	103
	Total	**175**
Auto rickshaws and Battery Operated Vikrams (Tempo)		
1	Auto Rickshaws (with catalytic converter)	1490
2	Vikram with Scrubber	2200
3	Vikram Battery Operated	75
4	Auto Rickshaws with CNG	29
5	Tempo with CNG	32
	Total	**3826**

Source: RTO, Lucknow

Uttar Pradesh State Road Transport Corporation (UPSRTC), introduced bus services under the banner "Lucknow Mahanagar Parivahan Sewa" on different routes of Lucknow city during October, 2005. The details of bus routes and number of buses plying as on 01-06-2006 are given in **Table-4**.

Table-4: Details of Lucknow city bus service

Sl. No.	Route No.	To & Fro	No. of Buses
1	11	Chinhat-Gomtinagar- Alambagh	18
2	22	Munshiphulia-Lekhraj-Alambagh	12
3	23	Gomtinagar Thana-Rajini Khand	8
4	24	Engineering College-Munshiphulia-Charbagh	10
5	25	Azad Engineering College-Charbagh	2
6	31	IIM-Alambagh	2
7	33	Engineering Collge-Aliganj-Alambagh	14
8	35	Vikasnagar-Charbagh	6
9	44	Dubagga-Charbagh	8
10	45	Gomtinagar Thana-Parag Dairy	8
11	66	Rajajipuram-Hazratganj	4
12	--	Charbagh-Banthara (upanagari seva)	5
		Total	97

Source: UPSRTC, Lucknow

Monitoring of Environment status of Lucknow city with respect to air and water quality is being conducted by ITRC, since 1997 twice in a year (pre monsoon and post monsoon in the month of May and October respectively) to assess the environmental quality and its trends. The study was conducted with the following aim and objectives.

- To assess ambient air quality with respect to SPM, RSPM, $PM_{2.5}$, SO_2, NOx, HCHO and Pb released from the automobile exhaust.
- To study trends of pollutants over a period of time.
- To assess day and night time noise to ensure compliance of permissible noise levels.
- To study bacteriological quality of potable water.
- To create a database for future use.
- To create public awareness about environmental pollution.

The present study is conducted during the month of May, 2006 representing the pre monsoon (summer) period.

In Lucknow city there are 125 petrol pumps operated by four oil companies. The break-up of these petrol pumps is given in **Table-5.**

Table-5: Petrol Pumps in Lucknow City

Sl. No.	Agency	Number of outlet	
		31st March 2005	31st March 2006
1	Indian Oil Corporation (IOC)	33	44
2	Bharat Petroleum Corporation Limited (BPCL)	17	25
3	Hindustan Petroleum Corporation Limited (HPCL)	26	30
4	Indo Burma Petroleum (IBP)	20	26
	Total	**96**	**125**

Source: India Oil Corporation (IOC), Lucknow

The sales figure of oil companies for the last year has been compared with sale figure of 2005-06 (**Table-6).** It is observed that petroleum sale have been increased marginally by 0.16% whereas sale of diesel has decreased by 6.49%.

Table-6: Consumption of Fuel* in Lucknow

Sl. No.	Agency	Petrol (Unleaded)			High Speed Diesel		
		Apr., 04 to Mar., 05	Apr., 05 to Mar., 06	% Change	Apr.04 to Mar., 05	Apr., 05 to Mar., 06	% Change
1	IOC	35476	36186	2.0	46710	43116	-7.69
2	BPCL	24849	26727	7.56	23077	24221	4.96
3	HPCL	20165	19853	-1.55	29466	28778	-2.33
4	IBP	15363	13243	-13.80	24237	19365	-20.10
Total		95853	96009	0.16	123490	115480	-6.49

*KL (1 KL = 1000 litres). *Source: India Oil Corporation (IOC), Lucknow*

1.2 MONITORING LOCATIONS AND METHODOLOGY

1.2.1 AIR QUALITY

Eleven locations representing different activities/areas i.e., four in residential, five in commercial cum traffic, one in industrial and one adjacent area as control were selected for the study as summarised in **Table-7**.

Table-7: Air Monitoring Locations

Sl. No.	Locations	Activity
1	Aliganj	Residential
2	Vikasnagar	
3	Indiranagar	
4	Gomtinagar	
5	Hussainganj	Commercial cum traffic
6	Charbagh	
7	Alambagh	
8	Aminabad	
9	Chowk	
10	Amausi	Industrial
11	Guari Gaon	Village

The brief description of each sites are given below.

I. Aliganj

Earlier, Aliganj was a residential area, now it has become a semi commercial area. In this locality the main source of air pollution is vehicular emission. Most of the people are using LPG gas for cooking. Aliganj has a traffic route from Engineering College to Power House LDA Colony Kanpur Road via Charbagh railway station. In this route means of mass public transportation is by jeep, city buses, which are run by diesel. Monitoring location was at CSIR Scientist Apartments; sector K, near main road. The main traffic was two wheeler, passenger car and maxi cab (Jeep).

II. Vikasnagar

Like Aliganj, Vikasnagar was earlier a purely residential area and now it has become a semi commercial area. On the main route public transport is by Vikram tempo, minibuses and buses. In Vikasnagar, vehicular emission is mainly dominated by two wheelers, passenger cars and pubic transport. The monitoring location was at a residential area, which is about 500 meter away from the Vikasnagar main road.

III. Indiranagar

Indiranagar is now a semi commercial area. In this area the means of public transport is by Jeep and buses running on diesel. In daytime, main source of vehicular emission is public transport, two wheelers and passenger cars. The main Ring Road pass through Indiranagar is carrying high volume of mixed vehicular traffic. During night time large volume of different capacity of commercial trucks pass though this route, generating high level of air and noise pollution. Monitoring was carried out 30 m away from the main Ring Road.

IV. Gomtinagar

Gomtinagar is a residential area, dominated by middle and upper class families, using LPG gas for cooking. Source of air pollution is public transport (tempo, jeep and mini buses), two wheeler and passenger car. Night time traffic flow is low. The monitoring location was in Vinay khand, near Jaipuria crossing about 25 meter away from the main road

V. Hussainganj

In Hussainganj the monitoring location was 40 meter away from the main road. It is a purely commercial place and during day time traffic flow are city buses, jeeps, two wheelers and passenger cars. Night time commercial vehicles were the main source of pollution.

VI. Charbagh

The place is congested with roadside make shift shops/hawkers and having a high traffic flow. The major source of pollution is auto exhaust from mixed type of vehicles including buses and trucks during night hours. One of the important sources is diesel locomotive. It is one of the busiest places in Lucknow city. The monitoring location was near the main traffic junction.

VII. Alambagh

In Alambagh monitoring location was 100 m away from the Alambagh crossing on the main Lucknow – Kanpur road. The main source of pollution is vehicular exhaust. In daytime, source of pollution is from city as well as from inter city buses, tempos, two wheelers and passenger cars. In night time trucks and long distance buses are the main sources of pollution. Major source of pollution in the area is diesel engine driven vehicular traffic.

VIII. Aminabad

The monitoring location was situated in the central place of Aminabad. This is purely commercial area mainly consisting mainly of shopping complexes. Aminabad serves as major shopping area for upper middle class and middle class family. The whole area is congested having narrow lanes and mixed traffic ranging from bicycles, rickshaws to two wheeler & passenger cars. Sampling site was located adjacent to the Jhandewala Park.

IX. Chowk

The monitoring location was 100 m away from the main road. Area is residential cum commercial. Source of pollution is mainly from tempo, two wheeler and passenger

car. During night time commercial vehicles passes through the main road.

X. Amausi

Amausi is an industrial area. There are a number of small-scale industries. In this area, main source of pollution is from vehicular as well as industrial. The monitoring location was about 300 meter away from the main Lucknow - Kanpur road.

XI. Guari Gaon

Guari Gaon is situated in the eastern part of the city adjacent to Viram Khand, Gomtinagar. It is a village area and as such there is no regular vehicular pollution. This location considered as control.

Overall, the major source of pollution in Lucknow city is vehicular emission. Some major industries located in Lucknow are Mohan Meakins, Eveready Flash Lights, Scooter India Ltd., Hindustan Aeronautic Ltd., and Swaroop Chemicals etc. These industries are situated in different parts and directions of the city. In addition operation of D.G. set during non-availability of power particularly in summer season by commercial establishment.

The pollution level in a particular area also varies from place to place which depend on the type of vehicles, their speed, road condition, topography as well as the meteorological condition of the area.

The monitoring of Ambient Air Quality was carried out as per standard procedures. The details of the sampling and analysis are summarised in **Table-8.**

Table-8: Methodology for Air Quality Monitoring

Particulars	SPM / RSPM	Lead	SO_2	NOx	HCHO
Sampling Equipment	HVS/RDS	RDS	HVS/RDS with gaseous sampling attachment		
Collection Media	Glass Fibre	EPM-2000	TCM	NaOH	Distilled Water
Flow rate	1.0-1.3 m^3/min		0.5 l/min		
Analytical Method	Gravimetric	AAS	Spectrophotometery		
Frequency	24 hour		8 hourly		
Sampling Duration	Continuous for 24 hours				
No. of days of sampling at each location	2 days				

HVS=High Volume Sampler, RDS=Respirable Dust Sampler

1.2.2 MONITORING OF FINE PARTICLES (PM $_{2.5}$)

The fine particle with less than 2.5 micrometer size is known as $PM_{2.5}$. Monitoring of fine particles ($PM_{2.5}$) was carried out during day and night time with the help of HAZ-DUST Environmental Particulate Air Monitor (EPAM-500) on the roadside at different air quality monitoring station as mentioned in **Table-7**. The monitoring period was 30 minutes with one-minute data logging along with counting of traffic volume.

1.2.3 NOISE LEVEL MEASUREMENTS

The measurement of noise level was carried out for 30 minutes at each location during the daytime (6 AM to 10 PM) and night time (10 PM to 6 AM). All measurements were made with the "A" weighing filter at a height of receptor organ, i.e., ~1.5 metres above the ground level. The location for the noise level measurement is given in **Table- 9.**

Table-9: Noise Monitoring Location

Sl. No.	Locations	Activity
1	Aliganj	Residential
2	Vikasnagar	
3	Indiranagar	
4	Gomtinagar	
5	Hussainganj	Commercial cum traffic
6	Hazratganj	
7	Charbagh	
8	Alambagh	
9	Aminabad	
10	Chowk	
11	Amausi	Industrial
12	Talkatora	

1.3 RESULTS

1.3.1 AIR QUALITY

The detailed of results of air quality monitoring are presented in **Table-10 &11 and Figure-1 to 10.**

1.3.1.1 PARTICULATE MATTER (RSPM and SPM)

Residential Area

In residential areas (Aliganj, Vikasnagar, Indiranagar and Gomtinagar) the average concentration of RSPM and SPM were found in the range of 141.9 to 199.9 and 315.6 to 442.8 µg/m^3 respectively.

Commercial Area

In commercial areas (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk) the average concentration of RSPM and SPM were found in the range of 154.6 to 206.5 and 361.0 to 414.7 µg/m^3 respectively.

Industrial Area:

In industrial area (Amausi), the average concentration of RSPM and SPM were found to be 141.4 and 327.8 µg/m^3 respectively.

Village Area (Control):

In village (Guari goon), the average concentration of RSPM and SPM were found to be 73.1 and 196.3 µg/m^3 respectively.

The details of SPM & RSPM levels are presented in **Table-10 & 11** and **Figure-1 & 2.**

All the values of RSPM and SPM, except in Amausi under industrial area were above the prescribed National Ambient Air Quality Standards (NAAQS) 100 and 150 µg/m^3 for RSPM and 200, and 500 µg/m^3 for SPM in residential, rural and other area and Industrial areas respectively.

Table 10: Concentration (ug/m3) of SPM, RSPM, SO_2, NO_x, HCHO and Pb

Location	Days	SPM	RSPM	SO_2				NOx				HCHO				Pb
				A	B	C	Mean	A	B	C	Mean	A	B	C	Mean	
Aliganj	I	340.0	144.7	19.6	23.1	26.3	23.0	29.0	36.5	30.1	31.9	5.5	7.1	2.9	5.2	0.0411
	II	403.1	177.5	14.5	26.8	17.4	19.6	31.6	38.4	31.4	33.8	6.3	8.3	5.2	6.6	
	Avg	**371.6**	**161.1**	**17.1**	**25.0**	**21.9**	**21.3**	**30.3**	**37.5**	**30.8**	**32.8**	**5.9**	**7.7**	**4.0**	**5.9**	
Vikasnagar	I	348.4	165.6	18.8	27.9	15.9	20.9	28.9	34.5	27.1	30.2	6.7	5.7	8.5	7.0	0.0463
	II	387.6	174.2	17.4	26.8	18.7	21.0	20.1	34.9	18.8	24.6	7.8	5.8	7.3	7.0	
	Avg	**368.0**	**169.9**	**18.1**	**27.4**	**17.3**	**20.9**	**24.5**	**34.7**	**23.0**	**27.4**	**7.25**	**5.7**	**7.9**	**6.9**	
Indiranagar	I	403.2	194.3	25.2	33.9	25.5	28.2	23.6	43.1	36.4	34.4	8.2	11.8	7.1	9.0	0.1811
	II	482.4	205.4	19.5	29.2	21.0	23.2	26.9	46.0	43.6	38.8	10.2	5.2	6.5	7.3	
	Avg	**442.8**	**199.9**	**22.4**	**31.6**	**23.3**	**25.7**	**25.3**	**44.6**	**40.0**	**36.6**	**9.2**	**8.5**	**6.8**	**8.7**	
Gomtinagar	I	330.8	148.1	16.2	23.1	14.2	17.8	26.7	31.1	25.5	27.8	5.3	11.3	4.7	7.1	0.0412
	II	300.3	135.7	19.4	22.0	13.3	18.2	26.6	37.1	23.9	29.2	5.8	5.7	7.1	6.2	
	Avg	**315.6**	**141.9**	**17.8**	**22.6**	**13.8**	**18.0**	**26.7**	**34.1**	**24.7**	**28.5**	**5.55**	**8.5**	**5.9**	**6.6**	
Hussainganj	I	406.2	172.2	29.4	34.1	31.4	31.6	29.3	52.5	45.8	42.5	10.8	8	6.8	8.5	0.0541
	II	458.1	188.4	22.2	36.4	29.7	29.4	33.8	58.9	47.3	46.7	10.8	12.9	8.7	10.8	
	Avg	**432.2**	**180.3**	**25.8**	**35.3**	**30.6**	**30.5**	**31.6**	**55.7**	**46.6**	**44.6**	**10.8**	**10.5**	**7.7**	**9.7**	
Charbagh	I	438.8	221.1	31.3	36.6	33.5	33.8	36.4	61.8	48.5	48.9	8.7	14.3	11.9	11.6	0.091
	II	390.2	191.8	24.5	40.2	28.4	31.0	40.7	48.1	40.7	43.2	9.6	12.1	9.3	10.3	
	Avg	**414.5**	**206.5**	**27.9**	**38.4**	**31.0**	**32.4**	**38.6**	**55.0**	**44.6**	**46.0**	**9.15**	**13.2**	**10.6**	**10.9**	
Alambagh	I	417.1	178.2	18.7	29.6	35.8	28.0	31.1	44.4	35.9	37.1	9.1	12.2	6.1	9.1	0.0842
	II	361.7	160.8	20.9	32.1	35.4	29.5	34.3	48.9	35.8	39.7	6.3	14.9	6.3	9.2	
	Avg	**389.4**	**169.5**	**19.8**	**30.9**	**35.6**	**28.8**	**32.7**	**46.7**	**35.9**	**38.4**	**7.7**	**13.5**	**6.2**	**9.15**	
Aminabad	I	435.8	207.5	17.6	31.5	13.9	21.0	24.7	40.1	19.6	28.1	2.5	6.7	2.4	3.9	0.074
	II	365.5	173.2	20.2	30.8	12.2	21.1	24.9	35.6	17.2	25.9	4.9	7	2.4	4.8	
	Avg	**400.7**	**190.4**	**18.9**	**31.2**	**13.1**	**21.0**	**24.8**	**37.9**	**18.4**	**27.0**	**3.7**	**6.8**	**2.4**	**4.3**	
Chowk	I	373.4	171.6	24.9	34.1	21.5	26.8	35.1	42.1	28.3	35.2	5.7	12.3	4.5	7.5	0.0684
	II	348.6	137.5	23.2	35.2	23.6	27.3	36.8	42.7	31.9	37.1	9.9	7	4.8	7.2	
	Avg	**361.0**	**154.6**	**24.1**	**34.7**	**22.6**	**27.1**	**36.0**	**42.4**	**30.1**	**36.2**	**7.8**	**9.6**	**4.6**	**7.4**	
Amausi	I	308.3	134.6	11.7	22.5	12.4	15.5	9.6	30.9	14.8	18.4	5.7	10.2	4.9	6.9	0.0244
	II	347.2	148.1	13.1	24.4	17.5	18.3	21.9	25.3	17.7	21.6	2.9	5	2.6	3.5	
	Avg	**327.8**	**141.4**	**12.4**	**23.5**	**15.0**	**16.9**	**15.8**	**28.1**	**16.3**	**20.0**	**4.3**	**7.6**	**3.7**	**5.2**	
Guari Gaon	I	**217.1**	**87.2**	**11.4**	**16.3**	**9.6**	**12.4**	**16.6**	**18.8**	**11.2**	**15.5**	**2.5**	**2.4**	**2.3**	**2.4**	0.0157
	II	175.5	59.0	10.8	12.4	9.4	10.9	13.5	17.9	10.0	13.8	2.3	2.2	2.3	2.3	
	Avg	**196.3**	**73.1**	**11.1**	**14.4**	**9.5**	**11.7**	**15.1**	**18.4**	**10.6**	**14.7**	**2.4**	**2.3**	**2.3**	**2.3**	

A=06:00 – 14:00 hr, B=14:00 – 22:00 hr, C=22:00 – 06:0 hr

Table-11: Average Concentration (µg/m^3) of SPM, RSPM, SO_2, NO_x, HCHO & Pb

Area	Location	SPM	RSPM	SO_2	NOx	HCHO	Pb
Residential	Aliganj	371.6	161.1	21.3	32.8	5.9	0.041
	Vikasnagar	368.0	169.9	20.9	27.4	6.9	0.046
	Indiranagar	442.8	199.9	25.7	36.6	8.7	0.181
	Gomtinagar	315.6	141.9	18.0	28.5	6.6	0.041
Commercial	Hussainganj	432.2	180.3	30.5	44.6	9.7	0.054
	Charbagh	414.5	206.5	32.4	46.0	10.9	0.091
	Alambagh	389.4	169.5	28.8	38.4	9.1	0.084
	Aminabad	400.7	190.4	21.0	27.0	4.3	0.074
	Chowk	361.0	154.6	27.1	36.2	7.4	0.068
Industrial	Amausi	327.8	141.4	17.0	20.0	5.2	0.024
Village (Control)	Guari Gaon	196.3	73.1	11.7	14.7	2.3	0.016

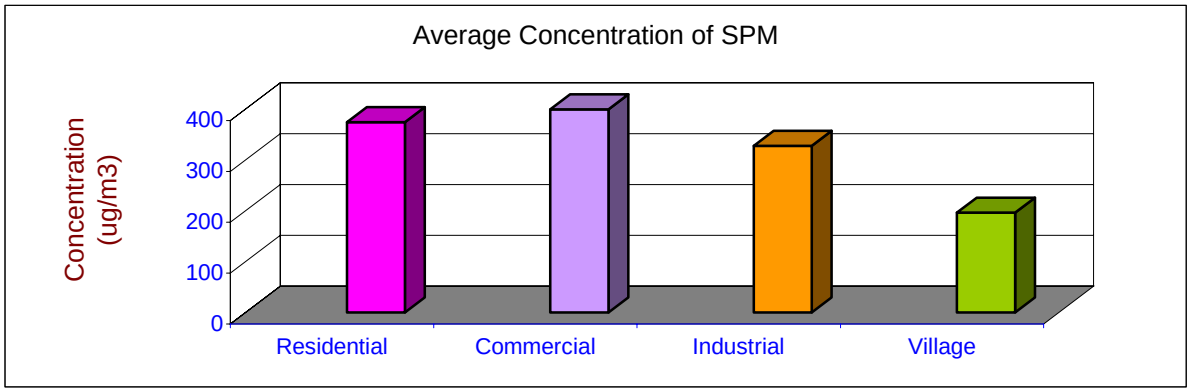


Figure-1: Concentration of SPM in different areas

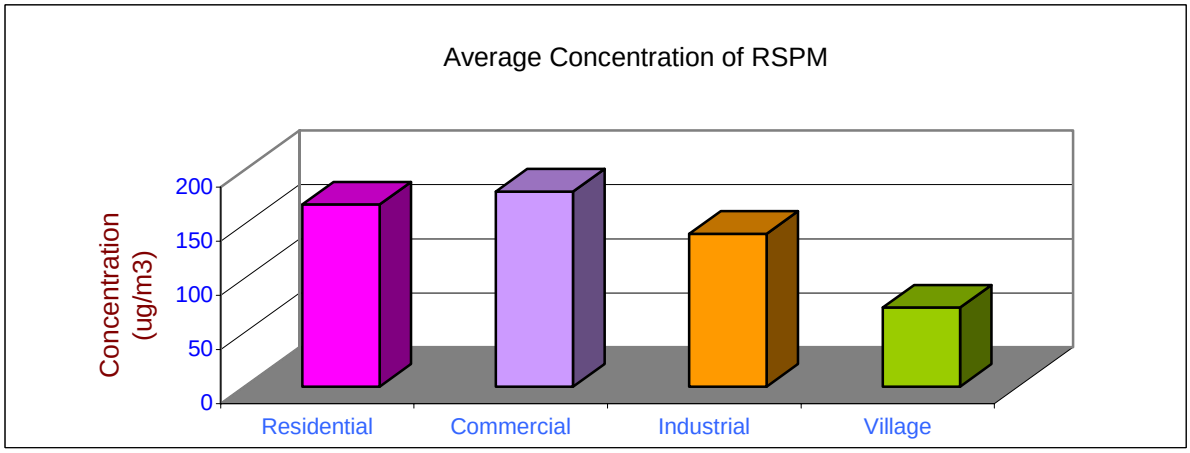


Figure-2: Concentration of RSPM in different areas

1.3.1.2 SULPHUR DIOXIDE (SO_2)

Residential Area

In residential area (Aliganj, Vikasnagar, Indiranagar and Gomtinagar) the average concentrations of SO_2 were found in the range of 18.0 to 25.7 µg/m^3.

Commercial Area

In commercial area (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of SO_2 were found in the range of 21.0 to 32.4 µg/m^3.

Industrial Area

In industrial area (Amausi) the average concentrations of SO_2 was found in the range of 16.9 µg/m^3.

Village Area (Control):

In village area (Guari Gaon) the average concentrations of SO_2 was found in the range of 11.7 µg/m^3.

All the values are within the prescribed limit of the NAAQS of 80 µg/m^3 for residential, rural and other areas and 120 µg/m^3 for industrial area. The details of SO_2 levels at different locations are presented in **Table-10 & 11** and **Figure-3.**

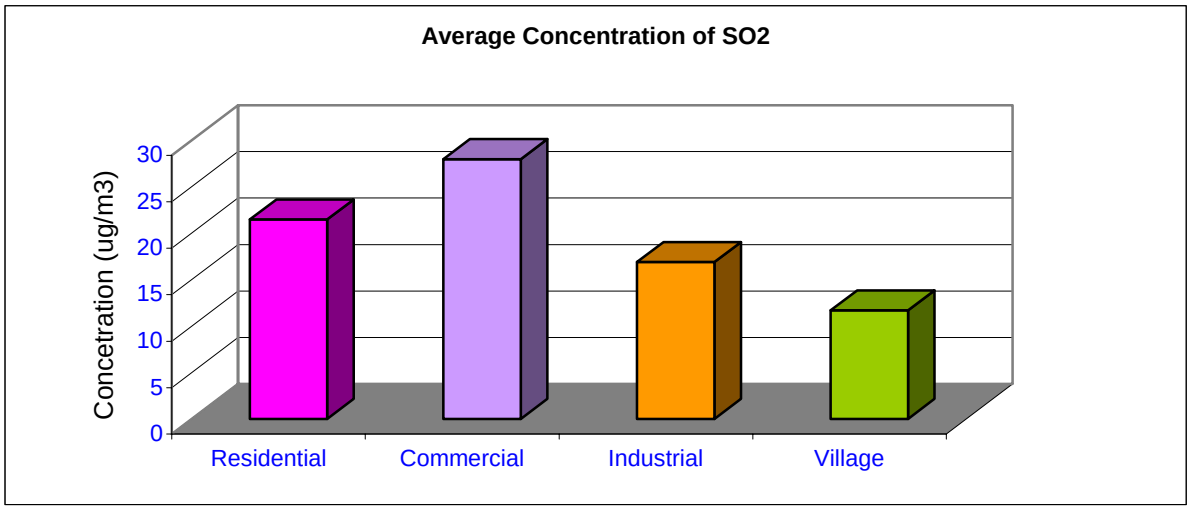


Figure-3: Concentration of SO_2 in different areas

The main source of SO_2 is the sulphur content in diesel fuel, which is normally present at 0.05%. The level of SO_2 depends on the engine efficiency as well as on the quality and quantity of fuel used. Redesigning of the engine to follow the Bharat - I & II norm reduced the SO_2 level in urban areas to some extent, but levels may

increase due to day-by-day increase in number of vehicle, especially diesel engine driven in the long run.

1.3.1.3 OXIDES OF NITROGEN (NO_x)

Residential Area:

In residential areas (Aliganj, Vikasnagar, Indiranagar and Gomtinagar) the average concentrations of NO_X were found in the range of 27.4 to 36.6 µg/m^3.

Commercial Area

In commercial areas (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of NO_X were found in the range of 27.0 to 46.0 µg/m^3.

Industrial Area

In industrial areas (Amausi) the average concentrations of NO_x was 20.0 µg/m^3.

Village Area (Control):

In village area (Guari Gaon) the average concentrations of NO_x was found in the range of 14.7 µg/m^3

All the values of NO_x were within the prescribed NAAQS of 80 µg/m^3 for residential, rural and other areas and 120 µg/m^3 for industrial area. The details of NO_X levels at different locations are presented in **Table-10 & 11** and **Figure-4.**

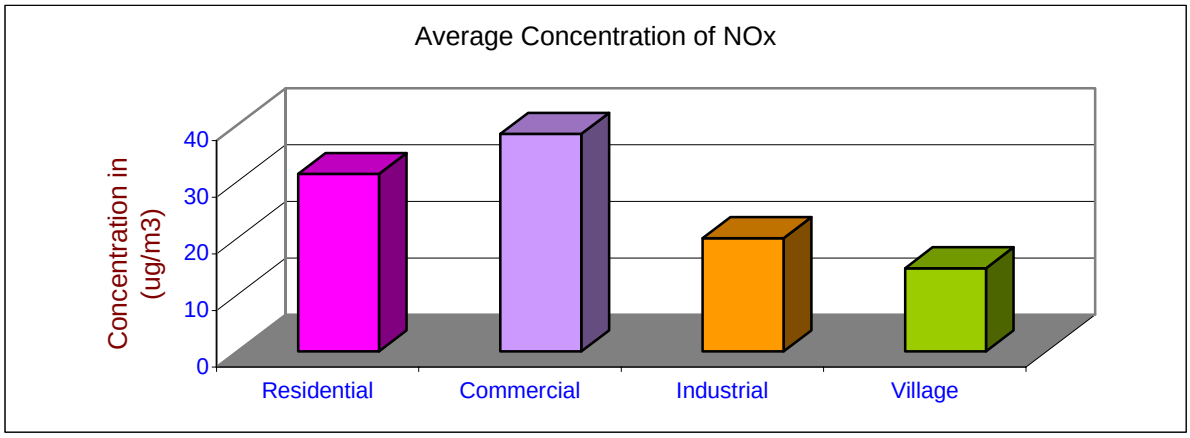


Figure-4: Concentration of NO_x in different areas

1.3.1.4 FORMALDEHYDE (HCHO)

Residential Area

In residential areas (Aliganj, Vikasnagar, Indiranagar and Gomtinagar), which have now became semi commercial areas; the average concentrations of HCHO were found in the range of 5.9 to 8.7µg/m^3.

Commercial Area

In Commercial areas (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of HCHO were found in the range of 3 to 10.9 µg/m^3.

Industrial Area

In industrial area (Amausi) the average concentrations of HCHO was found 5.2 µg/m^3.

Village Area (Control):

In village area (Guari Gaon) the average concentrations of daytime HCHO was found in the range of 2.3 µg/m^3

There is no prescribed limit under NAAQS. The details of HCHO levels are presented in **Table- 10 &11** and **Figure-5.**

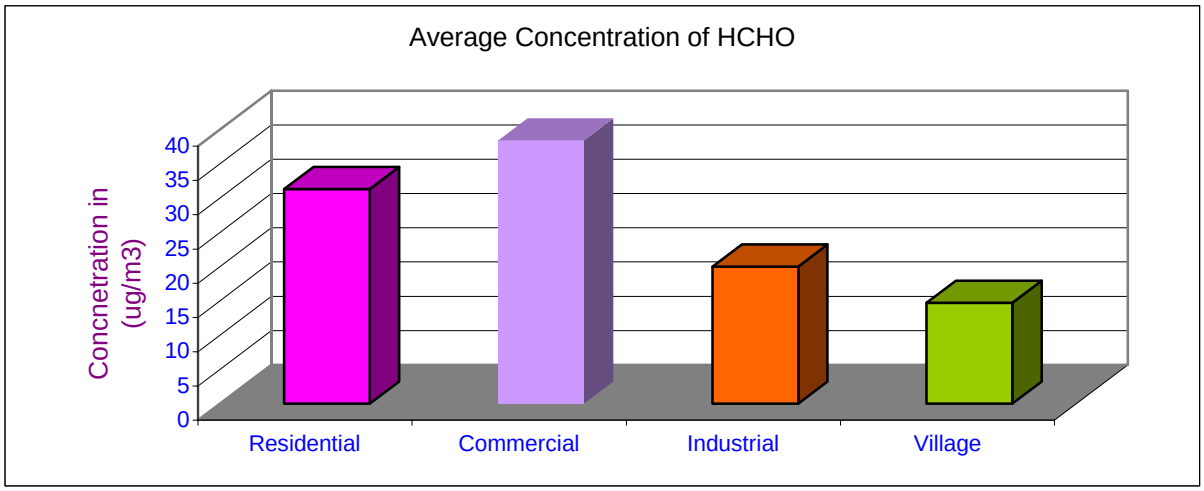


Figure-5: Concentration of Formaldehyde (HCHO) in different areas

1.3.1.5 LEAD (Pb)

While leaded petrol was in use, automobile exhaust was considered to be a significant contributor to the total atmospheric lead. With the supply of the unleaded

petrol in the city, this source of lead emission was gradually phased out. However other sources of lead emissions still exists. The presence of lead is reflected in our measurements and summarised in **Table-10 & 11 and Figure-6.**

The results revealed that the concentration of Pb in residential area ranged between 0.041 to 0.181 μg/m^3. At commercial and traffic junctions it ranged between 0.054 to 0.091 μg/m^3 and in industrial and village area it was 0.024 and 0.016 μg/m^3 respectively. All the values are within NAAQS of 1.0 and 1.5 μg/m^3 for residential, rural & other areas and industrial area respectively.

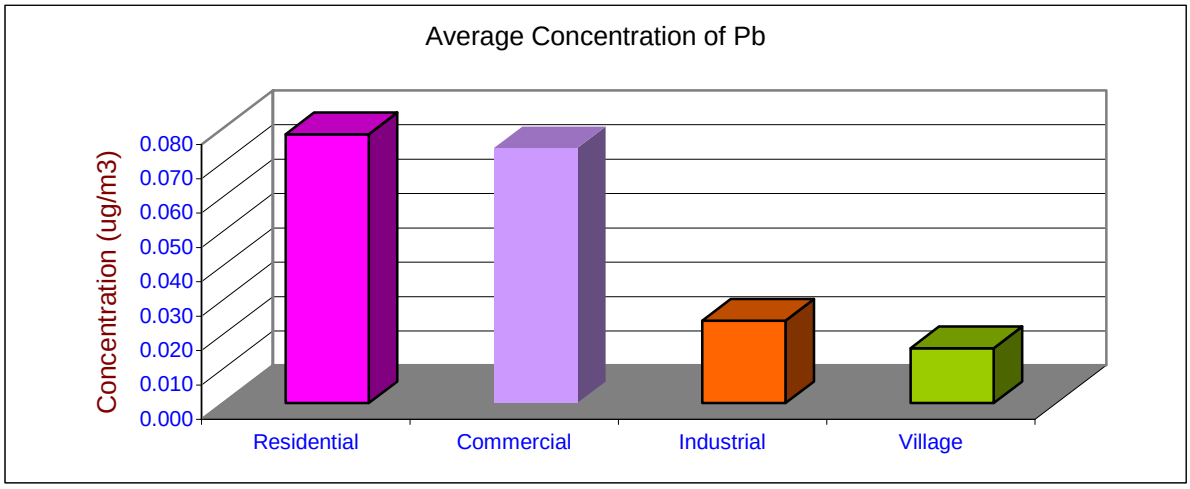


Figure-6: Concentration of Lead (Pb) in different areas

1.3.1.6 FINE PARTICLES ($PM_{2.5}$)

It is known that the vehicle exhaust consist of fine particles i.e. <2.5 micro meter in size, which is aerodynamic in nature and remain suspended for longer time than other suspended particles and can move longer distances. During day and night time concentration are present in **Table-12 & 13**.

The minimum values were found in the range of 2.0 to 59.0 and 3.0 to 37 μg/m^3 and the maximum value were found in the range of 48.0 to 337.0 and 56.0 and 178.0 μg/m^3 during day and night time respectively. The Total Weight Average (TWA) values during day and night times were found to be in the range of 34.0 to 174.0 and 35.0 and 84.0 μg/m^3 respectively.

There is no NAAQS in India. Environmental Protection Agency (EPA), USA recommended the ambient air quality standard for annual and 24 hours average value is 15.0 and 65.0 μg/m^3 respectively. The observed values are not comparable with this US EPA standard because the monitoring period is only 30 minutes. The results also showed that in some locations the daytime recorded values are

comparatively less than the nighttime values, which may be attributed to meteorological conditions like temperature, wind speed, wind direction and relative humidity. Results also showed that the night time values are more consistent than the day time values.

Table-12: Concentration of Fine Particles ($PM_{2.5}$) on Roadside at different Location during Day time

Sl. No.	Location	Monitoring Time (hr.)	Minimum	Maximum	T.W.A.	No. of Vehicle During measurement
1	Aliganj	16-17	2.0	70.0	43.0	794
2	Vikasnagar	17-18	12.0	172.0	123.0	584
3	Indiranagar	18-19	25.0	188.0	139.0	699
4	Gomtinagar	12-13	16.0	89.0	65.0	622
5	Hussainganj	15-16	15.0	305.0	50.0	1262
6	Charbagh	16-17	14.0	71.0	49.0	803
7	Alambagh	15:16	59.0	337.0	174.0	1173
8	Aminabad	16:17	8.0	129.0	39.0	NC
9	Chowk	18:19	24.0	137.0	81.0	1972
10	Amausi	14:15	6.8	48.0	34.0	651
11	Talkatora	17-18	3.0	296.0	44.0	621

Table-13: Concentration of Fine Particles ($PM_{2.5}$) on Roadside at different Location during Night time

Sl. No.	Location	Monitoring Time (hr.)	Minimum	Maximum	T.W.A.	No. of Vehicle During measurement
1	Aliganj	23-00	25.0	56.0	41.0	165
2	Vikasnagar	22-23	21.0	158.0	79.0	232
3	Indiranagar	22-23	22	127.0	84.0	460
4	Gomtinagar	22-23	8.0	72.0	58.9	198
5	Hussainganj	04-05	37.0	178.0	78.2	456
6	Charbagh	03-04	3.0	141.0	64.0	342
7	Alambagh	01-02	8.0	117.0	52.0	356
8	Aminabad	22-23	12.0	129.0	49.0	NC
9	Chowk	00-01	6.0	82.0	58.0	346
10	Amausi	02-03	17.0	60.0	41.6	236
11	Talkatora	01-02	3.0	84.0	35.0	96

NC= Not Counted

1.3.2 NOISE

Elevated noise levels have been associated with adverse impact on human health, ranging from minor annoyance to physiological damage. As such, traffic noise has

become a major environmental concern and a source of an ever-increasing level of discomfort particularly in urban areas with high traffic congestion. The sources of noise in the urban settings are primarily vehicular engines; exhaust systems, aerodynamic friction, and tyre-pavement interaction. Traffic noise is affected by factors such as traffic volume and speed, vehicle mix, pavement type, and vehicle conditions. In general, from small vehicles the major part of noise emitted is at the pavement-tyre interface, heavy vehicles emit much of their noise at the engine/exhaust. The monitoring data recorded during the pre monsoon period- (May, 2006) is presented in **Table-14.**

In residential areas, the day and night time noise level were recorded between 72.8 to 77.9 and 60.2 to 73.2 dB(A) respectively. All the values are higher than the prescribed limit of 55 and 45 dB(A) for day and night time respectively.

In commercial and traffic area the day and night time noise level were recorded between 74.9 to 79.8 and 58.6 to 74.5 dB(A) respectively. Noise level at all the commercial sites during day and night time are above the prescribed limit of 65 and 55 dB(A).

In industrial areas, Amausi and Talkatora the day and night time noise level were recorded between 72.8 to 76.5 and 69.5 to 71.1 dB(A) respectively. Noise level at Talkatora and Amausi in the day time and night time were higher that the prescribed standard of 75 and 70 dB(A) respectively.

Table-14: Noise Level dB(A) during Day and Night Time

Sl. No.	Area	Location	Time	
			Day	Night
1	Residential	Aliganj	72.8	67.0
		Vikasnagar	76.9	68.6
		Indiranagar	77.9	73.2
		Gomtinagar	73.5	60.2
2	Commercial	Hazratganj	79.8	65.2
		Hussainganj	74.9	71.3
		Charbagh	76.6	72.3
		Alambagh	77.1	74.5
		Aminabad	75.1	58.6
		Chowk	78.0	69.4
3	Industrial	Amausi	72.8	71.1
		Talkatora	76.5	69.5

1.4 TRENDS

1.4.1 AMBIENT AIR QUALITY

The observed RSPM for 9 years, SO_2 and NO_x for 10 years and Pb for 6 years data have been compared to find out the prevailing trend of air pollution in Lucknow city.

1.4.1.1 Respirable Suspended Particulate Matter (RSPM)

In all the four locations in residential areas, slight increase was recorded over previous year and all the values are higher than the NAAQS (**Figure-7**).

Among the commercial areas, RSPM values showed increasing trend at all the locations except in Aminabad and Hussainganj, which showed slightly lower or equal values respectively than the previous year. All the values are higher than the NAAQS (**Figure-8**).

Amausi under industrial area showed increasing trend over the previous year but within the NAAQS (**Figure-9**).

1.4.1.2 Sulphur Dioxide (SO_2)

SO_2 level in residential areas namely Vikasnagar, Indiranagar and Gomtinagar registered slightly increasing trend in comparison to last year (**Figure-10**).

In the commercial areas, SO_2 registered a slightly increasing trend except Aminabad when compared with the last year values (**Figure-11**).

The only industrial area Amausi showed almost equal value when compared with last year value (**Figure-12**).

1.4.1.3 Oxides of Nitrogen (NO_x)

Among the four locations namely Aliganj and Gomtinagar registered slightly increasing trend whereas Vikasnagar and Indiranagar showed slightly lower values in comparison to last year (**Figure-13**).

Among commercial areas, NO_x registered decreasing trend at all the locations when compared with the last year data (**Figure-14**).

The only industrial area Amausi showed decreasing trend (**Figure-15**).

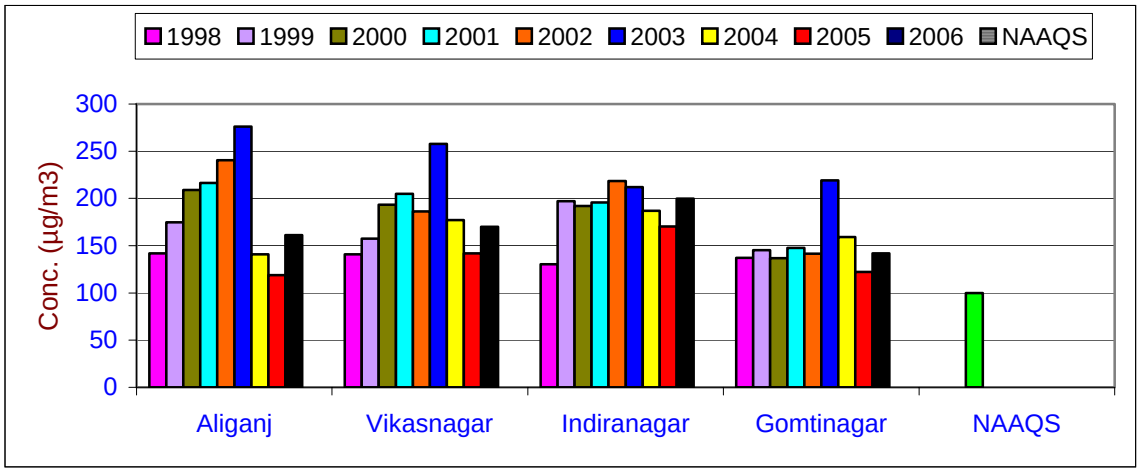
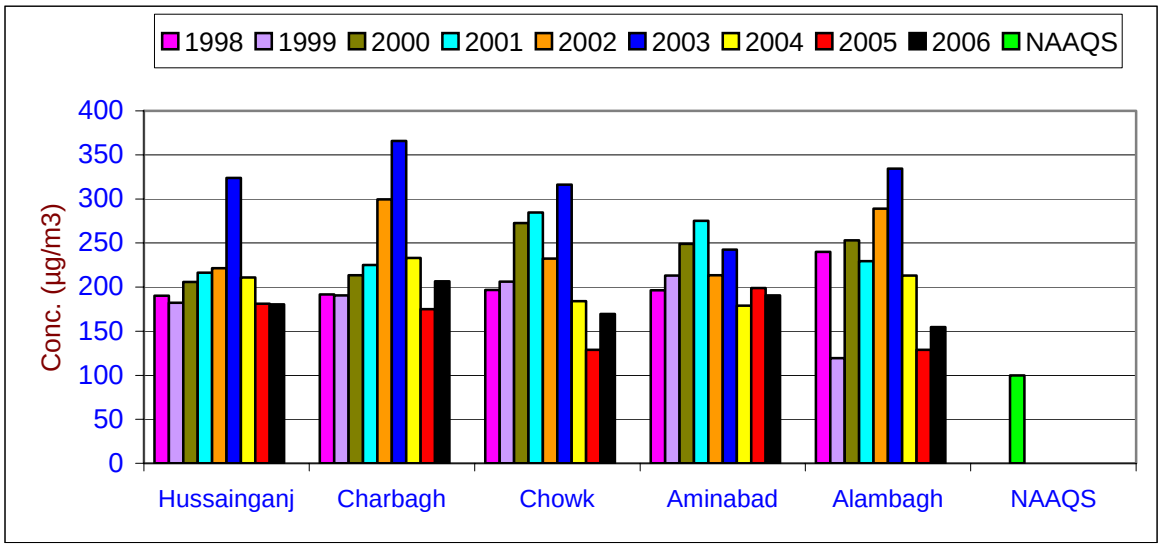


Figure- 7: Trend of RSPM during 1998-2006 it Residential Area



Fugure-8: Trend of RSPM during 1998-2006 in Commercial Area

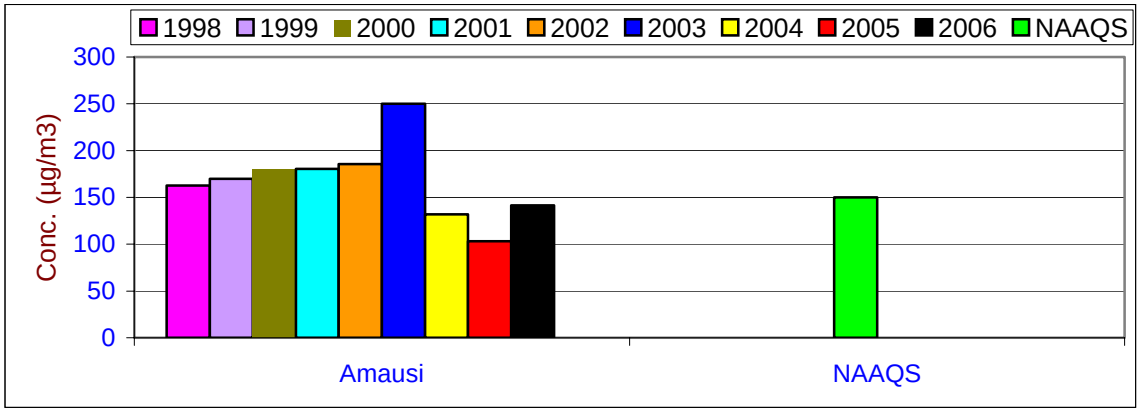


Figure-9: Trend of RSPM during 1998-2006 in Industrial Area

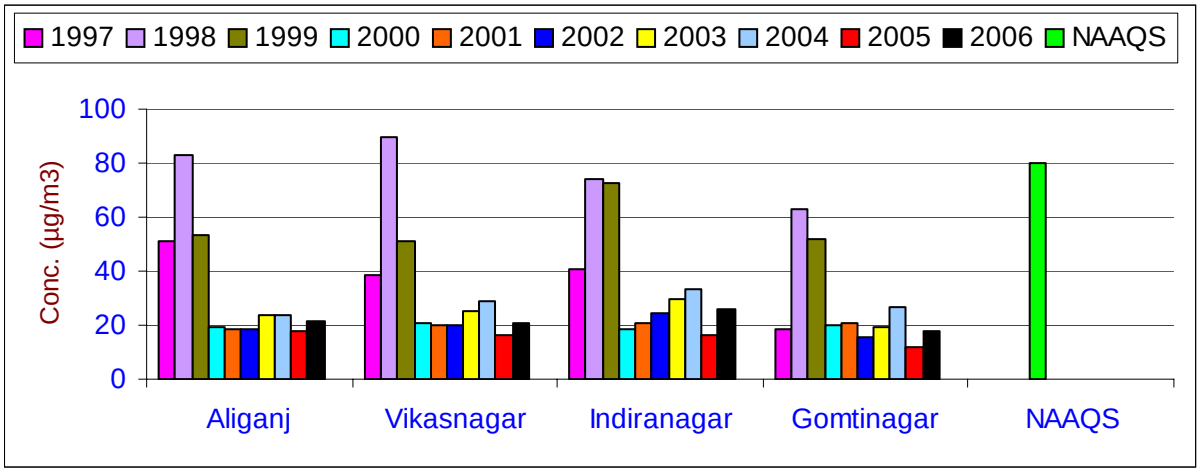


Figure-10: Trend of SO_2 during 1997-2006 in Residential Area

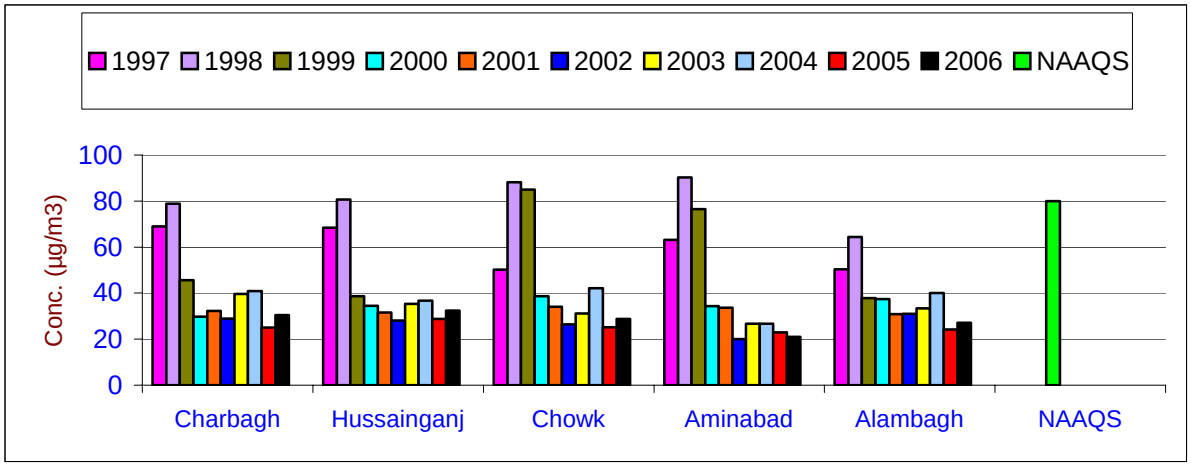


Figure-11: Trend of SO_2 during 1997-2006 in Commercial Area

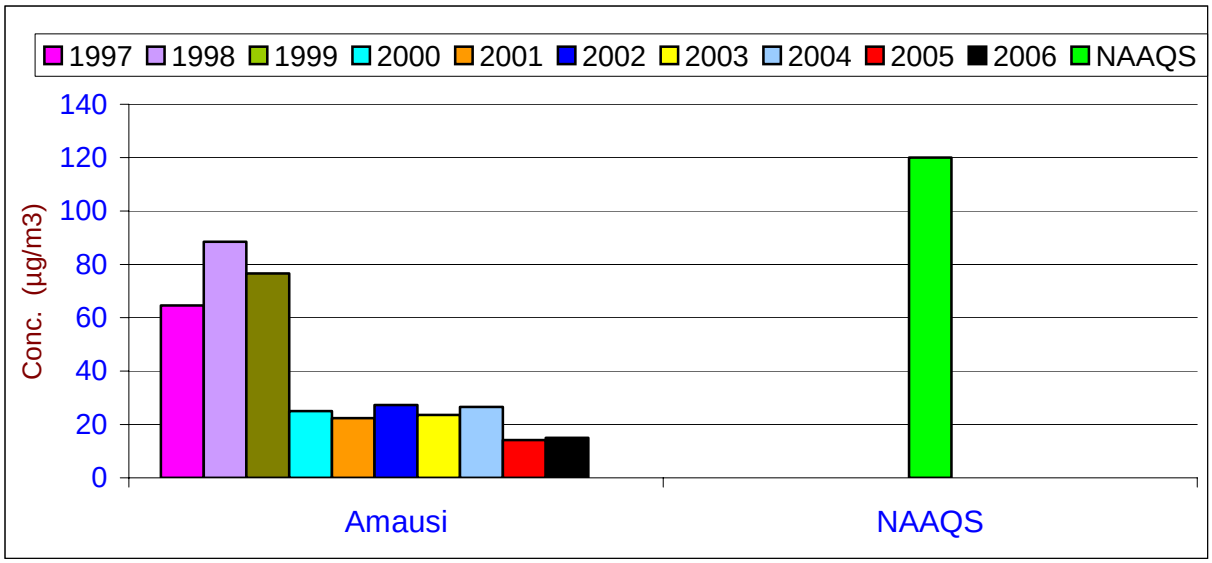


Figure-12: Trend of SO_2 during 1997-2006 in Industrial Area

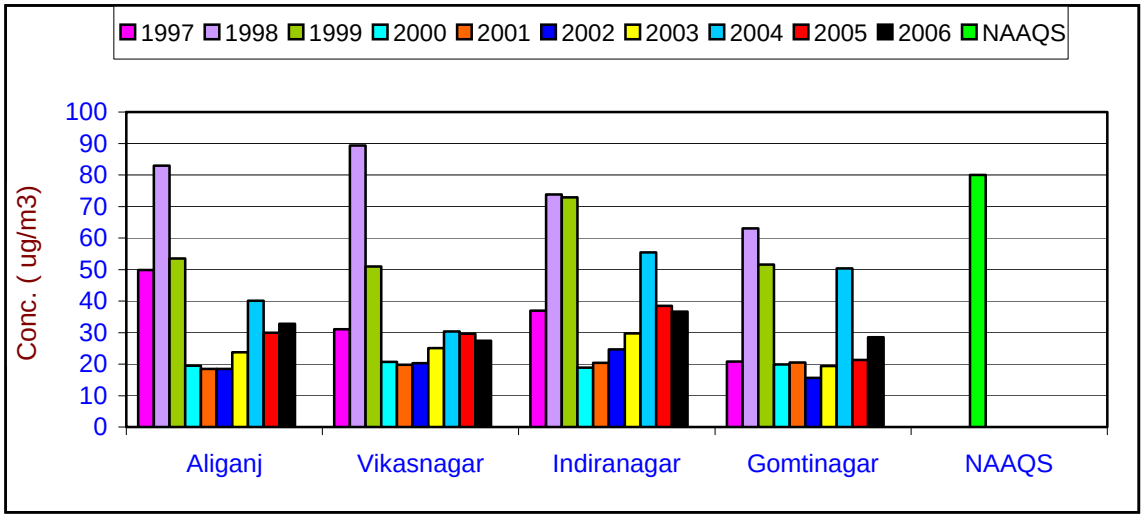


Figure-13: Trend of NOx during 1997-2006 in Residential Area

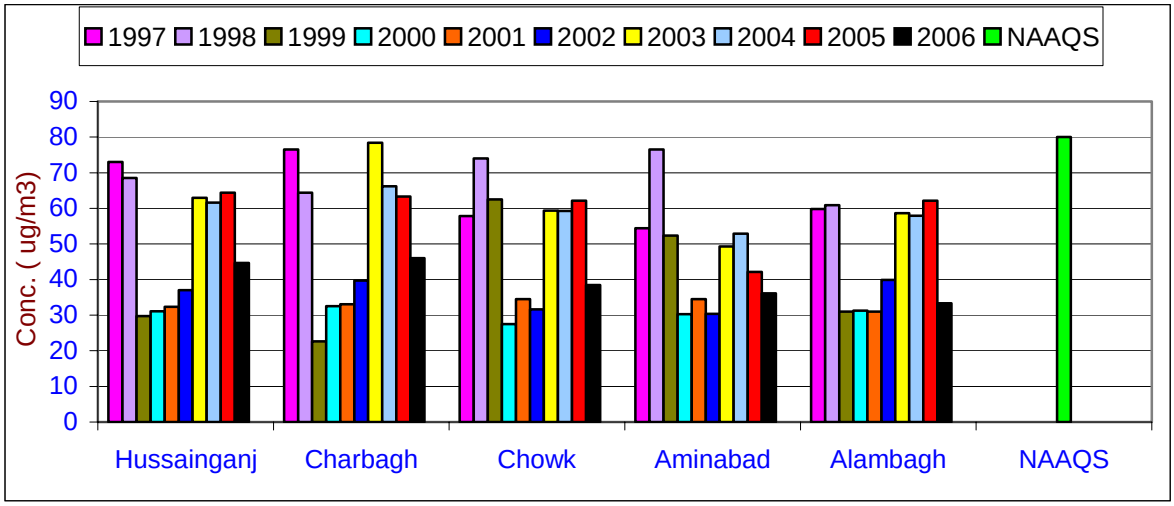


Exhibit-14: Trend of NOx during 1997-2006 in Commercial Area

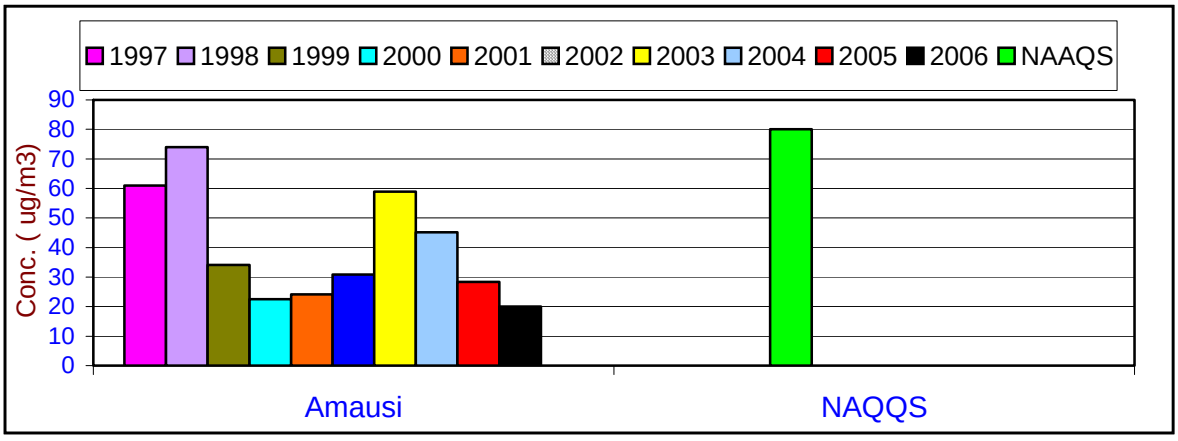


Figure- 15: Trend of NOx during 1997-2006 in Industrial Area

1.4.1.4 Lead (Pb)

Pb level in residential areas namely Aliganj, Vikasnagar, Indiranagar and Gomtinagar registered decreasing trend in comparison to last year (**Figure-16**).

All the locations of commercial areas, except Alambagh registered decreasing value over last year (**Figure-17**).

The only industrial area Amausi showed lower value when compared with the last year value (**Figure-18**).

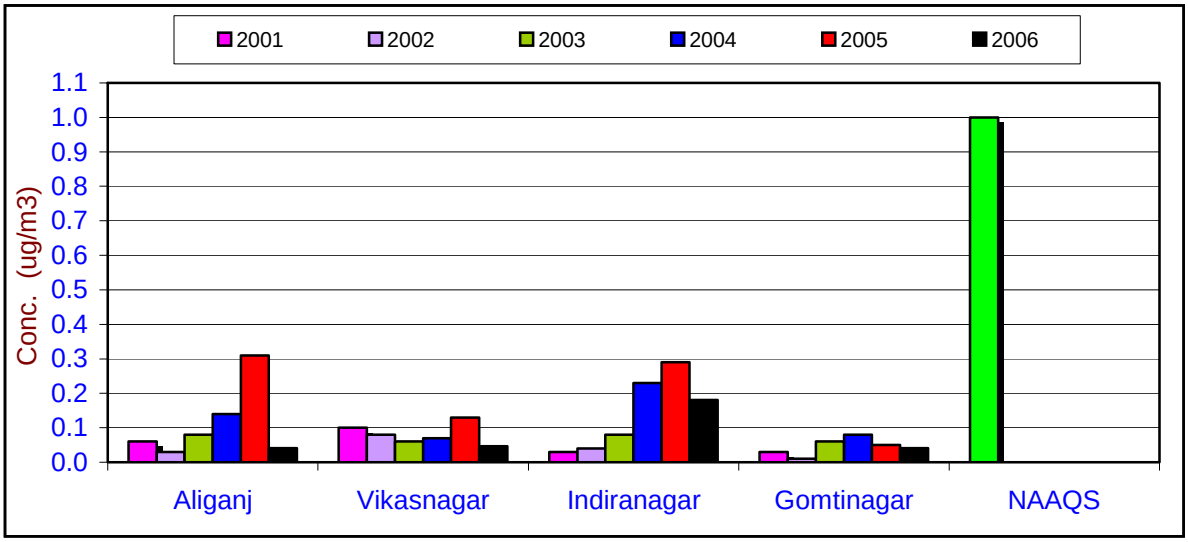


Figure-16: Trend of Pb during 2001-2006 in Residential Area

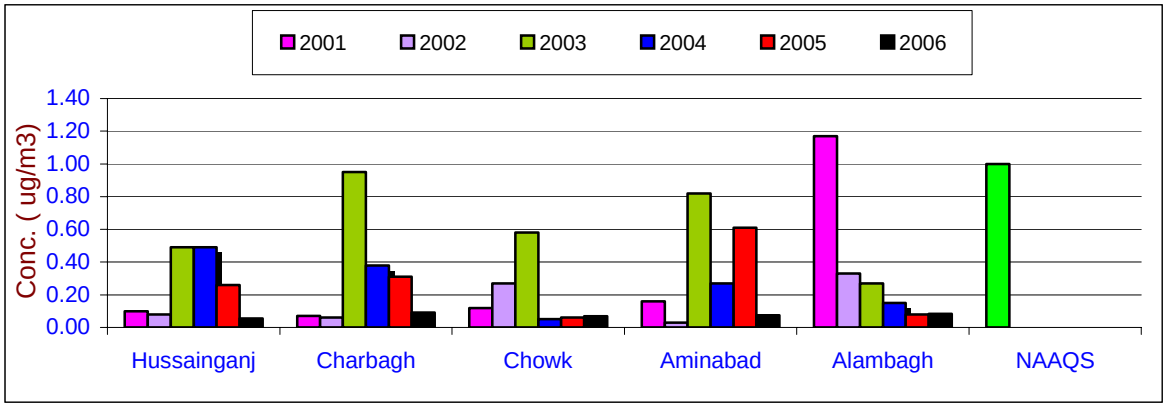


Figure-17: Trend of Pb during 2001-2006 in Commercial Area

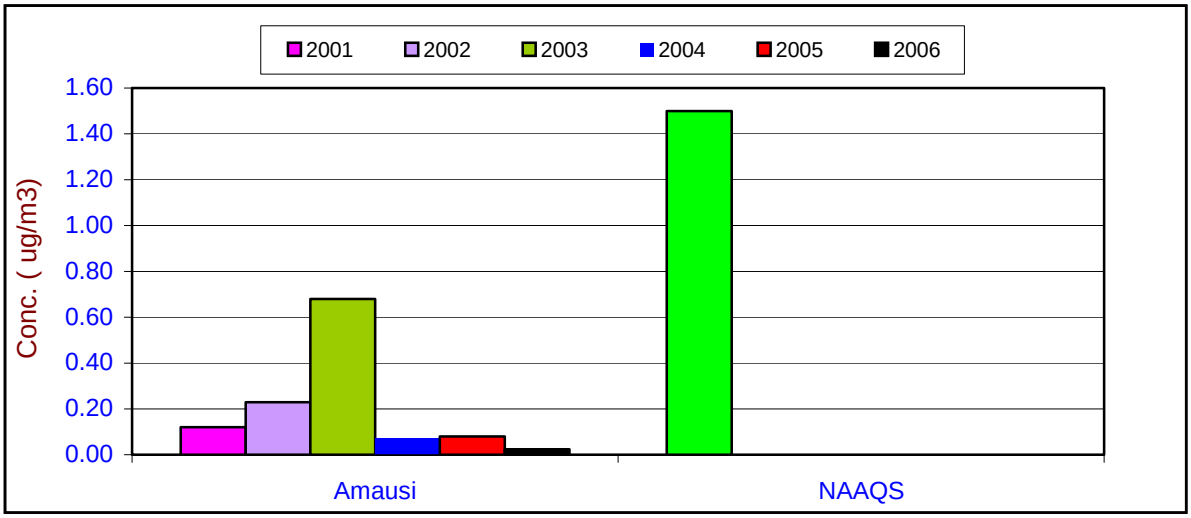


Figure- 18: Trend of Pb during 2001-2006 in Industrial Area

1.4.2 TRENDS OF NOISE LEVEL

Current year's noise data has been compared with the corresponding data of previous years and are presented in **Figure-19 to 24**. The comparative noise level in residential, commercial and Industrial areas is described below:

1.4.2.1 Day Time Noise Level

In residential areas slight increase was recorded at all the locations over the last year level (**Figure-19**).

In commercial cum traffic areas slightly higher levels were recorded at Hazaratganj, Chowk and Aminabad whereas at other locations slightly decreasing trends was recorded over the last year (**Figure–20**).

In industrial area, in both the locations the noise level was recorded higher over last year data. The comparative data are presented in **Figure-21**.

1.4.2.2 Night Time Noise Level

Amongst the four residential areas except Aliganj, where the level remained almost same, slight increase was recorded at the remaining locations over the last year level (**Figure–22**).

Among commercial areas, Charbagh and Chowk showed almost the same values as in the last, Hussainganj showed slightly higher values whereas Aminabad and Alambagh slightly lower values than the previous year (**Figure-23**).

Both the locations of industrial area registered a slight decrease in the noise level during night time over last year data (**Figure-24**).

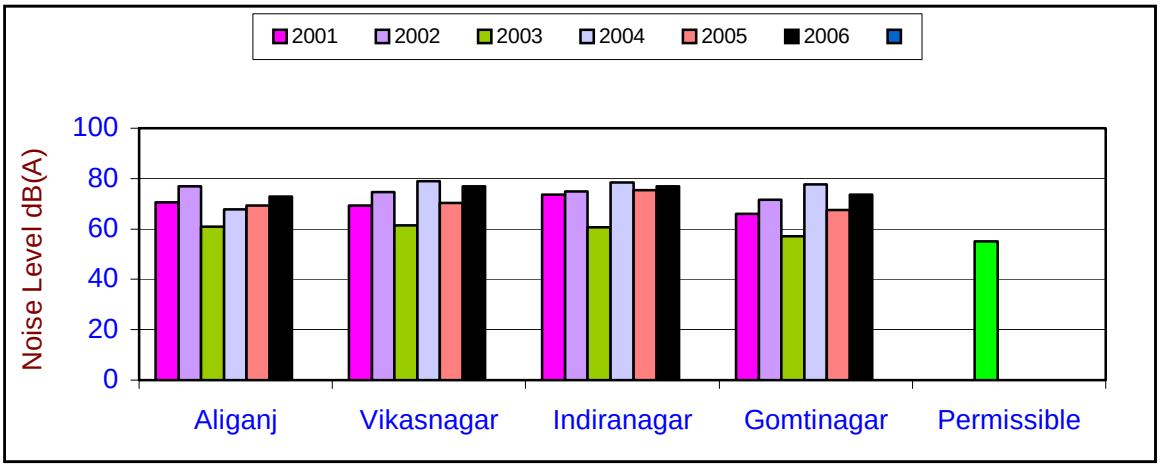


Figure-19: Comparison of Day Time Noise Level dB(A) in Residential Area dring 2001-2006

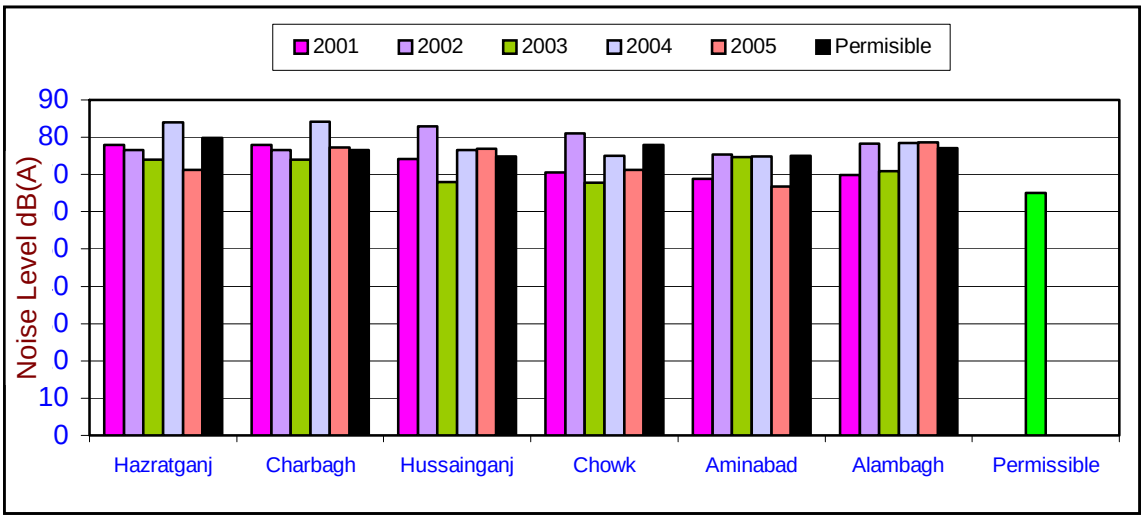


Figure-20: Comparison of Day Time Noise Level dB(A) in Commercial Area during 2001-2006

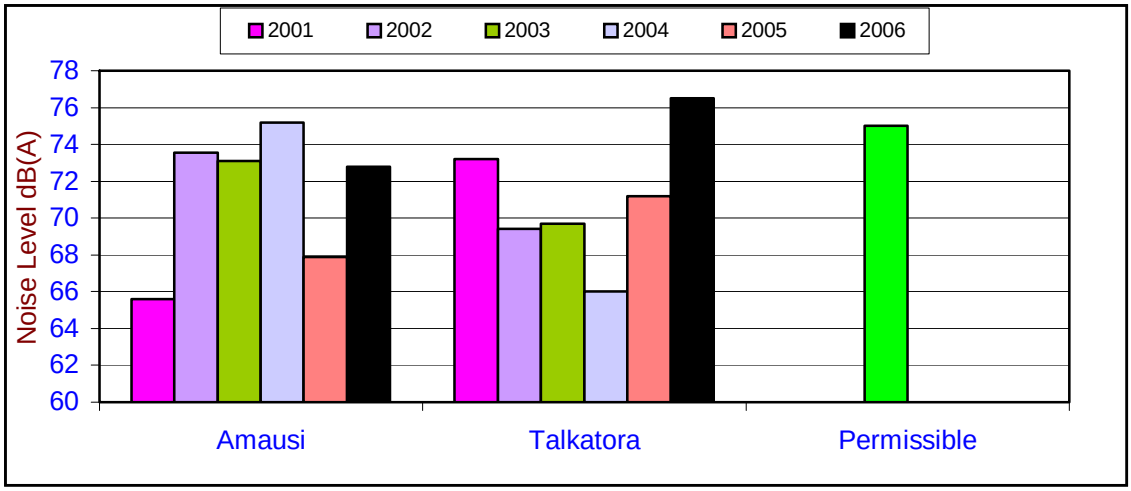


Figure-21: Comparison of Day Time Noise Level dB(A) in Industrial Area during 2001-2006

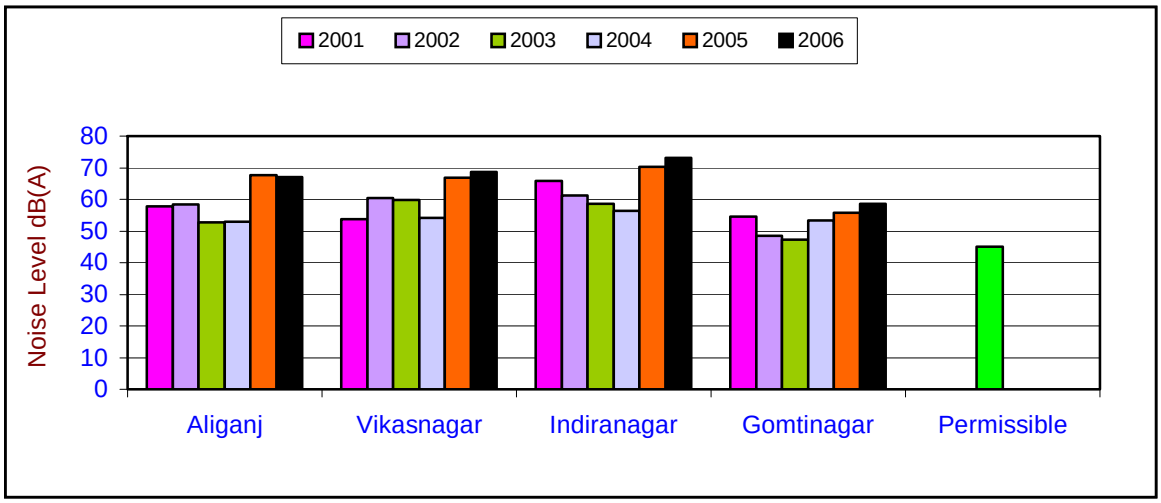


Figure-22: Comparison of Night Time Noise Level dB(A) in Residential Area during 2001-2006

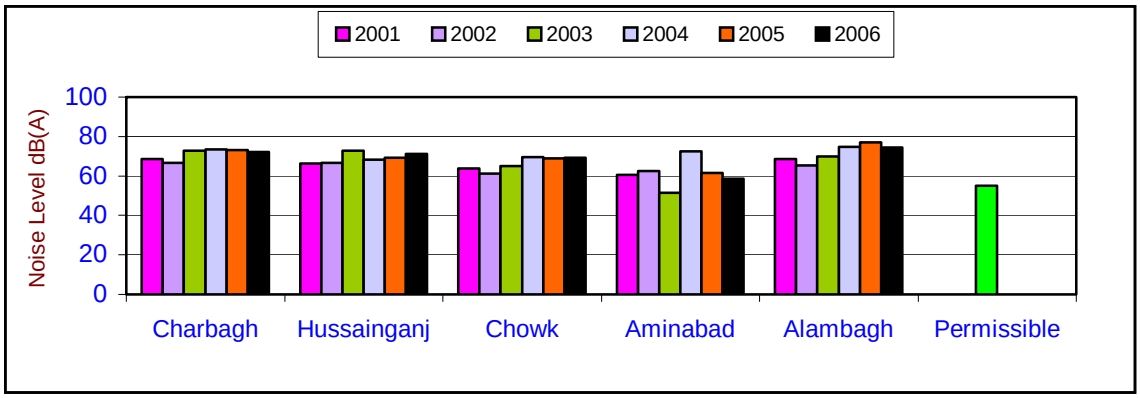


Figure-23: Comparison of Night Time Noise Level dB(A) in Commercial Area during 2001-2006

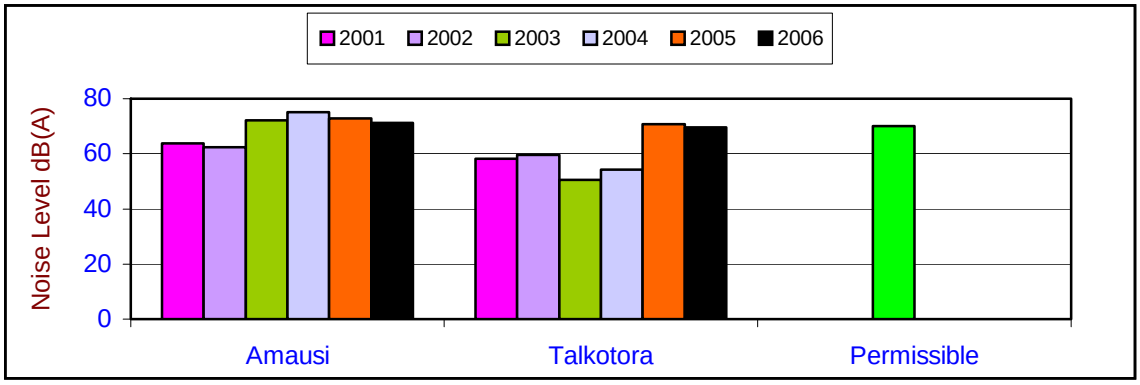


Figure-24: Comparison of Night Time Noise Level dB(A) in Industrial Area during 2001-2006

1.5 HEALTH HAZARDS OF AIR POLLUTANTS

1.5.1 Particulate Matter

Particles known as PM_{10} have a diameter less than 10 µm and when inhaled would penetrate beyond the larynx.

Particulate air pollution is associated with a range of effects on health including effects on the respiratory and cardiovascular systems, asthma and mortality. In addition, constituents of particulate matter, such as acid sulphates, may irritate the upper airway and deep lung, reduce bronchial clearance, and modify the lung's resistance to infection.

Action/Effects:

- Small particles can penetrate deeply into the lung and result in bronco-constriction and an alteration in respiratory mechanisms.
- Ultra fine particles ranging from 0.001 to 0.1 micron in diameter are able to penetrate deep down into the lung and to the alveolar sacs where gaseous exchange occurs.
- Small particles penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory disease such as emphysema and bronchitis, and aggravate existing heart disease.
- They work by increasing both the rates of blood flow and vascular permeability to white blood cells, elevating clotting activity, constriction of the airways and fever induction.

1.5.2 Sulphur Dioxide (SO_2)

SO_2 is a colorless water-soluble gas. It smells like burnt matches. It can be oxidized to sulphur trioxide, which in the presence of water vapour is readily transformed to sulphuric acid mist. Sulphur dioxide is detectable to the human nose at concentrations of around 0.5–0.8 parts per million (1400–2240 μgm^{-3}).

Action/Effects:

- Exposure to concentrations of 10 to 50 parts per million for 5 to 15 minutes causes irritation of the eyes, nose and throat, choking and coughing.

- This causes a reflex cough, irritation, and a feeling of chest tightness, which may lead to narrowing of the airways, particularly likely to occur in people suffering from asthma and chronic lung disease, whose airways are often inflamed and easily irritated

- For nasal breathing with low to moderate volumes the penetration into the lungs is negligible.
- For oral inhalation and larger volumes, doses may reach the segmental bronchi
- Exposure of the eyes to liquid sulfur dioxide, (from, for example an industrial accident) can cause severe burns, resulting in the loss of vision.
- Repeated or prolonged exposure to moderate concentrations may cause inflammation of the respiratory tract, wheezing and lung damage
- Other health effects include headache, general discomfort and anxiety.

1.5.3 Oxides of Nitrogen (NO_x)

NOx causes a wide variety of health and environmental impacts because of various compounds and derivatives in the family of nitrogen oxides, including nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide.

NO_2 is a reddish-brown gas with a pungent and irritating odour. It transforms in the air to form gaseous nitric acid and toxic organic nitrates.

Nitrogen Dioxide (NO_2) can have both acute (short term) and chronic (long-term) effects on health, particularly in people with asthma. Its toxicity relates to its ability to form nitric acid with water in the eye, lung, mucus membrane and skin.

Action/Effects:

- Eye, nose, and throat irritation.
- NO2 causes inflammation of the airways.
- Long term exposure to NO2 may affect lung function.
- May increase the level of respiratory infections in children.
- Enhance the response to allergens in sensitized individuals.
- Lowering the resistance to diseases such as pneumonia and influenza.
- Extremely high-dose exposure (as in a building fire) to NO_2 may result in pulmonary edema and diffuse lung injury.
- Continued exposure to high NO_2 levels can contribute to the development of acute or chronic bronchitis.
- It can cause collapse, rapid burning and swelling of tissues in the throat and upper respiratory tract, difficult breathing, throat spasms, and fluid build-up in the lungs.
- It can interfere with the blood's ability to carry oxygen through the body, causing headache, fatigue, dizziness, and a blue color to the skin and lips.
- Industrial exposure to nitrogen dioxide may cause genetic mutations, damage a developing fetus, and decrease fertility in women.

- Industrial exposure to nitric oxide can cause unconsciousness, vomiting, mental confusion, and damage to the teeth.
- Exposure to low levels of nitrogen oxides in smog can irritate the eyes, nose, throat, and lungs and can cause coughing, shortness of breath, fatigue, and nausea.

1.5.4 Lead (Pb)

Action/Effects:

- Short-term exposure to high levels of lead can cause vomiting, diarrhea, convulsions, coma or even death.
- However, even small amounts of lead can be harmful, especially to infants, young children and pregnant women.
- Symptoms of long-term exposure are anemia and damage to the nervous system may cause impaired mental function.
- Other symptoms are appetite loss, abdominal pain, constipation, fatigue, sleeplessness, irritability and headache.
- Continued excessive exposure, as in an industrial setting, can affect the kidneys.
- Lead exposure is most serious for young children because they absorb lead more easily than adults and are more susceptible to its harmful effects.
- Even low-level exposure may harm the intellectual development, behaviour, size and hearing of infants.
- During pregnancy, especially in the last trimester, lead can cross the placenta and affect the unborn child.
- Female workers exposed to high levels of lead have more miscarriages and stillbirths.

1.5.5 Formaldehyde (HCHO)

Action/Effects:

- Eye, nose and throat irritation; wheezing and coughing, fatigue, skin rash, severe allergic reaction.
- May cause cancer.

1.5.6 Noise

Elevated levels of noise have

- Adverse effects varying from hearing loss to annoyance.

- Noise produces both temporary and permanent hearing loss. Noise can range from the bursting of the eardrum to permanent hearing loss.
- Cardiac and cardiovascular changes, stress, fatigue, dizziness, lack of concentration.
- Cause of accident, irritation, inefficiency, deterioration in motor and psychomotor functions, nausea, interference with work tasks and speech communication, headaches, insomnia and loss of appetite and many others.
- Continuous noise causes an increase in cholesterol level resulting in constriction of blood vessel making prone to heart attack and stress.
- Annoyance and psychological damage would occur at much lower noise levels.

1.6 DISSCUSSION

The automobile exhaust directly influences ambient air quality in urban area. The factors involved are already discussed earlier. Overall the pollution levels show an increasing trend with respect to RSPM, SO_2 and HCHO and decreasing trend with respect to NOx and Pb content when compared with previous year results.

The particles emitted by motor vehicles are mostly black carbon soot. Vehicular exhaust consists of mainly thoracic and alveolar particles (PM<10 and <2.5 µm respectively), which are mainly responsible for morbidity and mortality in the urban area. All the RSPM monitoring result presented in **Table-10** showed higher concentration than the permissible limit except Amausi. In our country the NAAQS for RSPM (PM_{10}) is comparatively higher than the US-EPA and EC (European Commission) prescribed limit. The annual daily limit has been fixed by EPA (1996) is 50 µg/m^3 and new EC directive establish 20 µg/m^3 and the 24 hour limit value of 50 µg/m^3, which can not be exceeded for more than 7 days/year.

The RSPM (PM_{10}) level due to automobile exhaust generally dominated by the fine (<2.5 µm) and ultra fine particle (<0.1 µm) are major concern with health hazard within short period of exposure. These particles usually contain most of the trace elements and toxins due to their higher diffusion coefficient and penetrate deeper into pulmonary interstitial spaces in the lungs provoking inflammation. This response is hypothesised to depend less upon the mass of the particles than on their number and size distribution.

There is scarcity of data regarding the mechanism of toxicity on human health. On the other hand the researchers are working especially to find out the threshold limit.

The effect of pollutant especially the particulate matter in urban areas depends on several factors like number of concentration, size composition, time of exposure, and

lastly the receptor (In case of humans these factors depend on age, health conditions, etc.).

Thus it is necessary to monitor the air quality as well as the health effects on regular interval at strategic locations. Our short term monitoring survey might be of help to focus on the pollution level in Lucknow city and its probable consequences. Our data base since 1997 will also help the planners for sustainable development of the city.

1.7 CONCLUSIONS

The higher growth of vehicular population and individualism is a matter of concern because that the system becoming automobile dependence which not only effect the environment also effect the economic and social aspect and not viable for sustainable developments for any cities or community.

Civilizing the car through technological advances is part of the solutions but it insufficient because the sheer volume of cars overwhelms cities. Despite doubling in fuel efficiency for new cars, increased the oil consumption. Heavy oil dependence is a significant threat to the sustainability of many cities as well as the countries.

Now it is evident that major problem arises for space occupied by cars (Parking space), which is not reduced by better technologies. A car required at least three parking spaces (residence, working place, market etc.).

So it is need of the hour to recognise the costs to the environment are real cost there is no simple choice between expensive environmental protection option and a cheap option trying to ignore environmental impacts.

1.8 RECOMMENDATION

- Public mass transport must be strengthened to reduce personal vehicle on the road.
- Traffic rule must be strictly enforced.
- Encroachment should be removed for smooth flow of traffic.
- Improvement of fuel quality and checking of fuel adulteration.
- Public awareness programme for automobile pollution is essential.
- Pressure horn must be banned.
- Green belt must be developed.

2.0 BACTERIOLOGICAL QUALITY OF DRINKING WATER IN LUCKNOW CITY

2.1 INTRODUCTION

Drinking water is one of the basic needs of life and essential for survival. According to the World Health Organization (WHO) report, approximately 2.5 billion people in developing world and about 80% disease worldwide are associated with contaminated drinking water. Several water born diseases are due to consumption of contaminated drinking water, particularly in undeveloped and developing countries.

In Lucknow city the prime source of municipal water supply is Gomti River flowing through the middle of city and booster pumps getting ground water through tube wells to supplement the piped supply in different areas of the city. The major source of water contamination is the faecal wastes of sewage. Apart from this, broken pipes and loose joints in the distribution system are also responsible for water contamination through seepage and back suction of sewage. More often improper cleaning and maintenance of overhead tanks and water reservoirs in water works as well as unhygienic conditions at consumers' level have been found to be responsible for water contamination. In addition to these, inadequate chlorination at the source of supply is also responsible for improper disinfections of supplied drinking water at consumers end.

2.2 MICROBIAL AGENTS OF WATER BORNE DISEASES

The pathogenic bacterium causes several water borne diseases like diarrhoea, gastroenteritis, cholera, dysentery, typhoid, amoebiasis, giardiasis, meningitis, poliomyelitis, encephalitis, hepatitis, schistosomiasis etc. Gastroenteritis, cholera, dysentery and typhoid are most common in tropical as well as subtropical countries particularly in warmer months. The causative bacteria of these diseases are *Escherichia coli*, *Vibrio cholerae, Shigella dysentriae* and *Salmonella typhimurium*, respectively.

2.3 WATER SAMPLING

A water quality surveillance (pre-monsoon) of drinking water from piped water supplies and ground water sources (hand pumps and tube wells) in Lucknow city has been conducted during April - May 2006. On the basis of usage, whole city has been divided in three areas viz. residential, commercial and industrial areas based on the population and social activities. The localities identified for the survey are: Aliganj, Vikasnagar, Indiranagar, Gomtinagar, Paper Mill Colony, Niralanagar, Triveninagar, Rajajipuram, Model House, Ashiana and Sadar Cantt. in residential area. Charbagh,

Alambagh, Chowk, Hazratganj, Hussainganj and Aminabad in commercial area along with Aishbagh, Amausi and Talkatora in industrial area. Fifty-five samples from residential area, thirty from commercial area and fifteen from industrial area were collected. All the hundred water samples were collected in sterilized glass bottles and analysed for their bacteriological quality assessment by determining the most probable number (MPN) of coliforms and faecal coliforms per 100 ml of sample according to standard methods BIS and APHA.

2.4 CONCLUSION AND RECOMMENDATIONS

In residential area 20% samples (11/55), in commercial area 13% sample (04/30) and in industrial area 26% sample (04/15) were found to be contaminated with ≥10 coliform and /or no faecal coliform as per Indian standard for drinking water of Bureau of Indian Standard (BIS, 2003). The analysis shows that bacterial contamination is more in samples from commercial areas than that from remaining two areas. Source-wise observations revealed that 30% piped supply and 08% of ground water samples from hand pumps were found bacteriologically unsafe for drinking purpose in the Lucknow city (**Table-15 & 16**). Therefore, it requires periodic water quality monitoring with special emphasis on proper disinfections and maintenance of drinking water sources.

Table -15: Bacteriological Quality of Drinking Water in Lucknow City,

Sl. No.	Areas	Locations	Total No. of Sample	Coliform* conta-minated samples	Faecal coliform* conta-minated samples	Total No. Samples with ≥ 10 coliform and/or ≥ faecal coliform	Source of conta-minated sample	Total Conta-minated Samples
1	RESI-DENTIAL	Aliganj	5	1	1	1	**PS**	**11 / 55** 20.00%=20%
2		Vikasnagar	5	0	0	0	**-**	
3		Indiranagar	5	1	1	1	**PS**	
4		Gomtinagar	5	1	0	1	**HP**	
5		Paper Mill Colony	5	0	0	0	**-**	
6		Nirala Nagar	5	1	1	1	**PS**	
7		Triveni Nagar	5	2	2	2	**PS & HP**	
8		Rajajipuram	5	1	1	1	**PS**	
9		Model House	5	2	1	2	**PS& HP**	
10		Ashiana	5	1	0	1	**PS**	
11		Sadar Cantt.	5	1	1	1	**PS**	
12	COM-MERCIAL	Charbagh	5	0	0	0	**-**	04 / 30 13.33%=13%
13		Alambagh	5	1	1	1	**PS**	
14		Chowk	5	1	1	1	**PS**	
15		Hazratganj	5	2	2	2	**PS**	
16		Hussainganj	5	0	0	0	**-**	
17		Aminabad	5	0	0	0	**-**	
18	INDUST-RIAL	Amausi	5	1	1	1	**PS**	04 / 15 26.67%=27%
19		Talkatora	5	1	1	1	**PS**	
220		Aishbagh	5	1	2	2	**PS& HP**	
	Total		100	18	16	19	**PS – 15 HP – 04**	**19 / 100** 19.00%

* Samples with >10 coliform/100 ml and / or >1 faecal coliform/100 ml as per Indian Standard for Drinking Water Specifications of Bureau of Indian Standard (BIS, 2003).

Total piped supply (PS) water samples collected = 50

Total piped supply (PS) water samples contaminated = 15/50 (30%)

Total ground water (GW) samples of hand pumps collected = 50

Total ground water (GW) samples of hand pumps contaminated = 04/50 (08.00%)

Table-16: Contamination profile of drinking water in Lucknow city - pre-monsoon 2006

Area	Piped supply water (PS)		Ground water (GW)		Total samples	
	No. of sample analysed	No. of Contaminated samples (%)	No. of sample analysed	No. of Contaminated samples (%)	No. of sample analysed	No. of Contaminated samples (%)
Residential	28	08 (28.6)	27	03 (11.1)	55	11 (20.0)
Commercial	16	04 (25.0)	14	00 (00.0)	30	04 (13.3)
Industrial	06	03 (50.0)	09	01 (11.1)	15	04 (26.7)
Total	50	15 (30.0)	50	04 (08.0)	100	19 (19.0)