ASSESSMENT OF ENVIRONMENTAL STATUS

OF

LUCKNOW CITY

(POST-MONSOON)
FINDINGS OF A RANDOM SURVEY

PRESENTED ON 44th IITR FOUNDATION DAY

INDIAN INSTITUTE OF TOXICOLOGY RESEARCH
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4th November, 2009

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Salient Features of the Study

❖ **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
❖ **Projected Population**	**:**	45 lakhs as per *Master Plan 2021*
❖ **Climate**	**:**	Subtropical climate, cool dry winter (Dec.-Feb.) and summer (Mar-Jun). Temperature about 45^{0}C in summer to 3^{0}C in winter. Average annual rainfall about 100 cm.
❖ **Total Vehicle Population In the Lucknow city as on 31/03/2009**	**:**	10,50,834
❖ **Growth of Vehicle over 2008-2009**	**:**	8.34%
❖ **Total Number of Petrol Pumps**	**:**	89
❖ **Consumption of Petrol**	**:**	96,982 KL
❖ **Consumption of Diesel**	**:**	99,353 KL
❖ **Major Sources of Pollution**	**:**	Automobiles, D. G. sets, Civil Construction
❖ **Parameters Monitored**	**:**	SPM, RSPM, SO_2, NO_X and Noise
❖ **Study Conducted by**	**:**	Environmental Monitoring Section IITR, Lucknow

1. INTRODUCTION

Prolonged, uncomfortable hot summer and delayed, erratic, abrupt monsoon which have recently been felt in Lucknow city and other parts of India is an indication of rapid qualitative and quantitative deterioration of environmental components and also urban atmosphere. Pollutant concentrations in terms of Suspended / Respirable Particulate Matter (SPM and RSPM) in urban atmosphere of Lucknow city has been found to be 2 to 5 times higher than the National Ambient Air Quality Standard (NAAQS) and is perceived to be the price paid for urbanization, high economic growth and modern life style. Urbanization of Lucknow city is happening at a very fast pace and it is growing in stature as well as in geographical area and it is almost in the same league as metropolitans now. Due to haphazard, awkward and improper development; upcoming residential areas are engulfing some of the major industries like HAL, Mohan Meakin Ltd. and industrial estates like Talkatora and Amausi. Urbanization is taking place at the cost of environment and ambient air quality. As a result, people of the surrounding areas have to bear with unpleasant odours and high noise and ill effects of air pollutants emitted by these industries.

When multi-complex potentially hazardous pollutants are discharged at a rate that exceeds its capacity to dispose them by dilution and air currents leads to build up of urban air pollution and may be the source of continuous exposure of public life and threatens the community health. Air pollution is not only detrimental to the atmosphere but also has adverse effects on human and animal health. These may be acute in form of irritation of eyes and respiratory tract as well as chronic in the form of chronic bronchitis, pulmonary emphysema, bronchial asthma, cardiovascular problems and lung cancer. Older and young population is mostly susceptible to exposure to air pollutants at high concentration or low concentration for a longer period.

Keeping in mind the rising air pollution problems in Indian cities, Environmental Monitoring Section of Indian Institute of Toxicology Research, Lucknow initiated random survey of air pollution and noise measurement in Lucknow city in May 1997 and has been doing it since then.

This study is being conducted twice in a year (pre monsoon - May and post monsoon - October) with the following aims and objectives.

- ✓ *To assess the ambient air quality with respect to SPM, RSPM, SO_2 and NO_X.*
- ✓ *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 create a database for future use.*
- ✓ *To create public awareness about environmental pollution.*

The present study is being conducted during the month of September-October, 2009 representing the post monsoon period.

Vehicular congestion in residential areas and near schools during peak hours has increased due to increase in number of vehicles as more people opt for private transport over public transport for comfort and safety. Auto exhaust has been identified as one of the major contributor of city's air pollution. Some of the important air pollutants directly discharged by the vehicular emissions are particulates (coarse, fine and ultrafine), SO_2, NOx, CO, CO_2, HCHO, benzene, polycyclic aromatic hydrocarbons, heavy metals, asbestos, volatile organic compounds (VOCs) and also formed secondary pollutants (ozone, photochemical smog, nitrates, sulfates) and other compounds through chemical reaction.

As per 2001 census Lucknow has a population of 22.45 lakhs (Municipal corporation + Cantonment). Total vehicle of different categories registered with RTO, Lucknow during 2008-2009 were 10,50,834 as against 9,69,915 during 2007-2008. The overall growth registered is 8.34% during 2008-2009 **(Table 1).**

Table 1: Registered Vehicle with R.T.O. Lucknow during 2007- 08 and 2008- 09

Sl. No.	Type of Vehicle	Number of Registered Vehicles On 31st March		% increase in the number of vehicles
		2008	2009	
1	Commercial vehicles	34,906	40,229	15.25%
2	Three Wheelers and Auto Rickshaw	13,224	19,963	50.96%
3	Two wheelers	7,71,846	8,26,083	7.03%
4	Four Wheeler	1,46,654	1,60,489	9.43%
5	Others	3,285	4,070	23.89%
Total		9,69,915	10,50,834	8.34%

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. The details of bus routes and number of buses plying as on 31.03.2009 are given in Table 2.

Table 2: Details of Lucknow city bus service, 2009

Sl. No.	Route No.	To and Fro	No. of Buses
1	11	Chinhat-Gomti Nagar-Alambagh	31
	11 A	Chinhat-Gomtinagar-Dalibagh-Charbagh	
	11B	Chinhat-Gomtinagar-Charbagh-SGPGI	
	11C	Charbagh-Uttaria-Sardar Patel Dental college	
	11D	Charbagh-Babasaheb Bhimrao Ambedkar-BB	
	11E	Charbagh-Telibagh-Ganesh Kunj	
2	12	Chinhat-Scooter India	6
3	23	Rajinikhand-Gudamba thana	13
4	24	Charbagh - Engineering College	14
5	25	Charbagh-Bijnor	02
6	31	Alambagh – IIM	02
7	33	Alambagh- Engineering College	15
8	34	Alambagh-Charbagh-Hazratganj-Kapoorthala-Keshavnagar	01
9	44	Charbagh-Andhi Chowki	09
10	45	Parag Dairy – Polytechnic Chowraha	10
11	66	GPO- Hazratganj-Rajajipuram	02
12	Shuttle service	Charbagh-Alambagh	03
		Total	108

Source: UPSRTC, Lucknow

In Lucknow city there are 89 petrol pumps operated by four oil companies. The break-up of these petrol pumps are given in **Table 3.**

Table 3: Petrol Pumps in Lucknow City

Sl. No.	Agency	Number of outlet 31st March 2009
1	Indian Oil Corporation (IOC)	45
2	Bharat Petroleum Corporation Ltd. (BPCL)	19
3	Hindustan Petroleum Corporation Ltd. (HPCL)	22
4	Compressed Natural Gas Stations (CNG)	3
Total		89

Source: Indian Oil Corporation (IOC), Lucknow

The sales figure of oil companies for the year (2008-09) has been compared with sale figure of 2007-08 **(Table 4)**. It is observed that petroleum sale have been increased marginally by 7.53% whereas sale of diesel has increased by 18.81%.

Table 4: Consumption of Fuel (in KL) in Lucknow

Sl. No.	Agency	Petrol (Unleaded)			High Speed Diesel		
		Apr. 07 to Mar. 08	Apr. 08 to Mar. 09	% increase in consumption	Apr. 07 to Mar. 08	Apr. 08 to Mar. 09	% increase in consumption
1	IOC	49410	53325	7.92	52248	61231	17.19
2	BPCL	25524	26728	4.71	16318	18889	15.75
3	HPCL	15253	16929	10.99	15052	19233	27.78
Total		90187	96982	7.53	83618	99353	18.81

Source: Indian Oil Corporation (IOC), Lucknow

1.1 MONITORING LOCATIONS AND METHODOLOGY

1.1.1 AIR QUALITY

Ten air quality monitoring locations representing different activities/areas i.e., four in residential, five in commercial cum traffic and one industrial area were selected for the study as summarized in **Table 5** and methodology is given in **Table 6**.

Table 5: Air Quality Monitoring Locations

Sl. No.	Locations	Activity
1	Aliganj	Residential
2	Vikas Nagar	
3	Indira Nagar	
4	Gomti Nagar	
5	Hussainganj	Commercial cum traffic
6	Charbagh	
7	Alambagh	
8	Aminabad	
9	Chowk	
10	Amausi	Industrial

The brief description of each sampling site is 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 transportations are jeep, city buses, three wheeler (Vikram and tempo) which use diesel fuel and CNG. Monitoring location was at CSIR Scientist Apartments, Sector K, near main road.

II. Vikas Nagar

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

III. Indira Nagar

Indira Nagar is now a semi commercial area. In this area, the means of public transport is Jeep and buses running on diesel. In day time, main sources of vehicular emission are public transport, two wheelers and passenger cars. The main Ring Road pass through Indira Nagar 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 Ring Road.

IV. Gomti Nagar

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

V. Hussainganj

At Hussainganj, the monitoring location was 40 m 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 has a high traffic flow. The major source of pollution is auto exhaust from mixed type of vehicles including buses and trucks during night hours. Another important source is diesel locomotive. It is one of the busiest places in Lucknow city. The monitoring location was near the main traffic junction.

VII. Alambagh

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 day time, 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 of shopping complexes. Aminabad serves as major shopping area for Lucknowites. The whole area is congested having narrow lanes and mixed traffic ranging from bicycles, rickshaws, two wheeler to 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 pass 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 m away from the main Lucknow - Kanpur road.

Table 6: Methodology for Air Quality Monitoring

Particulars	SPM	RSPM	SO_2	NOx
Sampling equipment	HVS	RDS	HVS/RDS with gaseous sampling attachment	
Collection media	Glass Fibre		Sodium Tetra Chloro-Mercurate	NaOH
Flow rate	1.0-1.3 m^3/min		0.5 L/min	
Analytical method	Gravimetric		Spectrophotometric	
Frequency	24 hourly		8 hourly	
Sampling duration	Continuous for 24 hours			
No. of days of sampling at each location	6 days (Twice a week)			

HVS: High Volume Sampler, RDS: Respirable Dust Sampler

1.1.2 NOISE LEVEL MEASUREMENTS

The measurement of noise level was carried out at twelve locations for 30 minutes at each location during the day time (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., ~1.5m above the ground level. The location for the noise level measurement is given in **Table 7**.

Table 7: Noise Monitoring Locations

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

2 RESULTS

2.1 AIR QUALITY

The detailed results of air quality monitoring of post monsoon season are presented in **Table 8 & 9** and **Fig. 1**.

2.1.1 PARTICULATE MATTER (RSPM and SPM)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar); the average concentrations of RSPM and SPM were in the range of 132.3 to 177.0 and 263.2 to 337.8 µg/m^3 respectively.

In commercial areas (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk); the average concentrations of RSPM and SPM were in the range of 169.3 to 204.0 and 304.5 to 397.7 µg/m^3 respectively.

In industrial area (Amausi); the average concentration of RSPM and SPM were found to be 165.7 and 304.7 µg/m^3 respectively.

All the values of RSPM were above the prescribed National Ambient Air Quality Standard (NAAQS) of 100 and 150 µg/m^3 for residential/commercial and industrial area respectively. All the values of SPM were above the NAAQS of 200 µg/m^3 in residential, rural and other areas whereas it was less than 500 µg/m^3 (NAAQS for industrial area) at Amausi.

Table: 8 Concentration (µg/m^3) of SPM, RSPM, SO_2 and NOx during post monsoon 2009

Location	Days	SPM	RSPM	SO_2				NOx			
				A	B	C	Mean	A	B	C	Mean
Aliganj	I	262	116	13.1	8.8	5.0	**9.0**	20.3	15.3	15.0	**16.8**
	II	262	143	13.4	10.7	11.1	**11.7**	22.3	25.6	17.6	**21.8**
	III	273	135	11.9	13.4	10.0	**11.8**	21.3	20.8	23.1	**21.7**
	IV	277	133	11.0	11.2	9.6	**10.6**	21.1	20.0	21.1	**20.7**
	V	240	121	13.3	10.5	12.7	**12.1**	22.0	20.2	20.1	**20.8**
	VI	265	146	12.8	10.7	9.5	**11.0**	22.6	24.9	23.6	**23.7**
	Avg	**263.2**	**132.3**				**11.0**				**20.9**
Vikas Nagar	I	289	155	10.4	11.6	12.3	**11.4**	21.4	22.2	20.4	**21.3**
	II	304	186	12.9	12.8	5.6	**10.4**	24.8	22.8	20.3	**22.7**
	III	280	131	13.1	11.5	10.8	**11.8**	21.0	19.7	14.3	**18.4**
	IV	285	147	15.0	11.6	11.2	**12.6**	23.2	18.5	15.6	**19.1**
	V	301	182	15.1	11.1	14.6	**13.6**	22.5	19.6	18.3	**20.1**
	VI	295	132	13.6	12.6	11.7	**12.6**	21.8	20.0	17.0	**19.6**
	Avg	**292.3**	**155.5**				**12.1**				**20.2**
Indira Nagar	I	363	198	18.1	17.0	8.5	**14.5**	32.5	34.7	21.9	**29.7**
	II	341	183	13.5	18.4	10.3	**14.1**	29.1	34.5	28.1	**30.5**
	III	311	152	13.6	12.8	11.7	**12.7**	28.5	26.2	27.1	**27.3**
	IV	279	172	14.7	14.0	12.8	**13.8**	25.7	27.7	26.2	**26.5**
	V	339	158	13.9	12.5	11.0	**12.5**	29.2	24.8	28.3	**27.4**
	VI	394	199	13.8	13.0	10.4	**12.4**	26.6	23.7	22.1	**24.1**
	Avg	**337.8**	**177.0**				**13.3**				**27.5**
Gomti Nagar	I	316	152	15.2	14.2	12.2	**13.9**	23.0	21.2	22.6	**22.3**
	II	303	137	15.6	13.4	13.0	**14.0**	25.8	23.7	25.0	**24.8**
	III	284	165	15.2	14.3	15.4	**14.9**	27.2	25.2	24.7	**25.7**
	IV	326	126	16.1	14.5	13.6	**14.7**	28.2	24.8	21.7	**24.9**
	V	339	132	14.0	11.9	13.5	**13.1**	25.1	20.4	25.8	**23.8**
	VI	305	184	13.0	12.9	14.7	**13.5**	27.2	26.5	23.4	**25.7**
	Avg	**312.2**	**149.3**				**14.0**				**24.5**
Hussainganj	I	325	191	17.3	10.0	12.8	**13.4**	26.7	19.3	15.3	**20.4**
	II	330	185	13.5	13.1	11.9	**12.8**	22.4	21.7	18.2	**20.7**
	III	337	188	15.0	13.7	15.3	**14.7**	22.7	21.9	17.7	**20.8**
	IV	313	162	17.7	15.3	9.2	**14.1**	26.0	24.6	15.9	**22.2**
	V	297	145	17.5	11.8	15.2	**14.8**	26.4	18.9	20.1	**21.8**
	VI	225	154	17.1	11.8	15.2	**15.8**	27.0	19.8	17.3	**21.3**
	Avg	**304.5**	**170.8**				**14.3**				**21.2**

Table 8 Continued…

Table 8 continued….

Location	Days	SPM	RSPM	SO_2				NO_X			
				A	B	C	Mean	A	B	C	Mean
Charbagh	I	472	163	15.3	15.7	14.3	**16.1**	34.7	34.8	35.6	35.1
	II	384	177	16.7	23.6	12.7	**17.6**	32.3	33.1	26.0	30.5
	III	308	175	18.9	13.6	9.5	**14.0**	38.3	36.1	30.2	34.9
	IV	304	162	17.3	15.6	14.5	**15.8**	33.7	33.1	35.9	34.3
	V	376	174	18.0	17.5	17.2	**17.5**	35.7	38.0	37.4	37.0
	VI	362	165	18.4	14.6	15.5	**16.1**	36.5	33.0	39.3	36.3
	Avg	**367.7**	**169.3**				**16.2**				**34.7**
Alambagh	I	358	184	14.3	15.6	14.0	**14.6**	28.4	29.5	30.1	29.3
	II	367	211	17.8	14.7	15.3	**15.9**	33.2	32.1	32.8	32.7
	III	435	208	14.6	18.8	13.9	**15.8**	32.5	37.4	37.8	35.9
	IV	381	185	14.3	15.6	11.2	**13.7**	32.5	39.5	31.0	34.4
	V	412	213	15.1	17.3	10.3	**14.2**	29.9	36.3	33.8	30.0
	VI	433	223	18.5	12.8	12.0	**14.4**	36.8	28.3	30.1	31.7
	Avg	**397.7**	**204.0**				**14.8**				**32.3**
Aminabad	I	343	201	15.7	14.7	12.4	**14.3**	36.4	32.8	28.8	32.7
	II	336	198	15.4	16.3	15.1	**15.6**	38.5	36.2	29.0	34.6
	III	343	162	17.3	14.7	12.5	**14.8**	32.7	30.8	23.1	28.3
	IV	366	155	15.4	15.8	13.5	**14.9**	29.2	33.1	17.9	26.7
	V	284	209	16.6	19.6	10.6	**15.6**	31.4	41.2	24.6	32.4
	VI	299	159	15.2	13.9	11.7	**12.6**	36.7	37.7	30.9	35.1
	Avg	**328.5**	**180.7**				**14.8**				**31.6**
Chowk	I	409	199	19.6	13.9	18.4	**17.3**	33.3	28.3	34.8	32.1
	II	412	191	20.6	15.6	10.3	**15.5**	38.3	31.7	29.5	33.2
	III	364	186	16.6	16.2	16.1	**16.3**	33.0	34.4	32.0	33.2
	IV	301	154	23.4	11.7	10.4	**15.2**	46.5	30.5	30.9	36.0
	V	375	157	19.1	17.9	13.0	**16.7**	36.4	32.1	20.8	29.8
	VI	372	164	15.6	13.3	11.3	**13.4**	34.5	33.5	23.5	30.5
	Avg	**372.2**	**175.2**				**15.7**				**32.4**
Amausi	I	310	156	17.0	17.5	17.3	**17.3**	31.3	31.4	36.3	33.0
	II	292	121	16.4	10.5	10.0	**12.3**	28.7	25.8	29.7	28.1
	III	309	169	17.5	19.3	8.1	**15.0**	32.2	40.5	18.8	30.5
	IV	304	166	17.7	16.0	10.2	**14.6**	31.0	33.5	24.3	29.6
	V	290	184	15.7	14.7	13.4	**14.6**	28.2	26.4	30.3	28.3
	VI	323	198	15.6	16.8	11.0	**14.5**	28.8	28.6	31.8	29.8
	Avg	**304.7**	**165.7**				**14.7**				**29.9**

Note : Twice a week during 16 September -26 October 2009.

A = 06:00-14:00 hr., B = 14:00-22:00 hr, C = 22:00-06:00 hr

Table 9: Average Concentration (µg/m^3) of SPM, RSPM, SO_2 and NO_x

Area	Location	SPM	RSPM	SO_2	NOx
Residential	Aliganj	263.2	132.3	11.0	20.9
	Vikas Nagar	292.3	155.5	12.1	20.2
	Indira Nagar	337.8	177.0	13.3	27.5
	Gomti Nagar	312.2	149.3	14.0	24.5
	Average	301.4± 31.5	153.5 ± 18.5	12.6 ± 1.3	23.3 ± 3.4
	NAAQS	**200**	**100**	**80**	**80**
Commercial	Hussainganj	304.5	170.8	14.3	21.2
	Charbagh	367.7	169.3	16.2	34.7
	Alambagh	397.7	204.0	14.8	32.3
	Aminabad	328.5	180.7	14.8	31.6
	Chowk	372.2	175.2	15.7	32.4
	Average	354.1 ± 37.2	180 ± 14.1	15.2 ± 0.8	30.4 ± 5.3
	NAAQS	**200**	**100**	**80**	**80**
Industrial	Amausi	304.7	165.7	14.7	29.9
	NAAQS	**500**	**150**	**120**	**120**

NAAQS=National Ambient Air Quality Standards

2.1.2 SULPHUR DIOXIDE (SO_2)

Among residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar); the average concentrations of SO_2 were in the range of 11 to 14 µg/m^3.

Among commercial areas (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk); the average concentrations of SO_2 were in the range of 14.3 to 16.2 µg/m^3.

Among industrial area (Amausi); the average concentration of SO_2 was found to be 14.7 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.

2.1.3 OXIDES OF NITROGEN (NO_x)

Among residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar); the average concentrations of NO_X were found in the range of 20.2 to 27.5 µg/m^3.

Among commercial areas (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk); the average concentrations of NO_X were found between 21.2 to 34.7 µg/m^3.

In industrial areas (Amausi) the average concentration of NO_x was 29.9 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.

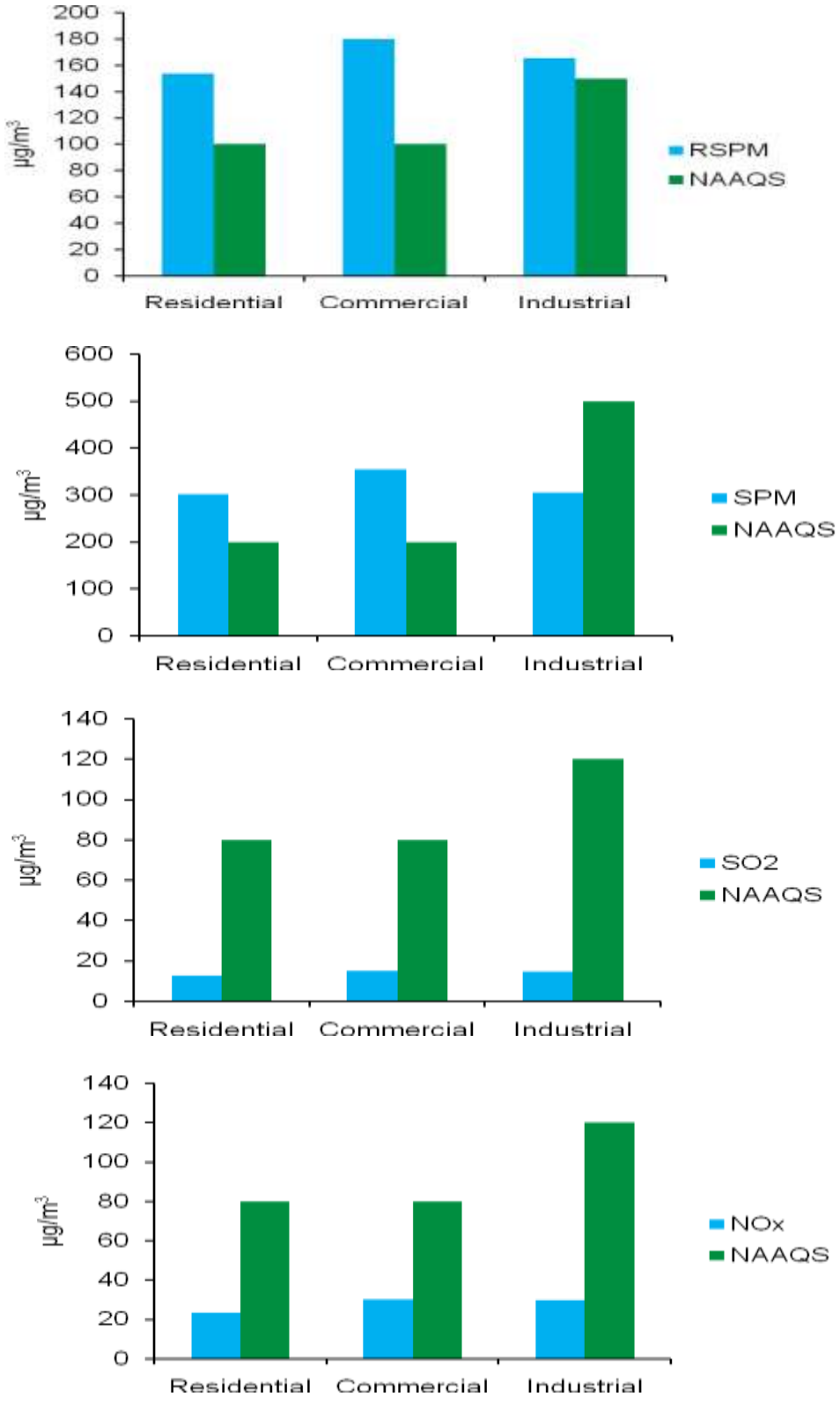

Fig. 1: Concentration (µg/m^3) of RSPM, SPM, SO_2 and NO_x in different areas of Lucknow city during post monsoon season (2009) and Standard (NAAQS).

2.2 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. The monitoring data recorded during the post monsoon period (September-October, 2009) is presented in **Table 10.**

In residential areas, the day and night time noise levels were recorded between 66.1 to 72.7 and 56.2 to 60.5 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 levels were recorded between 69.8 to 79.8 and 60.5 to 69.7 dB(A) respectively. Noise level at all the commercial sites during day and night time were found above the prescribed limit of 65 and 55 dB(A) respectively.

In industrial areas, Amausi and Talkatora the day and night time noise level were recorded between 75.8 to 78.2 and 66.4 to 68.5 dB(A) respectively. Noise levels at both the industrial locations in the day time were found to be above the prescribed limit of 75 dB(A) but it was within prescribed standards 70 dB(A) during nights.

Table 10: Noise Level dB(A) during Day and Night Time (September-October, 2009)

Sl. No.	Area	Location	Noise level dB(A)	
			Day	Night
1	Residential	Aliganj	66.1	56.8
		Vikas Nagar	69.0	56.2
		Indira Nagar	72.7	59.5
		Gomti Nagar	67.1	60.5
		Standard	**55.0**	**45.0**
2	Commercial	Hussainganj	69.8	61.8
		Charbagh	79.8	69.7
		Alambagh	72.4	64.3
		Aminabad	71.3	63.8
		Chowk	73.3	60.5
		Standard	**65.0**	**55.0**
3	Industrial	Amausi	75.8	66.4
		Talkatora	78.2	68.5
		Standard	**75.0**	**70.0**

3. TRENDS

3.1 AMBIENT AIR QUALITY

The observed SPM, RSPM, SO_2 and NO_x for 5 years (2003 to 2008 data excluding 2007 data) have been compared to found out the prevailing trend of air pollution in Lucknow city **(Fig. 2-4).**

3.1.1 Suspended Particulate Matter (SPM)

All the locations in residential areas showed slight decrease over last year but all the values are higher than the NAAQS **(Fig. 2).**

Among the commercial areas, SPM values showed decreasing trend except Alambagh. SPM level in Alambagh was similar to previous year data and all SPM data are higher than the NAAQS **(Fig 2).**

Amausi under industrial area showed lower value over the last year but lower than the NAAQS **(Fig. 2).**

3.1.2 Respirable Suspended Particulate Matter (RSPM)

All the locations in residential areas showed slight decrease over last year except Indira Nagar and all the values are higher than the NAAQS **(Fig. 3).**

Among the commercial areas, RSPM values showed increasing trend at all the locations except only in Charbagh which showed significantly lower value than the last year. All the values are higher than the NAAQS **(Fig 3).**

Amausi under industrial area showed gradual increasing trend over the previous years data and marginally higher than the NAAQS **(Fig. 3).**

3.1.3 Sulphur Dioxide (SO_2)

All the locations in residential areas showed slight decrease over last year but all the values are lower than the NAAQS **(Fig. 4).**

Among the commercial areas, SO_2 showed decreasing trend at all the locations when compared with the last year values **(Fig. 4).**

The industrial area, Amausi showed decreasing trend with the last year **(Fig.4).**

3.1.4 Oxides of Nitrogen (NO_x)

Among the Residential areas all the locations showed slightly decreasing trend with the last year value **(Fig.5).**

Among commercial areas, NOx registered decreasing trend at all the locations when compared with the last year data **(Fig.5).**

The industrial area Amausi showed slightly decreasing trend when compared with the last year data **(Fig.5).**

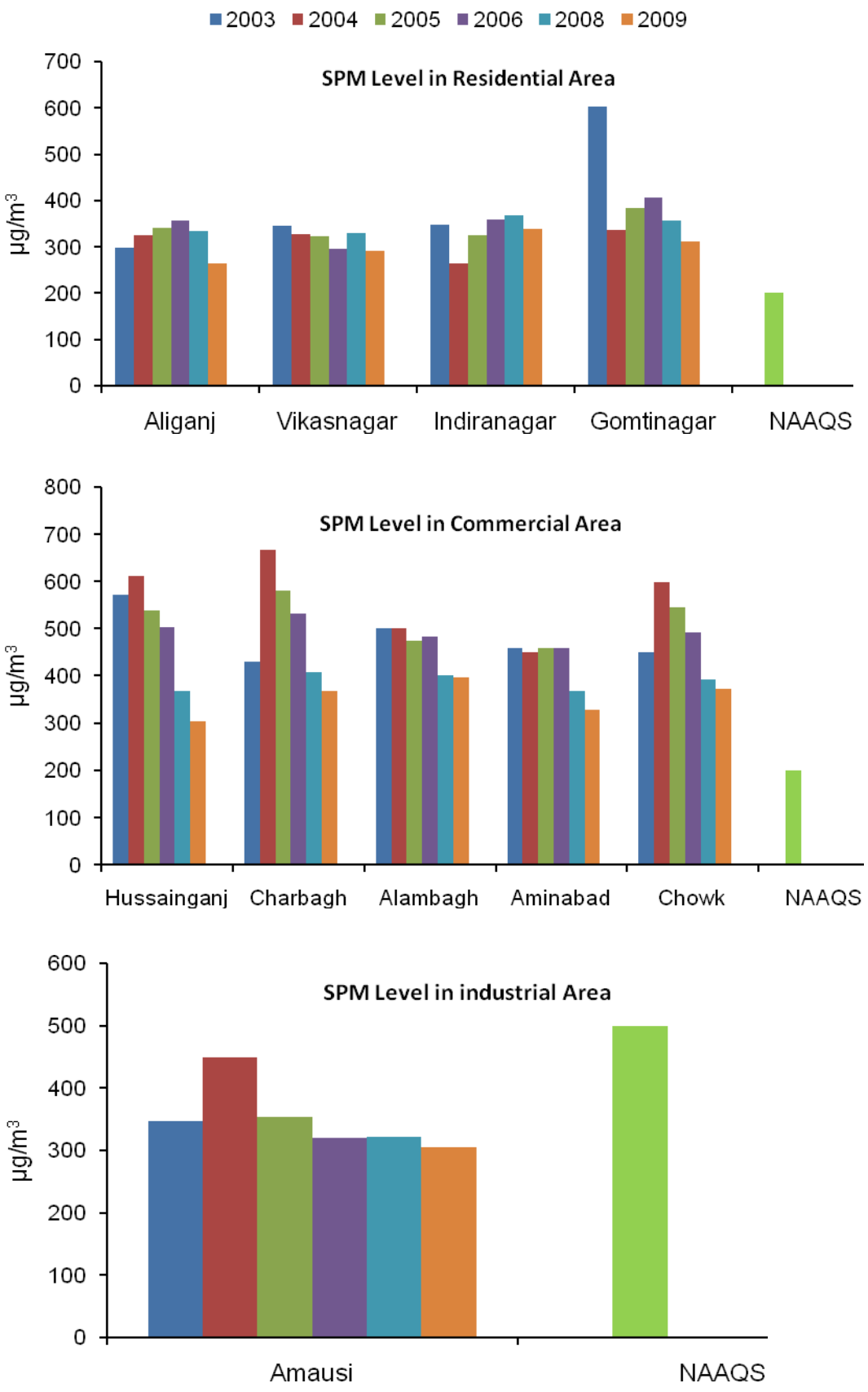

Fig. 2: Concentration (µg/m^3) of SPM in Residential, Commercial and Industrial areas of Lucknow city (2003-2009) and Standard (NAAQS).

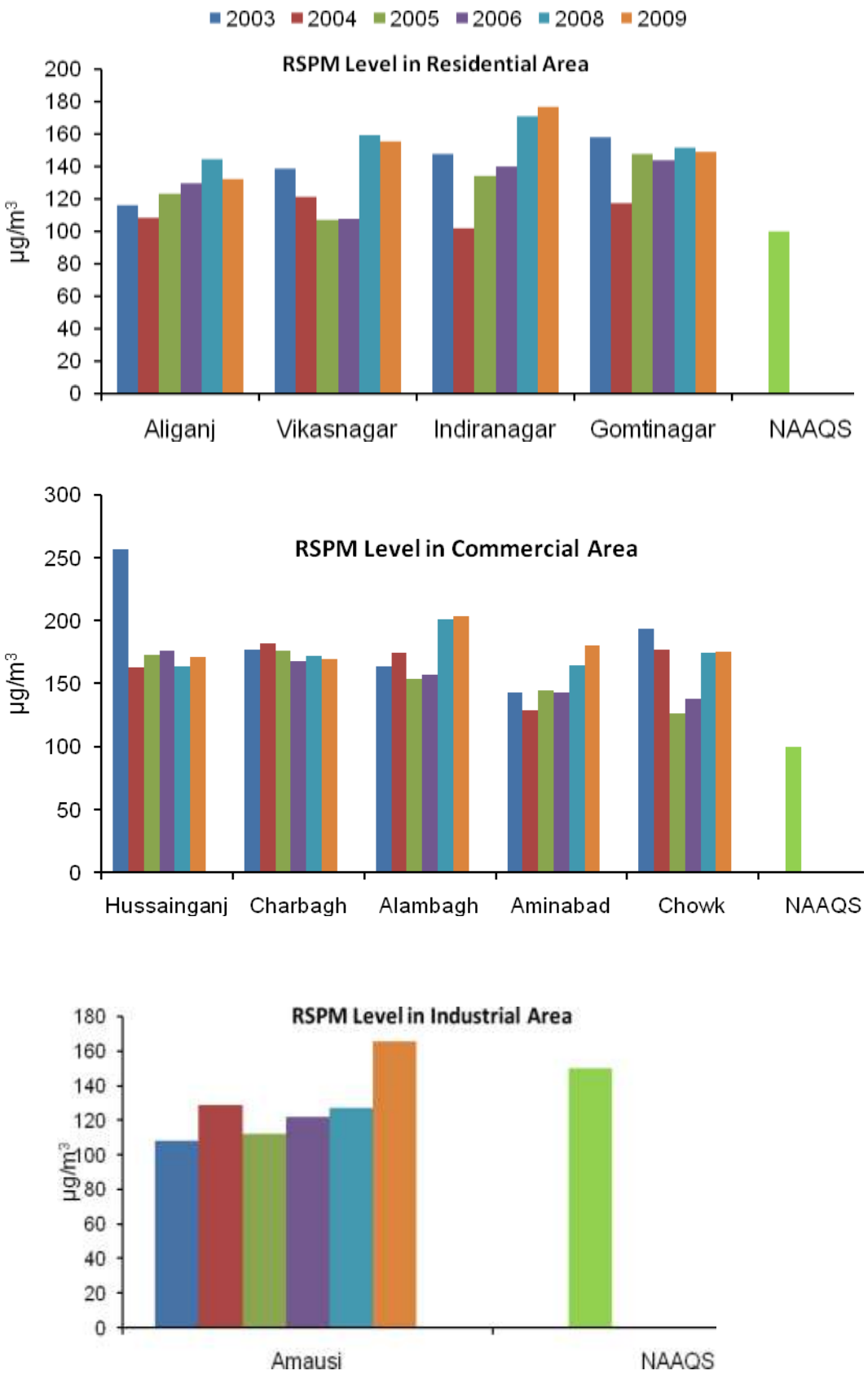

Fig. 3: Concentration (µg/m^3) of RSPM in Residential, Commercial and Industrial areas of Lucknow city (2003-2009) and Standard (NAAQS)

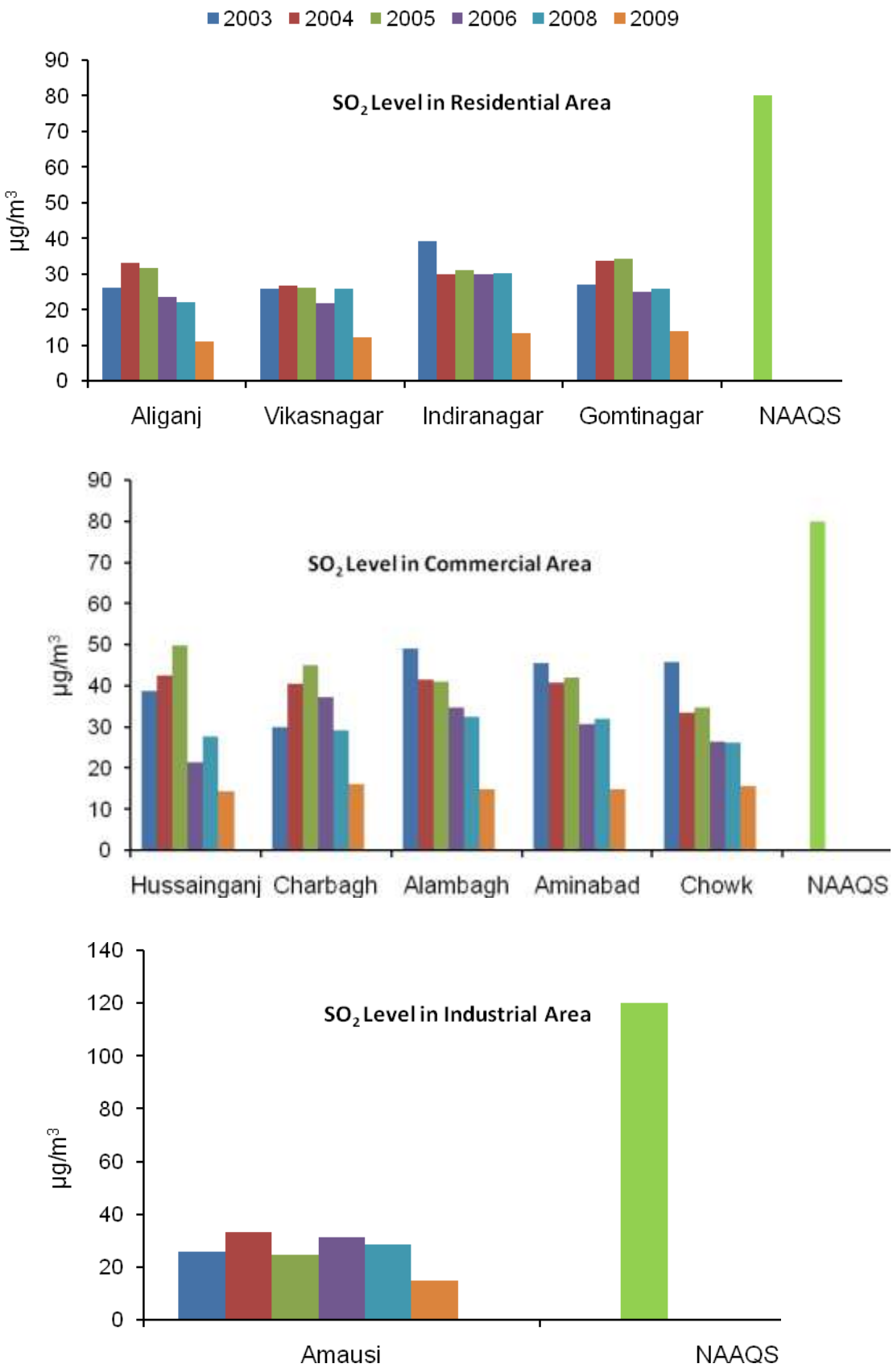

Fig. 4: Concentration (µg/m^3) of SO_2 in Residential, Commercial and Industrial areas of Lucknow city (2003-2009) and Standard (NAAQS)

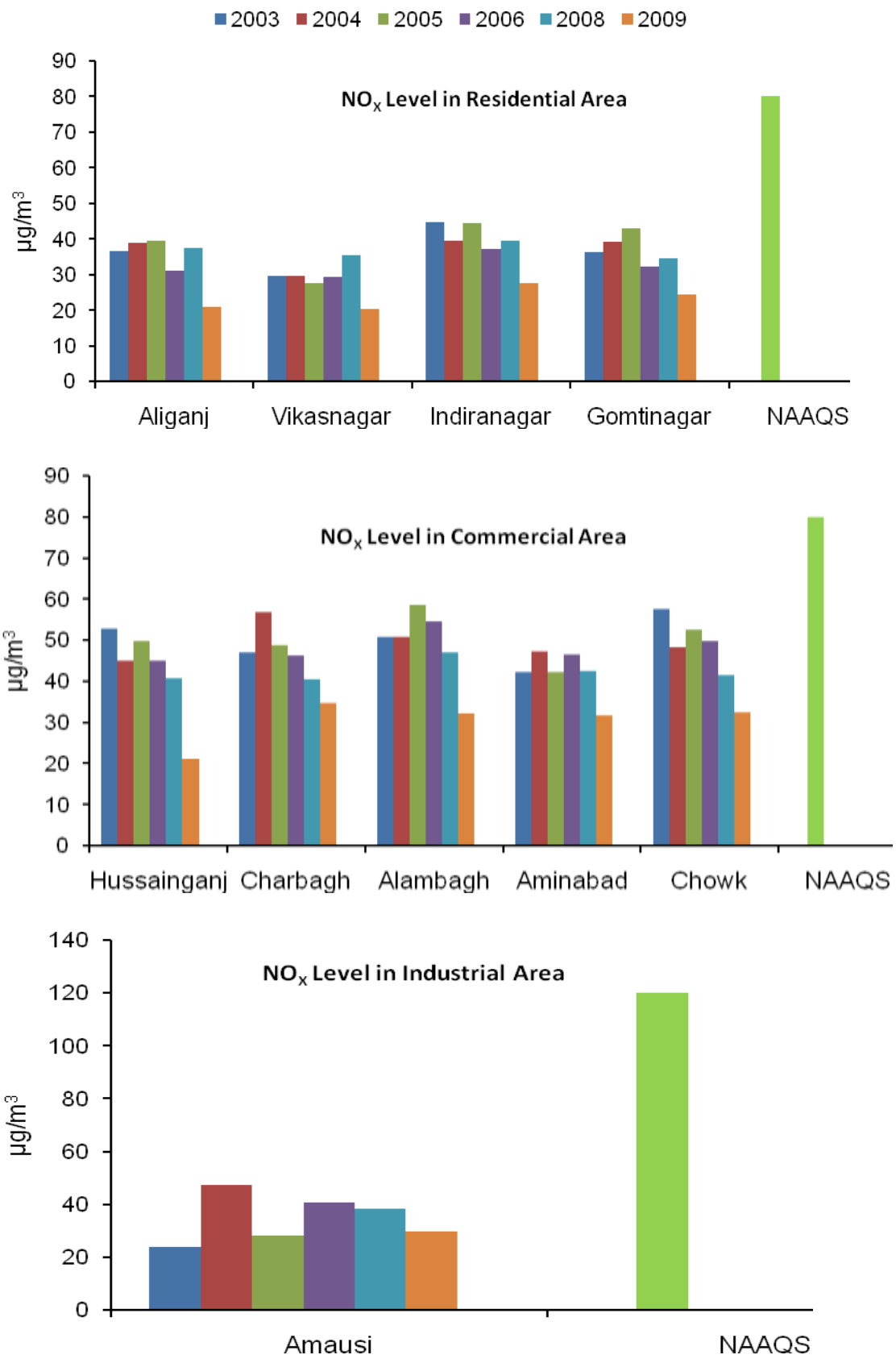

Fig. 5: Concentration (µg/m^3) of NO_x in Residential, Commercial and Industrial areas of Lucknow city (2003-2009) and Standard (NAAQS).

3.2 TRENDS OF NOISE LEVEL

Current year's noise data have been compared with the corresponding data of previous 6 years (excluding 2007) and are presented in **Fig.6 and 7**. The comparative noise level in residential, commercial and Industrial areas are described below:

3.2.1 Day Time Noise Level

Among residential areas all the locations showed slightly decreasing trend except Indira Nagar and Gomti Nagar over the last year level **(Fig. 6)**.

Among commercial cum traffic areas slightly lower levels were recorded except Charbagh and Alambagh which showed slightly increasing values over the last year **(Fig.6)**.

Among industrial area, both the locations showed variations in noise level. Talkatora showed increasing trend while lower trend was observed at Amausi over last year data. The comparative data are presented in **Fig. 6**.

3.2.2 Night Time Noise Level

Among the residential areas, noise levels at Aliganj and Gomti Nagar showed marginal increase in noise levels over last year, whereas Indira Nagar and Vikas Nagar showed decreasing trend.**(Fig. 7).**

Among the commercial areas, all the locations showed decreasing trend except Aminabad where observed value slightly higher compared to last year data. **(Fig. 7).**

In industrial area, both Amausi and Talkatora showed increasing trend over last year data. The comparative data are presented in **Fig. 7**.

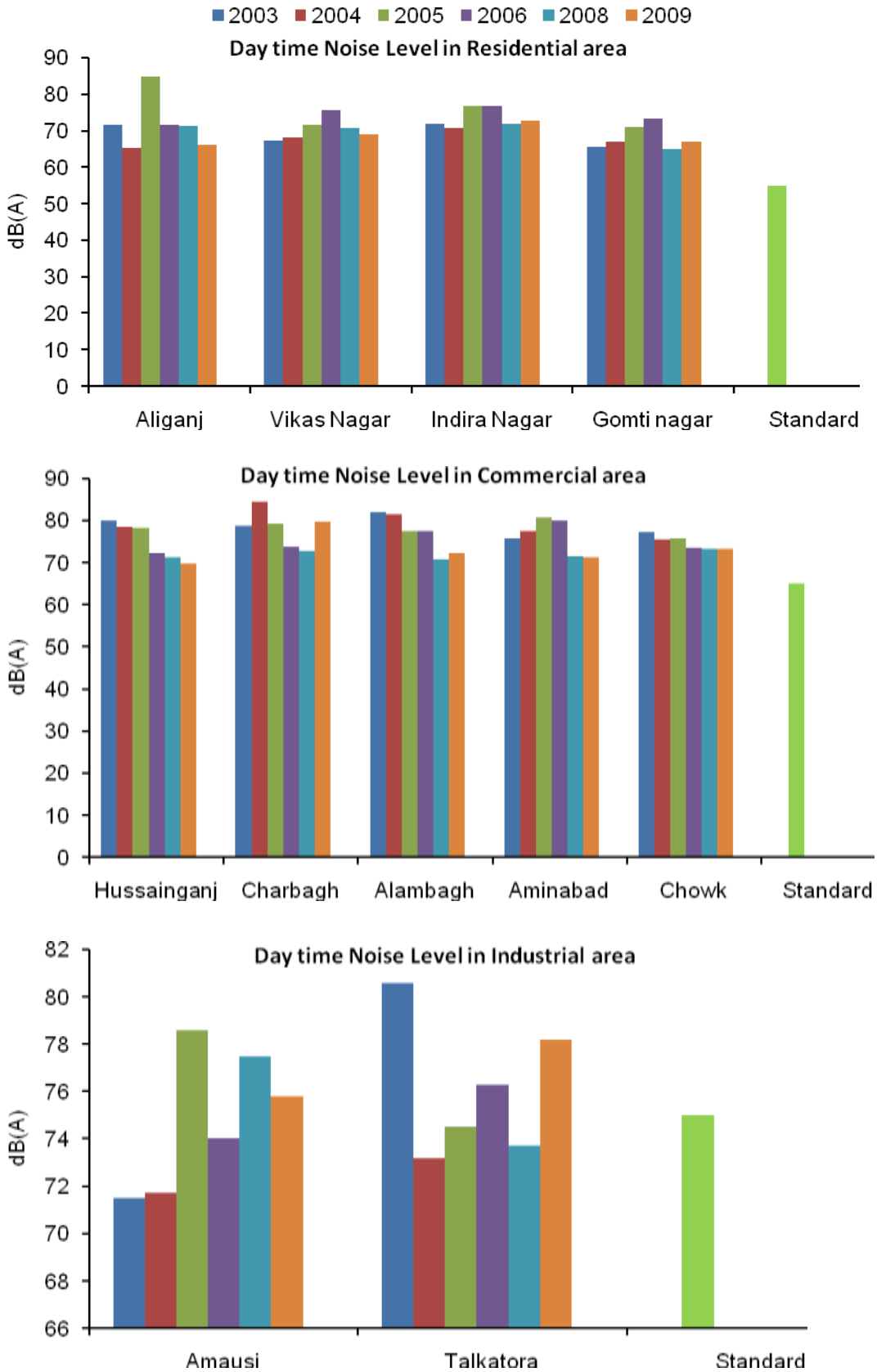

Fig. 6: Comparison of day time Noise Level dB(A) in different areas of Lucknow city (2003-2009)

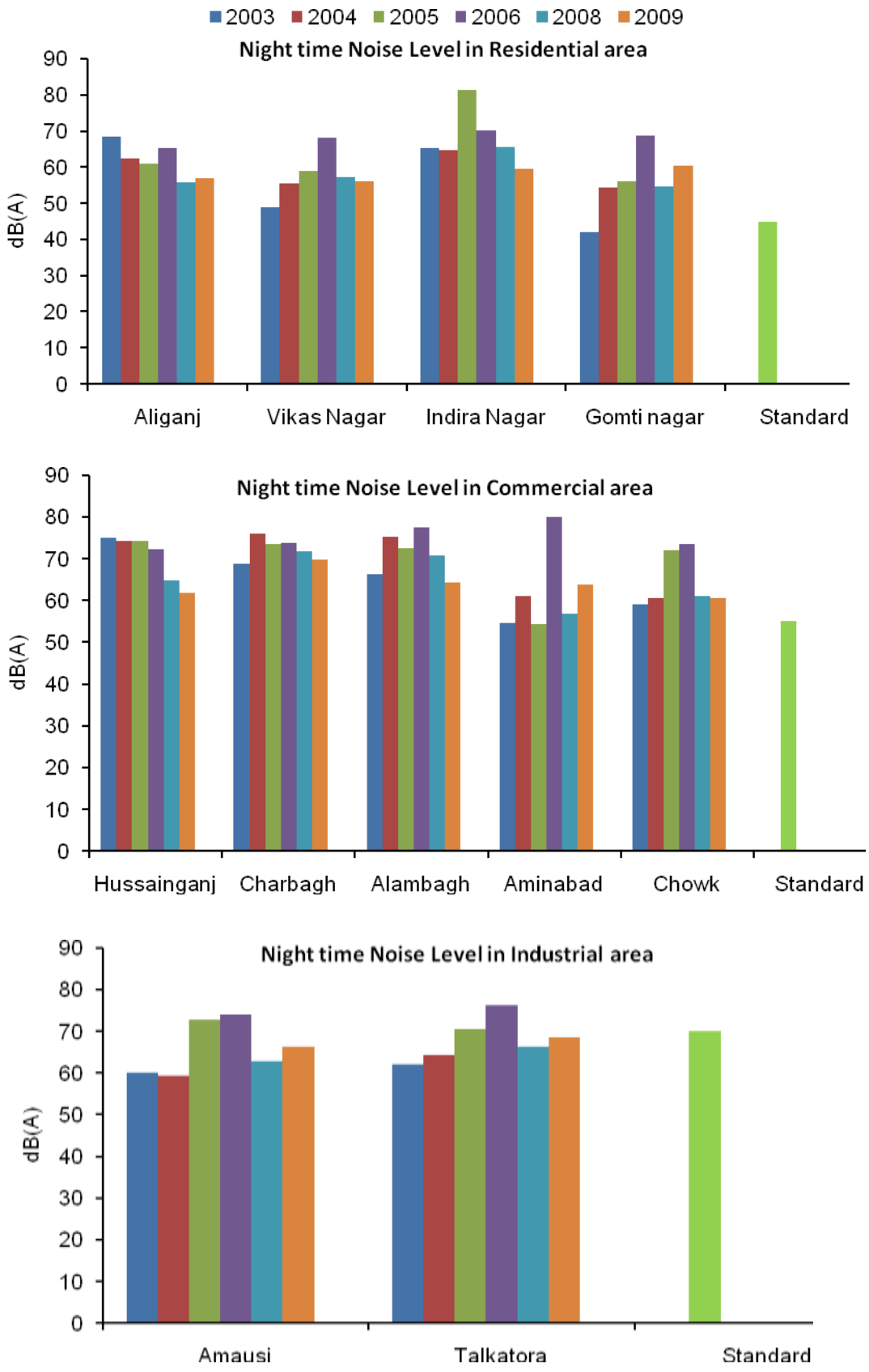

Fig. 7: Comparison of night time Noise Level dB(A) in different areas of Lucknow city (2003-2009)

4. POSSIBLE KNOWN HEALTH HAZARDS OF POLLUTANTS

Urban population is exposed to different types of pollutants in our daily life; studies have shown that air pollutants may affect the human health depending on pollutant composition, dose, exposure time and individual susceptibility. Mostly, humans come in contact with pollutants via inhalation, ingestion and dermal contact and have impact on our respiratory system, cardiovascular system, nervous system, urinary system and digestive system depending on mode of contact and type of pollutant. However, this report will focus only on adverse impacts of particulate matter, SO_2, NO_x and noise only.

4.1 Particulate Matter

Particulate matter consists of mixture of particles suspended in breathing air varying in size and composition. $PM_{2.5}$ and PM_{10} having aerodynamic diameter of ≤ 2.5 µm and ≤ 10 µm respectively have been known to be most fatal to human health and if inhaled may penetrate as deep as lung alveoli. PM_{10} particles deposit mainly in the upper respiratory tract while fine and ultra fine particles are able to reach lung alveoli.

- PM_{10} can settle in the bronchi and lungs and cause respiratory health problems like emphysema and bronchitis.
- $PM_{2.5}$ causes vascular inflammation and atherosclerosis - a hardening of the arteries and reduces elasticity due to high plaque deposits in arteries. This can lead to heart attacks and other cardiovascular problems.
- Particles smaller than 100 nanometers can pass through cell membranes and migrate into other organs, including the brain.
- Particulate matter may worsen the condition of patients with lung lesion and lung diseases due to pollutant initiated inflammation.
- Systemic inflammatory changes are also induced by particulate matter affecting blood coagulation and clotting patterns causing obstruction in blood vessels.
- Fine (<1 µm) and Ultra fine particles (<0.1 µm) are more hazardous than larger ones (coarse particles) in terms of mortality and cardiovascular and respiratory effects.

4.2 Sulphur Dioxide (SO_2)

Exposure to sudden high concentration of SO_2 or prolonged exposure to low concentration may cause-

- Mostly inhaled SO_2 penetrates gets trapped in nose and throat. However, if the person is breathing heavily or breathing only through the mouth or at elevated levels of SO_2 in air may reach lungs and cause damage.
- Sulphur dioxide causes irritation effects by stimulating nerves in the lining of the nose and throat and the lung's airways. This causes a reflex cough, irritation and a feeling of chest tightness, which may lead to narrowing of the airways.
- Irritation of nose and throat followed by broncho-constriction and dyspnoea, particularly in asthmatic individuals are due to exposure to increased levels of SO_2.
- Constriction of respiratory tract thereby increasing resistance to airflow during breathing and causes irritation of nose and throat, choking and coughing.
- Irritation and redness in eyes at low concentrations. However, exposure in high concentration in case of an industrial accident may cause severe burns leading to loss of vision.
- Prove fatal and lead to death at higher level of exposure as it may cause severe airway obstruction, hypoxemia (insufficient oxygenation of the blood) or pulmonary edema (accumulation of fluid in the lungs).
- Irritation, itching and lead to skin eruptions due to exposure of skin to SO_2.

4.3 Oxides of Nitrogen (NO_x)

NO_x is present in environment in more than one form and each form has different impact on human health. Some of the impacts of derivatives of NOx have been presented below:

- NO_x reacts with ammonia, moisture, and other compounds to form small particles, these particles can penetrate deep into lungs and can cause health impacts listed under particulate matter.

- Ozone is formed at ground level due to presence of NO_x, VOC's and sunlight. This ozone is harmful to elders, children and population having lung disease; it can also damage lung tissues in a normal individual.
- NO reacts with haemoglobin forming meta-haemoglobin which can be lethal.
- Presence of NO_2 in smog can irritate the eyes, nose, throat, and lungs and can cause coughing, shortness of breath and fatigue.
- Long-term exposure to nitrogen oxides increases susceptibility to respiratory infections and also lowers individual's resistance to diseases like pneumonia and influenza.
- Exposure to NO_x causes irritation of nose and throat followed by bronchoconstriction and dyspnoea.
- Exposure to high levels of NO_2 can cause acute or chronic bronchitis and affect normal functioning of lungs.

4.4 Noise

Each individual responds differently to sound levels and have different tolerance limits making it difficult to quantify health effects of noise. Nevertheless, with variations in degree certain effects which elevated level of noise may have on humans are:

- **Annoyance and Negative Social Behaviour:** Unexpected loud noise or continuous noise at workplace or home causes annoyance and also has physiological impact on human health which in long term may lead to changes in social behaviour.
- **Hearing Impairment:** Prolonged exposure to noise above certain limit or one time exposure to very loud noise may lead to temporary or permanent hearing impairment. Hearing loss in turn leads to loneliness, depression and sense of isolation and affects communication, behavior and social development.
- **Sleep Disturbance:** Noise is one of the major causes of disturbed sleep and disturbed sleeping pattern may become chronic over a period of time. This leads to emotional changes, poor physiological and mental functioning.
- **Cardiovascular Disturbances:** Noise can trigger human nervous system that affect the cardiovascular system. Some of the documented impacts of noise on human are increased blood pressure and heart rate, vasoconstriction, increased blood viscosity and hypertension.

- **Mental Health Disturbances:** Although noise does not cause mental illness it may accelerate development of latent mental disorders. Some of the adverse effects of noise on mental health are
    - Anxiety
    - Stress and nervousness
    - Headache and nausea
    - Emotional instability
    - Neurosis, hysteria and psychosis

5. DISCUSSION

The results of random survey of Lucknow city during post monsoon season with respect to SPM, RSPM, SO_2, NO_X and noise have been compared with the corresponding post monsoon data for last 6 years (excluding 2007) and prescribed standards. The level of pollutants monitored and noise levels were observed to be less than last year's concentrations at most of the locations. The variations in the level of pollutants may be attributed to delayed rainfall which might have washed out the pollutant from the urban atmosphere.

Although the average concentrations of SPM and RSPM are lower than the previous year data, it is still very high than their respective standards which may pose greater risk to the community health. In Lucknow city, the levels remain always higher than the prescribed standards. High concentrations of SPM and RSPM may be attributed to vehicular emissions, road dust, construction activities, combustion of bio fuel and tyre burning etc. However, role of regional topography, meteorological conditions (wind speed and direction, temperature, rainfall, relative humidity and solar intensity) cannot be ruled out. These two parameters especially PM_{10} and $PM_{2.5}$ are directly associated with upper respiratory irritation to chronic respiratory, heart or asthmatic attacks. Short term and long term exposure could be linked with reduced life expectancy, serious developmental delays in children and of the immune system leading to a number of diseases. Moreover, there exist several susceptibility factors such as age, nutritional status and predisposition conditions.

The size of the particles determines the site in the respiratory tract where they will deposit. Bigger particles of PM_{10} particles deposit mainly in the upper respiratory tract while fine and ultra fine particles are able to reach lung alveoli. So far, no single component has been identified that could explain most of the PM effects.

Among the parameters that play an important role for eliciting health effects are the size, shape and surface of particles, their number and their composition. The composition of PM varies as they can absorb and transfer a multitude of pollutants. However, their major components are metals, organic compounds, material of biologic origin, ions, reactive gases and the particle carbon core. There is strong evidence to support that ultrafine and fine particles are more hazardous than larger ones in terms of mortality and cardiovascular and respiratory effects. Although other indicator pollutants (SO_2 and NO_X) have been found to be within prescribed limits, they too need to be monitored regularly due to adverse impact they have on human health if exposed in high concentrations or low concentration for longer period.

A noise level at almost all monitored locations of the city was found to be above prescribed limits. It may be inferred that increasing noise levels not only affects the performance of people but also affects physiological health. Thus, it is important to regulate the noise levels and declare more zones as silence zones.

In order to abridge general public about these pollutants and to increase their awareness they should be monitored more frequently and results should be made available to the masses.

6. CONCLUSIONS

Present post monsoon study during September-October 2009 revealed that the SPM levels were higher than the National Ambient Air Quality Standard (NAAQS) prescribed by CPCB, New Delhi except Amausi area because the standard value of industrial area (500 $\mu g/m^3$) is much higher than the standard value of residential area (200 $\mu g/m^3$). In case of RSPM, all the 10 sampling locations were higher than their respective standards residential area (100 $\mu g/m^3$) and industrial area (150 $\mu g/m^3$).

Concentrations of SO_2 and NO_x were below the prescribed standard at all ten locations.

Noise levels at Residential and Commercial areas were above the standards prescribed for Day time [Residential 55 dB(A) Commercial 65 dB(A)] and night time [Residential 45 dB(A) Commercial 55 dB(A)]. In industrial area, day time noise levels were higher than the standard limit of 75 dB(A) but within the limit of 70 dB(A) during night.

7. RECOMMENDATIONS

- Construction of subways and flyovers along with widening of roads is advisable in high traffic density areas to overcome the traffic bottleneck problems.
- Encroachment and on road business should not be allowed which hampers the smooth traffic flow.
- Numbers and frequency of CNG buses in all routes to be increased which may be the good alternative of three wheelers and personal vehicles.
- Increase CNG filling stations and give incentives for those using CNG.
- Regular sweeping of roads to be done before 06:00 and after 22:00 hrs. to avoid re-suspension of road dust.
- Organization of environmental fairs at school, college and municipality level to generate interest and increase awareness among masses.
- Advance city planning considering the rate of increase in urbanization and population with vision 2050.
- Proper demarcation of industrial, residential and sensitive zones in Lucknow city and put up proper sign boards displaying the same.
- Extensive plantation should be done along the roads, in and around the public gardens
- All the roads either trunk route or loop lines should be metalloid and timely repairing and maintenance is needed
- Regular pollution check drives for vehicles to be conducted.
- Improvement in traffic management and stringent execution of traffic rules.

ANNEXURE: National Ambient Air Quality Standards (NAAQS)

Pollutants	Time weighted average	Concentration in ambient air			Method of measurement
		Industrial Area	Residential Rural & Other Areas	Sensitive Area	
Sulphur Dioxide (SO_2)	Annual Average*	80 µg/m^3	60 µg/m^3	15 µg/m^3	1. Improved West and Gaeke method
	24 hours**	120 µg/m^3	80 µg/m^3	30 µg/m^3	2. Ultraviolet fluorescence
Oxides of Nitrogen as NO_2	Annual Average*	80 µg/m^3	60 µg/m^3	15 µg/m^3	1. Jacob and Hochheiser modified (Na-Arsenite) Method
	24 hours**	120 µg/m^3	80 µg/m^3	30 µg/m^3	2. Gas Phase chemiluminescence
Suspended Particulate Matter (SPM)	Annual Average*	360 µg/m^3	140 µg/m^3	70 µg/m^3	High volume sampling, (Average flow rate not less than 1.1 m^3/minute).
	24 hours**	500 µg/m^3	200 µg/m^3	100 µg/m^3	
Respirable Particulate matter (RPM) (size less than 10 µm)	Annual Average*	120 µg/m^3	60 µg/m^3	50 µg/m^3	Respirable particulate matter sampler
	24 hours**	150 µg/m^3	100 µg/m^3	75 µg/m^3	
Lead (Pb)	Annual Average*	1.0 µg/m^3	0.75 µg/m^3	0.50 µg/m^3	AAS method after sampling using EPM 2000
	24 hours**	1.5 µg/m^3	1.00 µg/m^3	0.75 µg/m^3	or equivalent Filter paper
Carbon Monoxide (CO)	8 hours**	5 mg/m^3	2 mg/m^3	1 mg/m^3	Non dispersive Infrared spectroscopy
	1 hours	10 mg/m^3	4 mg/m^3	2 mg/m^3	

* Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval.

** 24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days.

NOTE :

1. National Ambient Air Quality Standard: The levels of air quality with an adequate margin of safety, to protect the public health, vegetation and property.
2. When every and whenever two consecutive values exceeds the limit specified above for the respective category, it would be considered adequate reason to institute regular/ continuous monitoring and further investigations.
3. The state Government/State Board shall notify the sensitive and other areas in the respective states within a period of six months from the date of Notification of National Ambient Air Quality Standard.

[S.O. 384 (E), Air (Prevention & Control of Pollution) Act, 1981 dated April 11, 1994]