ASSESSMENT OF ENVIRONMENTAL STATUS

OF

LUCKNOW CITY

(POST-MONSOON)

FINDINGS OF A RANDOM SURVEY

PRESENTED ON 45th IITR FOUNDATION DAY

INDIAN INSTITUTE OF TOXICOLOGY RESEARCH
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Post Box 80, Mahatma Gandhi Marg, Lucknow - 226001
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CONTENTS

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.) & summer (Mar - Jun.). Temperature about 45^0C in summer to 3^0C in winter. Average annual rainfall about 100 cm.
❖ **Total Vehicle Population In the Lucknow city as on 31/03/2010**	**:**	11,07,455
❖ **Growth of Vehicle over 2009-2010**	**:**	8.02%
❖ **Total Number of Petrol Pumps**	**:**	93
❖ **Consumption of Petrol**	**:**	10,89,59 KL
❖ **Consumption of Diesel**	**:**	1,13,779 KL
❖ **Major Source of Pollution**	**:**	Automobiles, D. G. sets, Civil Constructions
❖ **Parameters Monitored**	**:**	PM_{10}, $PM_{2.5}$, SO_2, NO_X, CO, O_3, C_6H_6, B(a)P, Pb, Ni and Noise
❖ **Study Conducted by**	**:**	Environmental Monitoring Section IITR, Lucknow

1.1 INTRODUCTION

Urban air quality is a matter of concern because of exposure of large number of people to it. Vehicular exhaust is one of the important sources of air pollutants like Particulate Matter (PM), Sulphur dioxide (SO_2), Oxide of Nitrogen (NOx), Carbon monoxide (CO) and other organic and inorganic pollutants including trace metals in urban area. Accumulation of these pollutants in the ambient air adversely affects the air quality, the human being and environmental health.

The quantity and types of pollutants released in the ambient air depends on the quality and quantity of combustion of diesel, gasoline, CNG, LPG etc. Apart from this road dust is also responsible for the higher level of air pollutants in urban area.

Besides that, various types of vehicles and their different operating modes such as idling, stop and start, accelerating and decelerating, combined with a high density of vehicles leads to a pollution source problem. Many trace metals present in leaded and unleaded petrol, diesel oil, antiwear substances which are added to lubricants are emitted by vehicles via their exhaust pipe, additionally particles emitted due to friction of brake pads and tyres. Over the past decades, the rapid growth in travel has increased traffic congestion, especially in the major metropolitan areas which leads to significant increase in air pollutants.

Accumulation of pollutants in the human body through inhalation of air is an important route. Every day, an average adult person inhale about 20,000 liters of air. Every time we breathe, risk inhaling dangerous chemicals that have found their way into the air.

Other studies revealed that higher level pollutants especially the Respirable Suspended Particular Matter (RSPM) found higher than the permissible limit in most of big cities is more dangerous for human health and responsible for several cardiovascular and respiratory diseases such as asthma, bronchitis, reproductive development, increased risk of preterm birth and even mortality and morbidity rate. The effect of PM depends on the mass and number concentration, shape and size, composition and the concentration of other inorganic and organic pollutants associated with it.

Air pollution in major cities is also attributed by high number of older vehicles, poor vehicle maintenance, inadequate infrastructure and low fuel quality. Due to rapid rate of urbanization, emission from mobile sources has become a cause of great concern. Not only the occupationally exposed people like traffic policemen, drivers, conductors and near shopkeepers but also the common residents and pedestrians in big cities are exposed to high level of pollutants.

The quality of ambient air in the Lucknow city has improved comparatively after the introduction of Compressed Natural Gas (CNG) for running public transport around four year ago especially for gaseous pollutants. In view of above facts, it is need of the hour to look in to the air quality of our city Lucknow, the capital of Uttar Pradesh which has a population of 22.45 Lakh (Municipal corporation + Cantonment) as per 2001 census and an area of 310 sq. km. Total vehicle of different categories registered with RTO, Lucknow during 2009-2010 were 11,07,455 which overall increased 8.02% over last year (2008-2009). The details are given in Table 1.

Table 1: Registered Vehicle with R.T.O. Lucknow during 2008-09 and 2009-10

Sl. No.	Type of Vehicle	Number of Registered Vehicles On 31st March		% Change
		2008-2009	2009-2010	
1	Multi Axial	1808	2134	18.03
2	Light, Medium and Heavy weight Vehicles (Four wheeler)	7957	8631	8.47
3	Light commercial vehicles (Three wheeler)	3776	3702	-1.95
4	Light commercial Vehicles (Four wheeler)	4434	4532	2.21
5	Buses	2794	2930	4.87
6	Taxi	4361	5055	15.91
7	Three Wheelers and Auto Rickshaw	11649	7410	-36.3
8	Two wheelers	825088	890442	7.92
9	Car	129234	145996	0.74
10	Jeep	13627	14910	9.41
11	Tractor	15477	16464	6.38
12	Trailers	1110	1182	6.49
13	Others	3927	4067	3.57
Total		10,25,242	11,07,455	8.02

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 31.03.2010 are given in Table 2.

Table 2: Details of Lucknow city bus service, 2010

Sl. No.	Route No.	To and Fro	No. of Buses
1	11	Chinhat-Gomti Nagar-Alambagh	37
	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	14
3	23	Rajinikhand-Gudamba thana	20
4	24	Charbagh - Engineering College	41
5	25	Charbagh-Bijnor	4
6	31	Alambagh – IIM	2
7	33	Alambagh- Engineering College	20
8	34	Alambagh-Charbagh-Hazratganj-Kapporthala-Keshavnagar	2
9	44	Charbagh-Andhi Chowki	6
10	45	Parag Dairy – Polytechnic Chowraha	11
11	66	GPO- Hazratganj-Rajajipuram	5
		Total	162

Source: UPSRTC, Lucknow

In Lucknow city there are 93 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 2010
1	Indian Oil Corporation. (IOC)	45
2	Bharat Petroleum Corporation Ltd. (BPCL)	20
3	Hindustan Petroleum Corporation Ltd. (HPCL)	22
4	Compressed Natural Gas Stations.(CNG)	6
	Total	93

Source: Indian Oil Corporation (IOC), Lucknow

The sales figure of oil companies for the year (2009-10) has been compared with sale figure of 2008-09 (Table 4). It is observed that petroleum sale have been increased marginally by 12.07% whereas sale of diesel has increased by 13.99%.

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

Sl. No.	Agency	Petrol (Unleaded)			High Speed Diesel		
		Apr. 08 to Mar. 09	Apr. 09 to Mar. 10	% increase in consumption	Apr. 08 to Mar. 09	Apr. 09 to Mar. 10	% increase in consumption
1	IOC	53345	60163	12.78	61267	66719	8.90
2	BPCL	26734	28828	7.83	18964	22252	17.34
3	HPCL	17142	19968	16.49	19583	24808	26.68
Total		97221	108959	12.07	99814	113779	13.99

Source: Indian Oil Corporation (IOC), Lucknow

Green Gas Limited (GGL) is a Joint Venture of GAIL (India) Limited and Indian Oil Corporation Limited (IOC). It has been incorporated for the implementation of City Gas Projects for supply of Piped Natural Gas (PNG) to domestic, commercial and industrial Consumers and Compressed Natural Gas (CNG) to automobile consumers in the cities of Lucknow and Agra. In Lucknow there are five CNG filling stations which are located at Ashiana, Gomti nagar, Kanpur Hardoi bypass and Madion (Sitapur road). Consumption of CNG on daily basis in last year was 50,000 Kg. On average 7490 vehicles fill CNG fuel daily. Distribution and number of CNG vehicles in Lucknow is summarized in Table 5.

Table 5: Distribution of CNG vehicles

Sl. No.	Vehicles	Number
1	Auto	4080
2	Taxi	2514
3	Buses (UPSRTC)	137
4	Buses (Private)	26
5	School Buses	246
6	Private Service Vehicles	77
7	Cars	410
	Total	7490

Monitoring of Environmental Status of Lucknow city with respect to air and noise is being conducted by IITR, 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 present study was conducted with the following aims and objectives.

- ✓ *To assess the ambient air quality with respect to PM_{10}, $PM_{2.5}$, SO_2, NOx, O_3, CO, Benzo(a)Pyrene, Benzene and trace metals (lead and nickel).*

- ✓ *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 conducted during the month of October, 2010 representing the post monsoon period.

1.2 AIR QUALITY

1.2.1 MONITORING LOCATIONS AND METHODOLOGY

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 6 and parameters along with methodology is given in Table 7.

Table 6: Monitoring Locations

Sl . No.	Locations	Activities
1	Aliganj	Residential
2	Vikas Nagar	Residential
3	Indira Nagar	Residential
4	Gomti Nagar	Residential
5	Hussainganj	Commercial cum traffic
6	Charbagh	Commercial cum traffic
7	Alambagh	Commercial cum traffic
8	Aminabad	Commercial cum traffic
9	Chowk	Commercial cum traffic
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. In Aliganj means of mass public transport is by city buses, three wheeler (Vikram and tempo) which are run by diesel 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 by Vikram tempo, minibuses and CNG buses. The monitoring location was at a Vishnupuri colony, which is about 500 meter away from the Vikas Nagar main road.

III. Indira Nagar

Indira Nagar is now a semi commercial area. In this area the means of public transport is by CNG buses. In day time, main source of vehicular emission is 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 at sector 11, 50 m away from the main Ring Road.

IV. Gomti Nagar

Gomti Nagar is a residential area, dominated by middle and upper class families, using LPG gas for cooking. Source of air pollution is public transport (tempo 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 near Hussainganj chauraha, 40 meter away from the main road. It is a purely commercial place and during day time traffic flow are city buses (CNG), 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 main road of Charbagh railway station.

VII. Alambagh

In Alambagh, monitoring location was Surendra nagar near Gurudwara, 100 m away from

the Alambagh crossing on the main Lucknow – Kanpur road. In day time, source of pollution is from city as well as from intercity 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 adjacent to Jhandewala Park. It is the central place of Aminabad. This is purely commercial area mainly consisting mainly of shopping complexes. Aminabad serves as major shopping area. The whole area is congested having narrow lanes and mixed traffic ranging from bicycles, rickshaws to two wheeler and passenger cars.

IX. Chowk

The monitoring location was Pata nala near police chauki, 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 at near Nadarganj power sub-station, about 300 meter away from the main Lucknow - Kanpur road.

Table 7: Parameters and Methodology for Air Quality Monitoring

Sl. No.	Parameters	Time Weighted average	Methods of Measurement
1	Sulphur di oxide (SO_2)	24 hours	Improved West Gaeke
2	Nitrogen Dioxide(NO_2)	24 hours	Modified Jacob & Hochhesier (Na-arsenite)
3	Particulate Matter (PM_{10})	24 hours	Gravimetric
4	Particulate Matter ($PM_{2.5}$)	24 hours	Gravimetric
5	Ozone (O_3)	1 hours	UV photometric
6	Lead (Pb)	24 hours	AAS method after sampling on EPM 2000 filter paper
7	Carbon Mono Oxide (CO)	1 hours	Non Dispersive infrared (NDIR) spectroscopy
8	Benzene (C_6H_6)	24 hours	Gas Chromatography based continuous analyzer-Adsorption and Desorption followed by GC analysis
9	Benzo (a) Pyrene-Particulate phase only	24 hours	Solvent extraction followed by HPLC/GC analysis
10	Nickel (Ni)	24 hours	AAS method after sampling on EPM 2000 or equivalent filter paper

1.2.2 NOISE LEVEL MEASUREMENTS

The measurement of noise level was carried out at twelve locations for 30 minutes at each location during the day (6 AM to 10 PM) and night time (10 PM to 6 AM) by Noise level Meter.

1.3 RESULTS

1.3.1 AIR QUALITY

The detailed results of air quality monitoring are presented in Table 9, 10 & 11 and Fig. 1.

1.3.1.1 RESPIRABLE SUSPENDED PARTICULATE MATTER (PM_{10} and $PM_{2.5}$)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the average concentration of RSPM was in the range of 120.6 to 134.2 µg/m^3 while $PM_{2.5}$ ranged between 64.8- 70.8 µg/m^3.

In commercial areas (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of RSPM were in the range of 161.0 to 200.3 and $PM_{2.5}$ 91.3- 150.4 µg/m^3 respectively.

In industrial area (Amausi), the mean level of PM_{10} and $PM_{2.5}$ were found to be 156.5 and 136.0 µg/m^3 respectively.

All the values of PM_{10} and $PM_{2.5}$ were above the prescribed National Ambient Air Quality Standard (NAAQS) of 100 and 60 µg/m^3 for industrial, residential, rural and other area respectively.

1.3.1.2 SULPHUR DIOXIDE (SO_2)

In residential area (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the average concentrations of SO_2 were in the range of 12.5 to 18.5 µg/m^3.

In commercial area (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of SO_2 were in the range of 15.2 to 21.5 µg/m^3.

In industrial area (Amausi) the mean level of SO_2 was found to be 15.8 µg/m^3.

All the values of SO_2 were well below the prescribed NAAQS of 80 µg/m^3 for all the locations.

1.3.1.3 OXIDES OF NITROGEN (NO_x)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the average concentrations of NO_X were found in the range of 22.5 to 24.9 µg/m^3.

In commercial areas (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of NO_X were found in the range of 22.3 to 27.7 µg/m^3.

In industrial areas (Amausi) the average concentrations of NO_x was 22.4 µg/m^3.

All the values of NO_x were within the prescribed NAAQS of 80 µg/m^3 for all the monitoring locations.

1.3.1.4 CARBON MONOXIDE (CO)

The monitoring was conducted for one hour during 12 noon to 5 PM and the avarage results are presented in Table 10.

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the average concentrations of CO were found in the range of 0.48 to 0.64 mg/m^3.

In commercial areas (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of NO_X were found in the range of 0.98 to 1.45 mg/m^3.

In industrial areas (Amausi) the mean level of CO was 0.87 mg/m^3.

All the values of CO were within the prescribed NAAQS of 4 mg/m^3 for all the monitoring locations.

1.3.1.5 OZONE (O_3)

The monitoring was conducted for one hour during 12 noon to 5 PM and the avarage results are presented in Table 10.

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the average concentrations of O_3 were found in the range of 100.1 to 117.1 µg/m^3.

In commercial areas (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of O_3 were found in the range of 138.7 to 170.3 µg/m^3.

In industrial areas (Amausi) the average concentrations of O_3 was 148.8 µg/m^3.

All the values of O_3 were within the prescribed NAAQS of 180 µg/m^3 for all the monitoring locations.

1.3.1.6 BENZENE (C_6H_6)

Benzene was monitored one time at ten locations and the results are presented in Table 10.

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the average concentrations of C_6H_6 were found in the range of 0.13 to 2.81 µg/m^3.

In commercial areas (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of C_6H_6 were found in the range of 3.74 to 7.27 µg/m^3.

In industrial areas (Amausi) the average concentrations of C_6H_6 was 0.39 µg/m^3.

All the values of C_6H_6 were within the prescribed NAAQS of 6 µg/m^3 for all the monitoring locations except Hussainganj.

1.3.1.7 BENZO(a)PYRENE (BaP)

Benzo(a) pyrene (BaP) was monitored and analysed for 24 hours at each location and the results are presented in Table 10.

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the average concentrations of B(a)P were found in the range of 0.17x10^{-3} to 13.1 x10^{-3} ng/m^3.

In commercial areas (Hussainganj, Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of B(a)P were found in the range of 4.3 x10^{-3} to 81.3 x10^{-3} ng/m^3.

In industrial areas (Amausi) the average concentrations of B(a)P was 0.68 x10^{-3} ng/m^3.

All the values of B(a)P were within the prescribed NAAQS of 1 ng/m^3 for all the monitoring locations.

Table 9: Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NOx, during Post monsoon 2010

Location	Days			SO_2				NOx			
		$PM_{2.5}$	PM_{10}	A	B	C	Mean	A	B	C	Mean
Aliganj	I	67.9	116	14.3	15.1	8.4	**12.6**	19.5	21.3	17.3	**19.3**
	II	61.6	117	12.0	14.5	10.5	**12.5**	25.0	23.9	12.6	**20.5**
	III		109	13.8	20.5	8.7	**14.3**	33.3	32.4	18.3	**28.0**
	IV		140.2	10.5	13.6	7.7	**10.6**	22.8	35.5	9.6	**22.6**
	Avg	**64.8**	**120.6**				**12.5**				**22.6**
Vikas Nagar	I	72.1	136	14.5	15.1	6.5	**12.1**	21	21.9	26.5	**23.2**
	II	69.5	153	9.5	24.0	11.5	**15.0**	29	30.3	19.7	**26.3**
	III		124	16.9	23.3	8.0	**16.1**	29.3	32	24.6	**28.6**
	IV		101	20.0	21.6	17.5	**19.7**	16.9	28.6	18.9	**21.4**
	Avg	**70.8**	**128.5**				**15.7**				**24.9**
Indira Nagar	I		114	16.9	22.0	9.0	**16.0**	19.2	27.4	25	**23.9**
	II		157	19.5	27.2	10.1	**18.9**	28.9	29.4	37.7	**24.0**
	III	68.2	123	15.5	20.8	14.0	**16.8**	19.3	23.3	20.8	**20.0**
	IV	70.4	143	16.7	19.5	16.2	**17.5**	23.9	26.4	16.5	**22.2**
	Avg	**69.3**	**134.3**				**17.3**				**22.5**
Gomti Nagar	I		126	16.1	27.4	16.6	**20.0**	16.9	30.2	23	**23.4**
	II		141	15.3	29.1	7.6	**17.3**	15.5	29.1	23.6	**22.8**
	III	73.4	140	14.7	23.1	11.9	**16.6**	25.4	28.8	16.5	**23.6**
	IV	68.2	124	20.7	21.5	18.2	**20.1**	23.1	24.0	19.0	**22.0**
	Avg	**70.8**	**132.8**				**18.5**				**22.9**
Hussainganj	I		165	11.4	17.1	15.0	**14.5**	20.0	33.7	21.4	**25.3**
	II		134	19.6	20.9	8.8	**16.4**	31.4	39.1	21.2	**30.5**
	III	89.2	141	12.1	24.5	15.7	**16.7**	22.5	33.3	27.2	**27.7**
	IV	93.3	160	20.2	21.4	16.6	**19.4**	28.3	38.4	15.3	**27.4**
	Avg	**91.3**	**161**				**16.5**				**27.7**
Charbagh	I		181	19.8	26.1	15.8	**20.5**	24	25.9	15.1	**21.7**
	II		176	25.9	13.6	11.0	**16.8**	21.5	26.5	23.2	**24.0**
	III	128.9	177	17.9	24.0	18.9	**20.8**	21	25.8	17.3	**21.4**
	IV	121.3	162	17.1	25.3	17.1	**19.8**	19.9	26.9	19.4	**22.1**
	Avg	**125.1**	**174**				**19.5**				**22.3**
Alambagh	I		184	21.1	24.5	16.5	**20.7**	26.3	26.1	17.2	**23.2**
	II		218	19.9	24.8	21.6	**22.1**	21.5	27.2	18.6	**22.1**
	III	139.2	208	16.0	28.2	19.8	**21.4**	20.5	25.5	22.5	**22.9**
	IV	120.6	191	17.4	23.3	16.5	**19.1**	23.8	28.4	21.8	**24.7**
	Avg	**129.9**	**200.3**				**20.8**				**23.2**
Aminabad	I		188	18.6	18.0	16.5	**17.7**	22.4	33.7	19.8	**25.3**
	II		167	14.2	21.8	10.2	**15.4**	29.6	35.9	15.3	**26.9**
	III	130.3	148	16.5	18.0	12.4	**15.6**	23.8	27.7	15.4	**23.3**
	IV	127.6	141	14.0	17.3	5.1	**12.1**	28.8	27.5	21.6	**23.3**
	Avg	**128.9**	**161**				**15.2**				**24.7**
Chowk	I		206	24.3	24.0	14.7	**21.0**	33.8	24.5	21.4	**26.6**
	II		201	21.1	26.1	21.9	**23.1**	30.6	34.1	23.9	**29.5**
	III	158.9	186	20.7	34.8	5.2	**20.3**	24.2	24.7	23.0	**24.0**
	IV	141.8	152	21.7	22.7	19.6	**21.4**	23.6	25.4	18.0	**22.4**
	Avg	**150.4**	**186.3**				**21.5**				**25.6**
Amausi	I		158	20.2	25.5	21.9	**22.5**	21.1	28.8	20.0	**23.3**
	II		160	14.6	16.7	12.4	**14.6**	19.0	27.5	20.4	**22.3**
	III	129.6	148	16.5	17.1	7.7	**13.8**	20.7	24.5	21.9	**22.4**
	IV	142.4	160	13.2	17.4	6.8	**12.4**	18.0	27.7	18.5	**21.4**
	Avg	**136.0**	**156.5**				**15.8**				**22.4**

**Once a week during post monsoon 2010. A =06:00-14:00 hr, B =14:00-22:00 hr, C =22:00-06:00 hr*

Table 10: Average Concentration of PM_{10}, $PM_{2.5}$, SO_2, NO_x, Benzene, B(a)P, CO, O_3

Area	Location	RSPM µg/m^3	$PM_{2.5}$ µg/m^3	SO_2 µg/m^3	Benzene µg/m^3	B(a) P ng/m^3	CO mg/m^3	O_3 µg/m^3	NOx µg/m^3
Residential	Aliganj	120.6	64.8	12.5	0.13	0.17 x10^{-3}	0.48	100.1	22.6
	Vikas Nagar	128.5	70.8	15.7	2.81	0.34x10^{-3}	0.52	110.7	24.9
	Indira Nagar	134.3	69.3	17.3	2.65	13.1x10^{-3}	0.63	117.1	22.5
	Gomti Nagar	132.8	70.8	18.5	0.39	5.4x10^{-3}	0.64	116.3	22.9
	Average	129.0	68.8	16.0	1.49	4.8 x10^{-3}	0.56	111.0	23.2
	NAAQS	**100.0**	**60.0**	**80.0**	**6.0**	**1.0**	**4.0**	**180.0**	**80.0**
Commercial	Hussainganj	161.0	91.3	16.5	7.27	9.3x10^{-3}	0.98	138.7	27.7
	Charbagh	174.0	125.1	19.5	5.96	7.5x10^{-3}	1.21	151.0	22.3
	Alambagh	200.3	129.9	20.8	3.89	27.8x10^{-3}	1.01	152.4	23.2
	Aminabad	161.0	128.9	15.2	4.65	81.3 x10^{-3}	1.45	170.3	24.7
	Chowk	186.3	150.4	21.5	3.74	4.3 x10^{-3}	1.00	162.8	25.6
	Average	174.3	125.1	18.7	5.10	26.0 x10^{-3}	1.1	155.0	24.7
	NAAQS	**100.0**	**60.0**	**80.0**	**6.0**	**1.0**	**4.0**	**180.0**	**80.0**
Industrial	Amausi	156.5	136.0	15.8	0.39	0.68x10^{-3}	0.87	148.8	22.4
	NAAQS	**100.0**	**60.0**	**80.0**	**6.0**	**1.0**	**4.0**	**180.0**	**80.0**

NAAQS=National Ambient Air Quality Standards

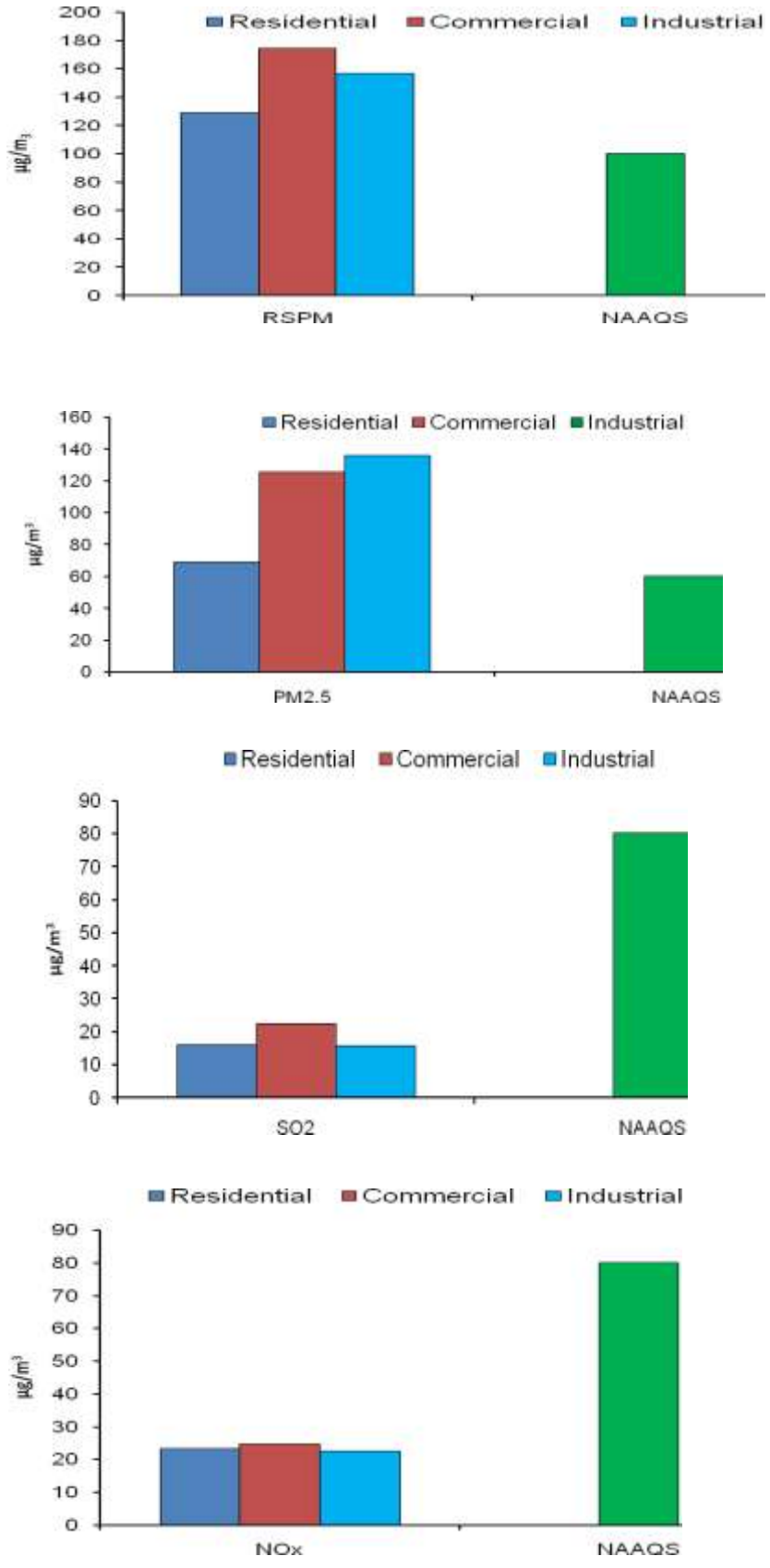

Fig 1: Concentration (µg/m^3) of RSPM, $PM_{2.5}$, SO_2 and NO_x in different areas of Lucknow city during post monsoon season (2010) and compared with prescribed National Ambient Air Quality Standard (NAAQS).

1.3.2 METALS ASSOCIATED WITH RESPIRABLE PARTICULATE MATTER (RSPM)

Trace elements are elemental parts of PM and are more enriched in the coarse mode than in fine mode. They may also originate from resuspension of soil. Many trace metals are present in leaded and unleaded petrol, diesel oil, antiwear substances which are added to lubricants, brake pads and tyres and are emitted by vehicles via their exhaust pipe. The high level of Pb can induce severe neurological and hematological effects on the exposed population especially children, whereas Cd and Ni are known for inducing carcinogenic effects in humans through inhalation. Average value of Lead (Pb) and Nickel (Ni) concentrations in ng/m^3 of all locations has been shown in Table 11.

The 24 hr concentration of Pb was found to be maximum in Gomti Nagar 61.8 minimum in Aliganj 42.2 ng/m^3 in residential area. In case of commercial locations minimum in Hussainganj 76.9 and maximum in Chowk 103.8 ng/m^3 respectively. In Amausi it was found 117.3 ng/m^3. All the values of lead was found below the prescribed limit of NAAQS 1000.0 ng/m^3 while found higher than EPA limit 150 ng/m^3 (Three month average).

The hierachy of locations for Lead were arranged in descending order of their average concentrations as given below.

Amausi>Chowk>Aminabad> Alambagh>Charbagh>Hussainganj>Gomti Nagar>Indira Nagar >Vikas Nagar>Aliganj

The 24 hr concentration of Ni was found to be maximum in Gomti Nagar 19.2 minimum in Indra Nagar 12.1 ng/m^3 in residential area. In case of commercial area minimum in Charbagh 18.3 and maximum in Chowk 38.3 ng/m^3. In Amausi was found 10.9 ng/m^3.

All the values of Nickel was found below the prescribed limit of NAAQS 20 ng/m^3 except in Alambagh, Aminabad and Chowk

The hierachy of locations for Nickel were arranged in descending order of their average concentrations as given below.

Chowk>Aminabad>Alambagh>Husainganj=Gomti Nagar>Charbagh>
Vikas Nagar>Aliganj>Indira Nagar>Amausi

There might be an influence of the prevailing meteorological conditions which are responsible for the dispersion of fugitive emissions of road side soil dust.

Table 11: Average value (ng/m^3) of Lead (Pb) and Nickel (Ni)

Location	Pb	Ni
Residential Area		
Aliganj	42.2	15.2
Vikas Nagar	51.6	17.3
Indra Nagar	57.2	12.1
Gomti Nagar	61.8	19.2
Average	**53.2**	**15.6**
Commercial Area		
Hussainganj	76.9	19.2
Charbagh	78.3	18.3
Alambagh	81.7	20.9
Aminabad	87.8	28.6
Chowk	103.8	38.3
Average	**87.9**	**26.5**
Industrial Area		
Amausi	117.3	10.9
NAAQS	**1000.0**	**20.0**

1.3.3 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 (October, 2010) is presented in Table 12.

In residential areas, the day and night time noise level were recorded between 57.2 to 60.2 and 50.2 to 65.2 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 68.9 to 75.7 and 57.7 to 63.1 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 area, Amausi the day and night time noise levels were recorded between 70.8

and 59.2 dB(A) respectively. Noise level at all industrial locations in the day and night time was found below the prescribed limit of 75.0 and 70.0 dB (A) respectively.

Table 12: Noise Level dB(A) during Day and Night Time

Sl. No.	Area	Location	Noise level dB(A)	
			Day	Night
1	Residential	Aliganj	57.2	52.0
		Vikas Nagar	58.9	54.3
		Indira Nagar	60.2	65.2
		Gomti Nagar	59.7	50.2
		Standard	**55.0**	**45.0**
	Commercial	Hussainganj	75.7	58.3
		Charbagh	69.2	60.6
		Alambagh	74.2	63.1
		Aminabad	71.7	57.7
		Chowk	68.9	61.1
		Standard	**65.0**	**55.0**
3	Industrial	Amausi	70.8	59.2
		Standard	**75.0**	**70.0**

1.4 TRENDS

1.4.1 AMBIENT AIR QUALITY

The observed RSPM, SO_2 and NO_x for 5 years data have been compared to find out the prevailing trend of air pollution in Lucknow city (Fig. 2-4). The slight decrease or increase in the values may be attributed to some local environmental and climatic factors.

1.4.1.1 RESPIRABLE SUSPENDED PARTICULATE MATTER (PM_{10})

In all the locations in residential areas, decrease was recorded over last year except Vikas Nagar and all the values are higher than the NAAQS (Fig. 2).

Among the commercial areas, RSPM values showed increasing trend at Chowk and Charbagh than the last year. All the values are higher than the NAAQS (Fig 2).

Amausi under industrial area showed decreasing trend over the last year and higher than the NAAQS (Fig. 2).

1.4.1.2 SULPHUR DIOXIDE (SO_2)

The level of SO_2 during post monsoon since 2003 is presented in Fig. 3 for all the locations.

SO_2 level in all residential and commercial areas showed increasing trend over the last year concentration.

The industrial area Amausi showed almost similar level when compared with last year.

1.4.1.3 OXIDES OF NITROGEN (NO_x)

The level of NOx during post monsoon since 2003 is presented in Fig. 4 for all the locations.

Among the Residential areas all the locations showed slightly decreasing trend except Aliganj and Vikas Nagar.

Among commercial areas, NOx registered decreasing trend at all the locations except Hussainganj when compared with the last year data.

The industrial area Amausi showed slightly decreasing trend when compared with the last year data.

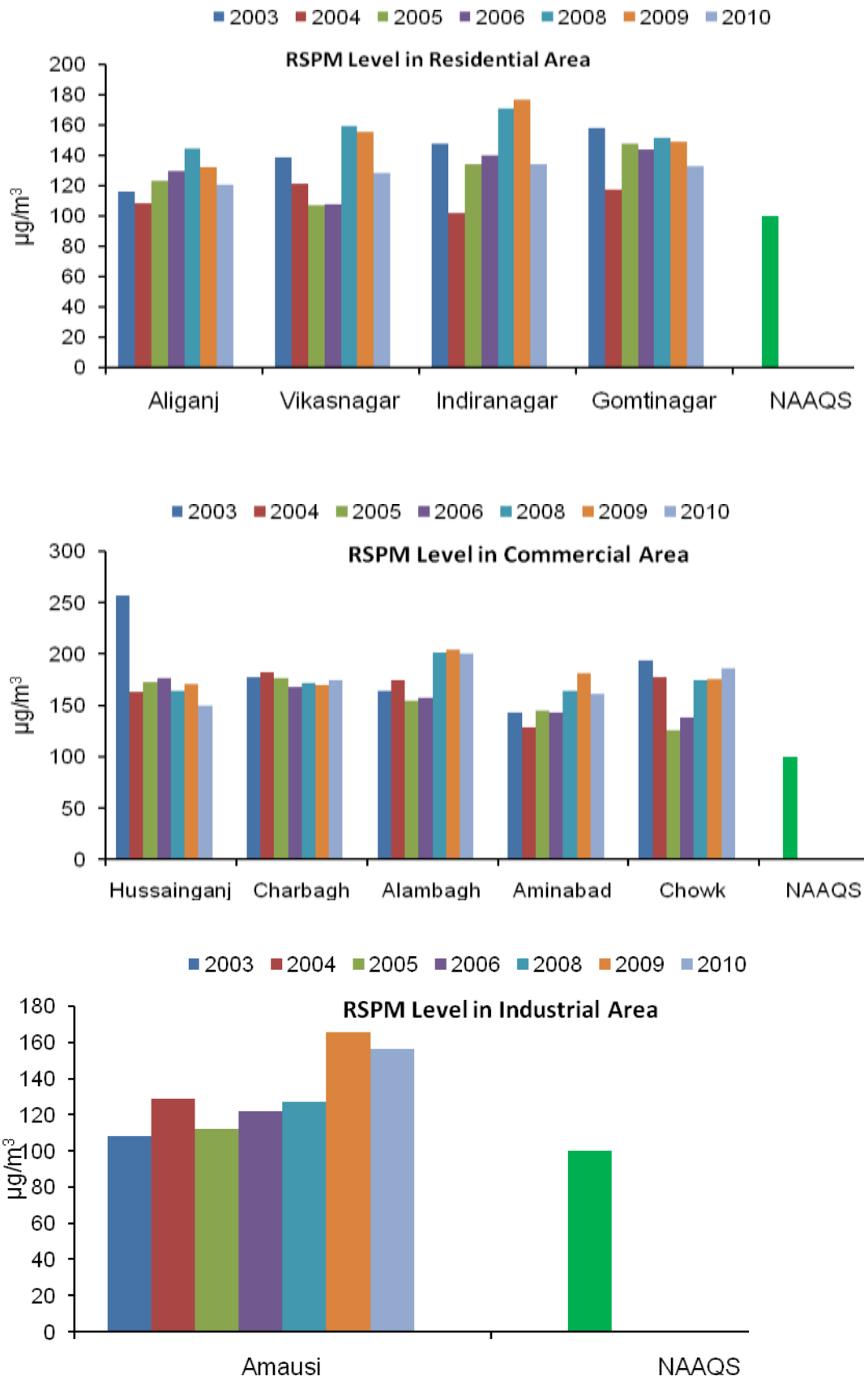

Fig 2: Concentration (µg/m^3) of RSPM in Residential, Commercial and Industrial areas of Lucknow city during 2003 to 2010 and compared with prescribed National Ambient Air Quality Standard (NAAQS).

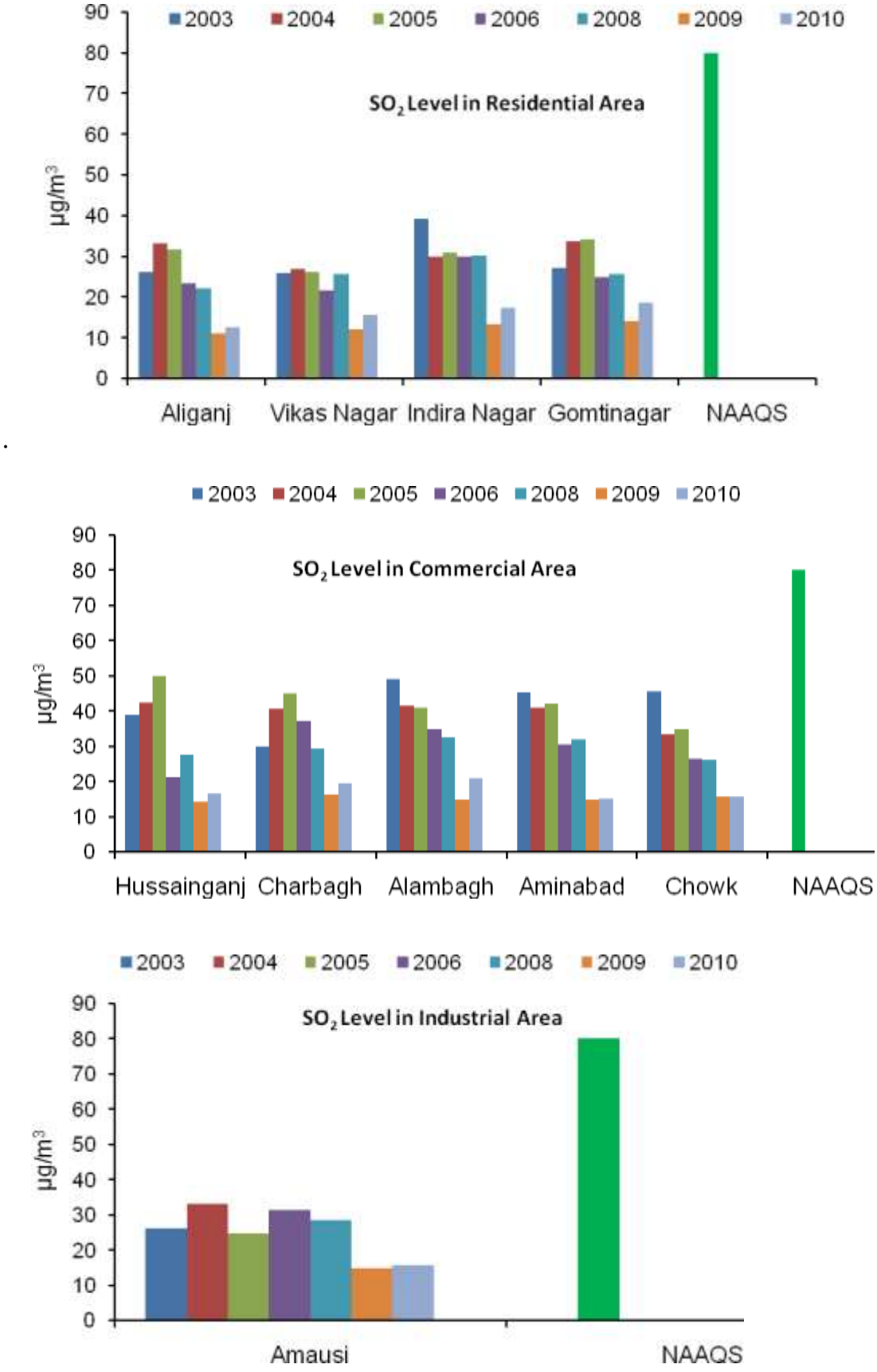

Fig 3: Concentration (µg/m^3) of SO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2003 to 2010 and compared with prescribed National Ambient Air Quality Standard (NAAQS).

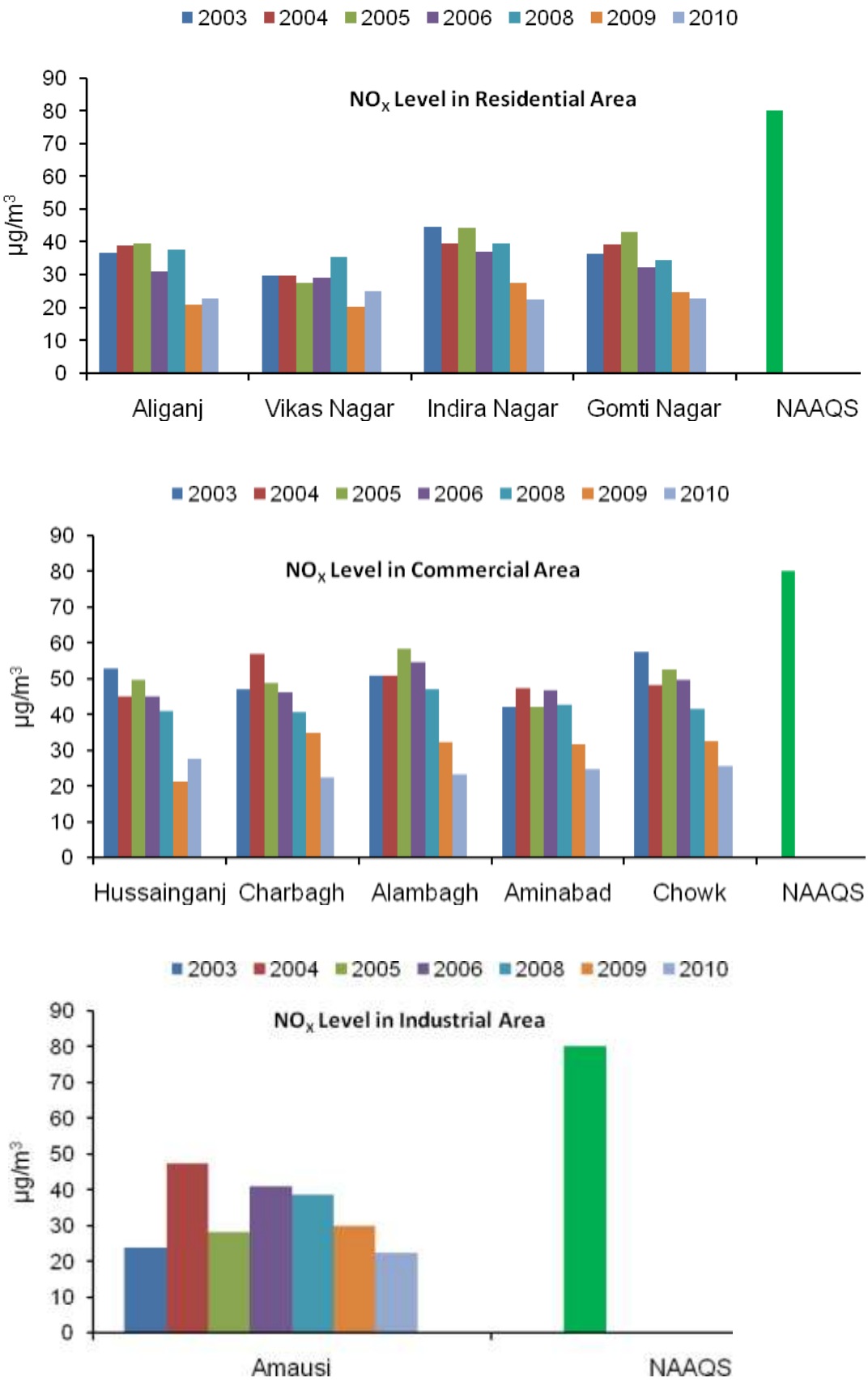

Fig 4: Concentration (µg/m^3) of NO_x in Residential, Commercial and Industrial areas of Lucknow city during 2003 to 2010 and compared with prescribed National Ambient Air Quality Standard (NAAQS).

1.4.2 TRENDS OF NOISE LEVEL

Current year's noise data has been compared with the corresponding data of previous five years and are presented in Fig. 5 and 6. The comparative noise level in residential, commercial and Industrial areas is described below:

1.4.2.1 DAY TIME NOISE LEVEL

In residential areas all the locations shows slightly decreasing trend over the last year level. (Fig. 5).

In commercial cum traffic areas slightly lower levels at all locations were recorded over the last year except Alambagh, Aminabad and Hussainganj. (Fig.5).

In industrial area, in Amausi the noise level was recorded lower value over last year data. The comparative data are presented in (Fig. 5).

1.4.2.2 NIGHT TIME NOISE LEVEL

All four residential areas showed slightly lower trend except Indira Nagar was recorded over the last year level (Fig. 6).

Among commercial areas, all the locations showed almost lower values except Chowk than the last year (Fig. 6).

In both the locations of industrial area, registered a decrease in the noise level during nighttime over last year data (Fig. 6).

Fig 5: Comparison of day time Noise Level dB(A) in different areas of Lucknow city (2003-2010)

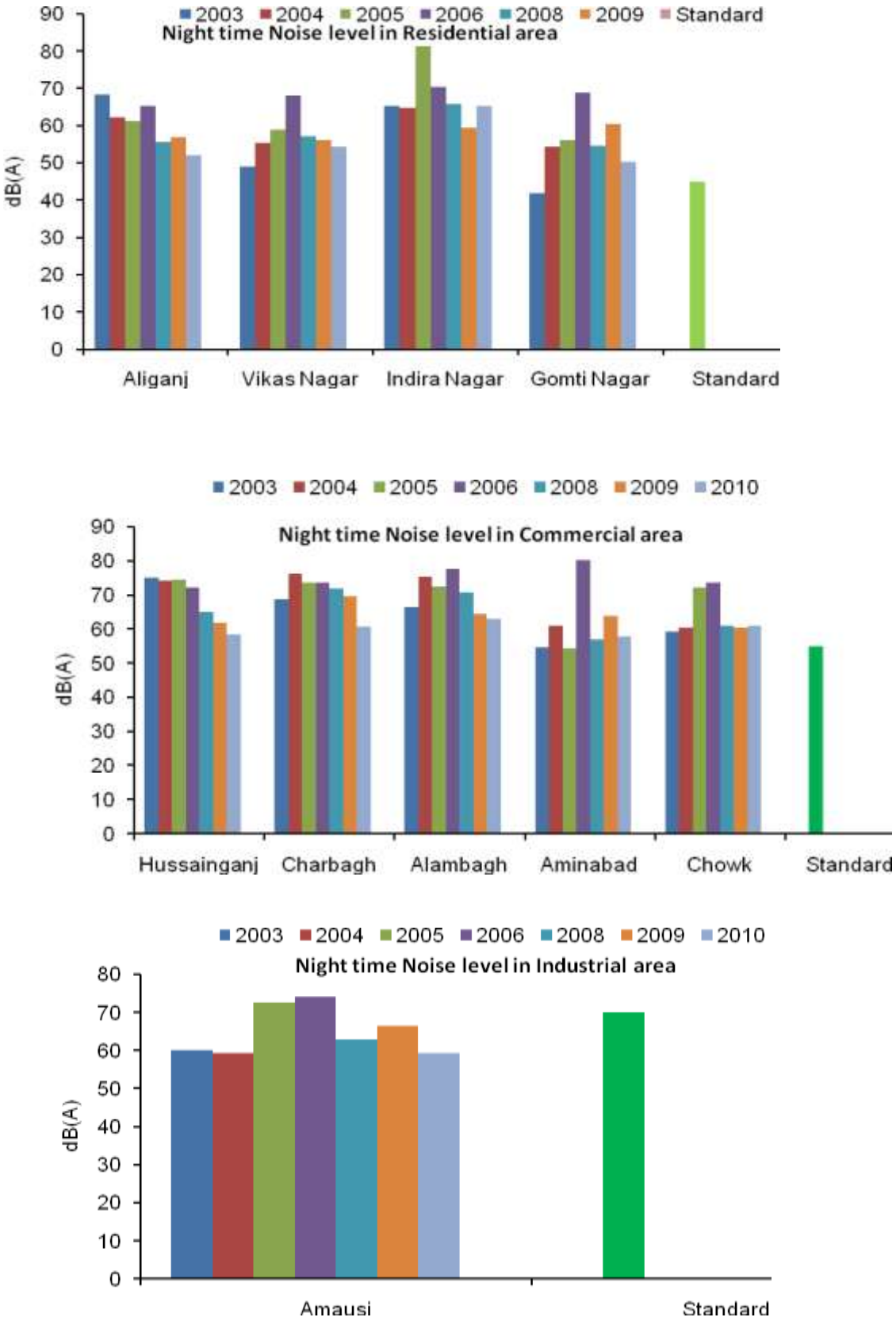

Fig 6: Comparison of night time Noise Level dB(A) in different areas of Lucknow city (2003-2010)

1.5 DETAILS & HEALTH HAZARDS OF POLLUTANTS

Sulfur dioxide (SO_2)

Sulfur dioxide is a colorless gas with a characteristic, irritating, pungent odor. It is a liquid below 14°F and shipped as a liquified compressed gas.

Sources - It is produced by volcanoes and in various industrial processes. Since coal and petroleum often contain sulfur compounds, their combustion generates sulfur dioxide unless the sulfur compounds are removed before burning the fuel.

Effects- Irritation to eyes, nose, throat; rhinorrhea (discharge of thin nasal mucus); choking, cough; reflex bronchoconstriction; liquid: frostbite.

Occupational Standard- Time Weighted Average (TWA) 2 ppm (5 mg/m^3).

Nitrogen Dioxide (NO_2)

Nitrogen dioxide is the chemical compound with the formula NO_2. One of several nitrogen oxides, NO_2 is an intermediate in the industrial synthesis of nitric acid, millions of tons of which are produced each year. This reddish-brown toxic gas has a characteristic sharp, biting odor and is a prominent air pollutant.

Sources- Combustion of automobile fuels, coal, which have significant nitrogen content, particularly when burned in combustors.

Effects- Decrease lung function and increase the risk of respiratory symptoms such as acute bronchitis and cough and phlegm, particularly in children.

Occupational Standard- The current WHO guideline values for NO_2 are: a 1-hour level of 200 $\mu g/m^3$ and an annual average of 40 $\mu g/m^3$.

Lead (Pb)

Lead is bright and silvery when freshly cut but the surface rapidly tarnishes in air to produce the commonly observed dull luster normally associated with lead. It is a dense, ductile, very soft, highly malleable, bluish-white metal that has poor electrical conductivity when compared to most other metals.

Sources - Paint, urban dust, and folk remedies, use of heat guns, battery making, smelter work, plastic manufacturers.

Effects- It damages the nervous system and causes brain disorders. Excessive lead also causes blood disorders in mammals including human being.

Occupational Standards- > 50 $\mu g/m^3$ (Permissible Exposure Limit) (OSHA)

Nickel (Ni)

Pure nickel is a hard, silvery-white metal, which has properties that make it very desirable for combining with other metals to form mixtures called alloys. Nickel is released into the atmosphere during nickel mining and by industries that make or use nickel, nickel alloys, or nickel compounds.

Sources - Coal burning units in utility, industrial, and residential use sectors, and municipal and sewage sludge incinerators, high temperature metallurgical operations (steel and nickel alloy manufacturing, secondary metals smelting, and co-product nickel recovery), chemical and catalyst sources (nickel chemical manufacturing, electroplating, nickel-cadmium battery manufacturing, and catalyst production, use, and reclamation).

Effects- Sensitization dermatitis, allergic asthma, cough, shortness of breath, pneumonitis; decreased sense of smell, Nickel sulfide fume and dust is believed to be carcinogenic, and various other nickel compounds may be as well. Nickel carbonyl, $[Ni(CO)_4]$, is an extremely toxic gas. Sensitized individuals may show an allergy to nickel affecting their skin, also known as dermatitis.

Occupational standards- TWA 0.015 mg/m^3

Benzene (C_6H_6)

Colorless to light-yellow liquid with an aromatic odour

Source- Auto exhaust and industrial emissions, vehicle exhaust, filling and evaporative losses

Effects- Irritation to eyes, skin, nose, respiratory system; dizziness; headache, nausea, staggered gait; anorexia, lassitude (weakness, exhaustion); dermatitis; bone marrow depression

Occupational Standards (OSHA)- Recommended exposure limits TWA 0.1 ppm

Benzo (a) Pyrene (BaP)

A benzopyrene is an organic compound with the formula $C_{20}H_{12}$. Structurally, these colourless pentacyclic hydrocarbons are related to pyrene by fusion of a phenylene group.

Sources - Benzo(a)pyrene is found in nature from the eruption of volcanoes and forest fires, wood-burning fireplaces and stoves, and tobacco smoking

Effects - Cancer-causing agent in humans, Bronchitis

Occupational Standard- Airborne permissible exposure limit (PEL) is 0.2 mg/m^3 averaged over an 8-hour work shift.

Respirable Particulate Matter (RSPM or PM_{10})

Those particulates which have aerodynamic diameter $\leq$10 μm (PM_{10})

Sources - Construction, abrasion, burning of fuels also form secondarily.

Effects- Irritation to eyes, skin, throat, upper respiratory system. Particle pollution contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in diameter pose the greatest problems, because they can get deep into lungs, and some may even get into bloodstream.

Occupational standard-TWA 15 mg/m^3 (total) TWA 5 mg/m^3 (resp), World Health Organization (WHO) air-quality guidelines of 50 $\mu g/m^3$ 24 hrs basis.

Fine Particles ($PM_{2.5}$)

Those particulates which have aerodynamic diameter $\leq$2.5 μm ($PM_{2.5}$)

Sources - Combustion of fuels, metal processing units.

Effects - Carriers of toxic air pollutants including heavy metals and organic compounds, chronic exposure may lead to lung cancer.

Occupational standard -World Health Organization (WHO) air-quality guidelines of 25 $\mu g/m^3$, 24 hrs basis.

Carbon Mono Oxide (CO)

Carbon monoxide (CO), also called carbonous oxide, is a colourless, odourless and tasteless gas which is slightly lighter than air.

Sources - Coal, oil and gas-fired furnaces, space heaters, and water heaters (watch especially for cracks in the chimney liner or flue) as well as wood-burning fireplaces.

Effects- Weakness and dizziness may be the only symptoms preceding collapse. The amount of carboxyhemoglobin formed in the blood is dependent on concentration and duration of exposure, ambient temperature, physical exertion, health, and individual metabolism. Symptoms are usually not noticeable until the carboxyhemoglobin level reaches 10%. At 10-40%, symptoms may include increasingly severe headache, dyspnea on exertion, decreased manual dexterity, impaired judgement and memory, irritability, emotional instability, dizziness, fatigue, drowsiness, confusion, nausea, vomiting, palpitations, and impaired vision and hearing.

Occupational standard- The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for carbon monoxide is 50 parts per million (ppm) parts of air (55 milligrams per cubic meter (mg/m^3) as an 8-hour time-weighted average (TWA) concentration.

Ozone (O_3)

Ozone (O_3) is a gas composed of three oxygen atoms. It is not usually emitted directly into the air, but at ground-level is created by a chemical reaction between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. Ozone has the same chemical structure whether it occurs miles above the earth or at ground-level and can be "good" or "bad," depending on its location in the atmosphere.

Sources- Ground-level or "bad" ozone is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight.

Effects- Breathing ozone, a primary component of smog, can trigger a variety of health problems including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Ground-level ozone also can reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue.

Occupational Standard- The Food and Drug Administration (FDA) requires ozone output of indoor medical devices to be no more than 0.05 ppm. The Occupational Safety and Health Administration (OSHA) require that workers not be exposed to an average concentration of more than 0.10 ppm for 8 hours. The National Institute of Occupational Safety and Health (NIOSH) recommends an upper limit of 0.10 ppm, not to be exceeded at any time.

1.6 DISCUSSION

The air quality of Lucknow city mainly affected due to accumulation of air pollutants which is emitted due to vehicular movement. Earlier we observed unburned black carbon shoot emitted from tail pipe of a vehicle. Technological upgradation and scientific knowhow has

reduced the pollution level, especially of the gaseous pollutants, but increase in number of vehicles causes more emission of pollutants and also changes the composition ratio of the pollutants especially the particulate matter, which includes the fine and ultrafine particles which are invisible. The smaller in size invisible particulate matter is more dangerous than bigger visible particle because they can penetrate deep into the respiratory system, and studies indicates that the smaller the particle, more severe the health impacts. Ambient particulate matter may be carriers of acidic or toxic species (e.g., heavy metals, acids and carcinogenic organic compounds) and may have detrimental effects on human health and ecosystems. Besides the effect of particulate matter, literature also suggests that there is a strong relationship between higher concentration of SO_2 & NOx and several health effects, like cardiovascular diseases, respiratory health effects such as asthma and bronchitis, and reproductive and developmental effects such as increased risk of preterm birth.

The level and effect of emissions from vehicles exhaust are usually an outcome of several factors: population density, congestion, weather, type of fuel and vehicle used, driving habits, road conditions and maintenance schedule.

Similarly, weather, climate and topography of a region determine the ambient conditions. However, exposure to emissions is mainly a function of socio-economic status of an individual and the location both house and office.

Thus it is necessary to monitor the air quality as well as the health effects on regular interval at strategic locations. Our post monsoon 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 help the planners for sustainable development of the city.

1.7 CONCLUSIONS

First time we have monitored eleven air pollutants such as PM_{10}, $PM_{2.5}$, NH_3, CO, O_3, SO_2, NOx, B(a)P, Benzene, Ni and Pb as recommended by Ministry of Environment and Forest (MoEF), New Delhi for assessment of ambient air quality. Besides this we also monitored noise level during Day and Night Time at 10 locations during post monsoon (October), 2010 our data showed the following-

- The RSPM (PM_{10}) level at all the monitoring locations of residential and commercial areas were higher than the NAAQS.

- Fine Particle ($PM_{2.5}$) level at all the monitoring locations of residential and commercial areas were higher than the NAAQS (60 $\mu g/m^3$)

- The concentration of gaseous pollutants, SO_2 & NO_x were within the prescribed NAAQS (80 µug/m^3) at all the locations.

- Decreasing trend for the RSPM was found at all the locations over the 2005 data except at Vikas Nagar, Hussainganj, Charbagh and Aminabad. It may be due to local construction activity.

- The noise level at all the locations except in industrial areas during day and night time showed slightly higher level than the respective permissible limits.

- Level of Lead at all the locations found to be under permissible limit (1.0 µg/m^3)

- Level of Nickel at all the locations found to be under permissible limit when compared with annual average (20 ng/m^3) except Alambagh, Chowk and Aminabad.

- Overall results indicate that RSPM and associated metals are one of the major causes for deterioration of ambient air quality.

The results of the present study revealed that the level of PM_{10} and $PM_{2.5}$ are the major concern because their level is higher than the permissible limit. Results also indicate the presence of other pollutants like carbon monoxide (CO), ozone (O_3), benzo(a) pyrene (BaP), benzene and metals like lead, nickel in the urban area of Lucknow city. Some of these pollutants are carcinogenic but present in comparatively low level. Continuous exposure is a matter of concern with respect to health of Lucnowites in the long run.

1.8 RECOMMENDATIONS

- Public mass transport must be strengthened to minimize use of personal vehicle.
- Improvement in the traffic management.
- Encroachment should be removed for smooth flow of traffic.
- Check on fuel adulteration.
- Public awareness programme for automobile pollution.
- Pressure horns to be removed from all vehicles and avoid use of horn.
- Government should increase the parking charges on hourly basis to discourage the use of personal vehicle.
- Congestions charges for certain area for peak hours.
- Restored foot path for pedestrian