ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY

(POST-MONSOON)

FINDINGS OF A RANDOM SURVEY

PRESENTED ON 47th IITR FOUNDATION DAY

CSIR- INDIAN INSTITUTE OF TOXICOLOGY RESEARCH

Mahatma Gandhi Marg, Lucknow – 226001

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4th November, 2012

PERSONNEL

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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** : 28,15033 as per 2011 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 Vehicular Population in Lucknow city as on 31/03/2012** : 13,14,705
- **Growth of Vehicle over 2010-2011** : 8.68%
- **Total No. of Filling Stations (Petrol/Diesel/CNG)** : 100
- **Consumption of Petrol** : 1,24,805 KL
- **Consumption of Diesel** : 1,30,372 KL
- **Consumption of CNG** : 2,14,39,460 Kg
- **Major Source of Pollution** : Automobiles, D. G. sets, Civil Constructions
- **Parameters Monitored** : PM_{10}, $PM_{2.5}$, SO_2, NO_X and Noise Level
- **Study Conducted by** : Environmental Monitoring Division IITR, Lucknow

ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY DURING POST-MONSOON, 2012

Environmental Monitoring Division
CSIR- Indian Institute of Toxicology Research
M.G. Marg, Lucknow

1.0 SUMMARY

The study was carried out during the month of October, 2012 to see the status of air quality by monitoring and assessment of some selected air pollutants namely Respirable Particulate Matter (RSPM or PM_{10}), Fine Particulates ($PM_{2.5}$), Sulphur dioxide(SO_2), Nitrogen dioxide (NO_2), and noise level at 9 representative locations, categorized as residential (four), commercial (four) and industrial (one) areas in Lucknow city. The results revealed the 24 hours concentration of PM_{10} in the range of 107.1 to 343.6 µg/m^3 with an average of 205.3µg/m^3. The corresponding 24 hours values of $PM_{2.5}$ ranged between 53.3 to 195.8 µg/m^3 with an average of 91.9 µg/m^3. The average values of PM_{10} and $PM_{2.5}$ irrespective of locations were found to be above the permissible limit (PM_{10}= 100 µg/m^3 and $PM_{2.5}$= 60 µg/m^3) prescribed by MoEF. 24 hours concentration of SO_2 and NOx were found in the range of 13.8 to 34.8 and 34.0 to 91.8 µg/m^3 with an average concentration of 23.3 and 56.0 µg/m^3 respectively and all the values were below the permissible limits (80 µg/m^3). Noise levels during day and night time were found in the range of 60.5 to 72.5 dB (A) and 53.7 to 67.4 dB (A) which was above the respective permissible limits except in industrial area.

1.1 INTRODUCTION

Several scientific reports revealed that urban air quality is detoriating day by day mainly due to vehicular pollution. Some of the common criteria air pollutants like SO_2 (Sulphur dioxide), Oxides of Nitrogen (NOx), Particulate Matter (PM), etc are emitted from the tail pipe of a vehicles and accumulated in the air, affecting the living being including human being in different ways. Recent studies suggest that PM in urban areas above the prescribed standards in different cities in our country as well other countries especially the developing countries.

PM cause severe adverse effects on human health. PM is a complex mixture of chemical agents of different shapes and sizes. Studies reveal that the effect of PM on human health will depend on the chemical composition of PM, besides its number and mass concentration. In India, PM standard in ambient air is limited to two specified size ranges $PM_{2.5}$ (< 2.5 μm) and PM_{10} (< 10 μm,). At elevated levels at both size ranges, mortality and morbidity of humans have been reported. The routine air monitoring data on components of the PM mass is essential for epidemiological studies which may identify the chemical constituents of PM which cause health effects and also the source.

Nitrogen dioxide (NO_2) and carbon monoxide (CO) are good indicators of traffic exhaust emissions as they contribute most to the total emission. Epidemiological studies have shown that short-term exposure to NO_2 and CO is associated with increased cardiovascular mortality, including cerebrovascular diseases and ischemic heart disease.

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, pavement type and vehicle conditions.

It is need of the hour, for the awareness of common people especially in the urban area regarding vehicular pollution and human health and it’s consequences in the

short and long term. Unlimited growth of number of vehicles and human being which severely affecting the sustainable development and gradually becoming unbearable.

In view of above facts, it is need of the hour to look into the air quality of our city Lucknow, the capital of Uttar Pradesh which has a population of 28.15 Lakh (Municipal corporation + Cantonment) as per 2011 census and an area of 310 sq. km. Vehicular traffic is the main source of particulate air pollution in Lucknow city. Continuous emission of pollutants from vehicular traffic adversely affects the ambient air quality as well as on the human health. The number of different category of vehicles registered with RTO (Regional Transport Office) Lucknow is 13,14,705 as on 31.03.2012 which is 8.68% higher over the last year (Table 1). 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 31.03.2012 are given in Table 2. In Lucknow city there are 100 filling stations for petrol, diesel and CNG operated by different oil companies (Table 3).

As per Indian Oil Corporation (IOC), the consumption/sale of petrol and diesel was 1,24,805 and 1, 30,372 KL as on 31-03-2012. It is observed that petroleum sale have been increased by 3.95% whereas sale of diesel has increased by 3.73%. (Table 4). In Lucknow there are six CNG filling stations and consumption of CNG in last year was approximately 2,14,39,460.18 Kg (2011-12) which was 12.15% higher than the previous year (2010-11) (Green Gas Limited, Lucknow). Distribution and number of CNG vehicles in Lucknow is summarized in Table 5. Considering the above, assessment of ambient air quality of Lucknow city was carried out at 9 locations during post monsoon (October), 2012 with the following aims and objectives.

- *To assess the ambient air quality with respect to PM_{10}, $PM_{2.5}$, SO_2 and NOx.*
- *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*

Table 1. Vehicles registered with R.T.O. Lucknow during 2010-11 and 2011-12

Sl. No.	Type of Vehicle	Number of Registered Vehicles on 31st March		% Change
		2010-11	2011-12	
1	Multi Articulated	2288	2520	10.14
2	Light, Medium and Heavy weight Vehicles (Four wheeler)	14268	15593	9.29
3	Light commercial vehicles (Three wheeler)	2859	3022	5.70
4	Buses	2935	3098	5.55
5	Taxi	5354	6195	15.71
6	Three Wheelers and Auto Rickshaws	7318	7195	11.71
7	Two wheelers	970897	1052717	8.43
8	Car	165589	183288	10.69
9	Jeep	15513	16932	9.15
10	Tractor	17809	19012	6.76
11	Trailers	1318	1361	3.26
12	Others	3597	3772	4.87
Total		**12,09,745**	**13,14,705**	**8.68**

Source: RTO, Lucknow

Table 2. Details of Lucknow city bus service, 2012

Sl. No.	Route No.	To and Fro	No. of Buses
1	11	BBD -Chinhat-Gomti Nagar-Alambagh	42
	11 A	Malhaur railway station-Gomtinagar-Dalibagh-Charbagh	
	11B	Charbagh-Alambagh-Avadh hospital-SGPGI	
	11C	Charbagh- Alambagh -Sardar Patel Dental college	
	11D	Charbagh- Alambagh- BBAU	
	11E	Charbagh-Alambagh- Gopal Kunj-Kalindi Park	
2	12	BBD- Chinhat- Charbagh- Alambagh-Scooter India	24
	12 A	Samarpan college- Chinhat-Charbagh- Alambagh- Scooter India	
	12 B	BBD-Charbagh- Alambagh- Paasi Kila	
3	23	Gudamba – Vikasnagar- Alambagh- Rajnikhand	32
	23B	Rajnikhand-Gudamba	
4	24	Engineering College-Indiranagar-Charbagh-Alambag-Paasi Kila	24
	24 A	Alambagh-Manas Bihar colony	
5	25	Charbagh-Alambagh-Chandraval	7
	25 A	Charbagh-Aurangabad-Maati	
6	31	Alambagh – IIM	2
7	33	Engineering College-Charbagh-Alambagh-Scooter India	27
	33 A	Alambagh-Goal chauraha	
	33 C	Engineering College-Charbagh-Alambagh-Scooter India	
10	45	Virajkhand-Gomtinagar-Charbagh-Alambagh-Paasi Kila	16
11	Paryatak Sewa	Charbagh- Parivartan -Hazratganj-Charbagh	2
		Total	176

Source: UPSRTC, Lucknow

Table 3. Petrol Pumps in Lucknow City

Sl. No.	Agency	Number of outlets 31st March 2012
1	Indian Oil Corporation (IOC)	47
2	Bharat Petroleum Corporation Ltd. (BPCL)	22
3	Hindustan Petroleum Corporation Ltd. (HPCL)	25
4	Compressed Natural Gas Stations (CNG)	6
	Total	100

Source: Indian Oil Corporation (IOC), Lucknow

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

Sl. No.	Agency	Petrol (Unleaded)			High Speed Diesel			*CNG		
		Apr. 10 to Mar. 11	Apr. 11 to Mar. 12	% Change	Apr. 10 to Mar. 11	Apr. 11 to Mar. 12	% Change	Apr. 10 to Mar. 11	Apr. 11 to Mar. 12	% Change
1	IOC	65961	67849		70179	71351		--	---	
2	BPCL	31272	32456		25944	27121		--	---	
3	HPCL	22828	24500		29565	31900		--	---	
4.	Green Gas	--	--	--	--	--	--	19,117542	21439460	
Total		**120061**	**124805**	**3.95**	**125688**	**130372**	**3.73**	**1,91,17,542**	**2,14,39,460**	**12.15**

*Source: Indian Oil Corporation (IOC), Lucknow, * CNG in Kg, CNG Source: Green Gas Limited, Lucknow*

Table 5. Distribution of CNG vehicles

Sl. No.	Vehicles	Number	
		2010-11	2011-12
1	Auto Rickshaws	4213	4343
2	Tempo Taxi	2534	2534
3	Buses (UPSRTC)	247	260
4	Buses (Private)	26	34
5	School Buses	363	---
6	School Van	295	---
7	Private Vehicles	80	---

Source: UPSRTC, Lucknow

1.2 MONITORING LOCATIONS AND METHODOLOGY

Nine air quality monitoring locations representing different activities/areas i.e., four in residential, four in commercial cum traffic and one industrial area were selected for the study as summarized in Table 6 (brief description of each location is given in our earlier reports (Pre and Post monsoon, 2010) 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	Charbagh	Commercial cum traffic
6	Alambagh	Commercial cum traffic
7	Aminabad	Commercial cum traffic
8	Chowk	Commercial cum traffic
9	Amausi	Industrial

Table 7. Parameters and Methodology for Air Quality Monitoring

Sl. No.	Parameters	Time Weighted average	Methods of Measurement
1	Particulate Matter- PM_{10} and $PM_{2.5}$	24 hours	Gravimetric
2	Sulphur dioxide (SO_2)	24 hours	Improved West Gaeke
3	Nitrogen Dioxide (NO_2)	24 hours	Modified Jacob & Hochhesier (Na-Arsenite)
4.	Noise Level	1 hour	The measurement of noise level was carried out during the day (6 AM to 10 PM) and night time (10 PM to 6 AM) by Noise level Meter.

1.3 RESULTS

The detailed results of air quality monitoring are presented in Table 8 and Fig. 1.

1.3.1 Respirable Suspended Particulate Matter (RSPM or PM_{10})

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar), the 24 hours average concentrations of PM_{10} were in the range of 154.8 to 194.8 µg/m^3 with an average of 167.1µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of PM_{10} were in the range of 177.3 to 260.5µg/m^3 with an average of 230.9 µg/m^3 respectively. In industrial area (Amausi), the average concentrations of PM_{10} was 217.9 µg/m^3 .

The maximum 24 hours mean concentration of PM_{10} was observed in Gomti Nagar (194.8 µg/m^3) in residential area and Alambagh (260.7 µg/m^3) in commercial area.

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

1.3.2 Fine Particles ($PM_{2.5}$)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the 24 hours mean level of $PM_{2.5}$ were in the range of 77.9 – 89.1 µg/m^3 with an average of 83.5 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk), 24 hours mean concentrations of $PM_{2.5}$ were in the range of 81.0 to 120.9 with an average of 107.3 µg/m^3 respectively. In industrial area (Amausi), the average concentration of $PM_{2.5}$ was 85.2 µg/m^3.

The maximum 24 hours mean concentration of fine particles was in Aliganj (89.1 µg/m^3) in residential area and Alambagh (120.9 µg/m^3) in commercial area.

All the mean values of $PM_{2.5}$ were above the prescribed National Ambient Air Quality Standard (NAAQS) of 60 µg/m^3 at all nine monitoring locations.

1.3.3 Sulphur dioxide (SO_2)

In residential area (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the mean levels of SO_2 were in the range of 18.1 to 22.9 µg/m^3 with an average of 20.3 µg/m^3. In commercial area (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of SO_2 were in the range of 21.3 to 24.6 µg/m^3 with an average of 22.6 µg/m^3. In industrial area (Amausi) the average concentration of SO_2 was 27.2 µg/m^3.

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

1.3.4 Oxides of Nitrogen (NOx)

In residential areas (Aliganj, Vikas Nagar, Indira Nagar and Gomti Nagar) the 24 hours average concentrations of NO_X were found in the range of 49.2 to 60.5 µg/m^3 with an average of 52.9 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of NO_X were found in the range of 58.3 to 77.6 µg/m^3 with an average of 66.8 µg/m^3. In industrial areas (Amausi) the average concentration was 48.3 µg/m^3

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

Table 8: Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NOx during Post monsoon 2012

Location	RSPM			$PM_{2.5}$			SO_2			NOx		
Residential	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Aliganj	107.1	190	154.8	53.3	111.4	89.1	17.4	25.7	20.8	34	82	52.5
Vikas Nagar	109.2	207.6	157.2	54.5	109.8	80.7	15.2	34.0	22.9	40.8	60.9	49.6
Indira Nagar	146.4	185.8	161.4	65.6	102.6	86.2	15.8	23.3	19.4	48.5	58.7	60.5
Gomti Nagar	120.6	244.3	194.8	65.5	90.2	**77.9**	13.8	23.0	18.1	42.3	56.2	49.2
Average			**167.1**			**83.5**			**20.3**			**52.9**
Commercial												
Charbagh	176.2	287.4	241.2	101.9	137.6	117.9	17.6	23.3	21.3	51.1	77.4	67.2
Alambagh	202.0	343.6	260.5	73.8	195.8	120.9	17.0	26.5	21.5	57.3	73.2	64.7
Aminabad	110.4	238.1	177.3	63.1	94.6	81.0	15.9	33.0	22.8	40.1	75.6	58.3
Chowk	188.4	308.2	244.7	77.1	160.4	109.5	17.0	34.8	24.6	53.4	91.8	77.6
Average			**230.9**			**107.3**			**22.6**			**66.8**
Industrial												
Amausi	193.0	280.2	217.9	69.7	107.4	85.2	21.0	31.7	27.2	55.2	44.5	48.3
NAAQS	100			60			80			80		
WHO Guidelines	50			25			20			40*		

N=4, *= Annual Average, NAAQS=National Ambient Air Quality Standards

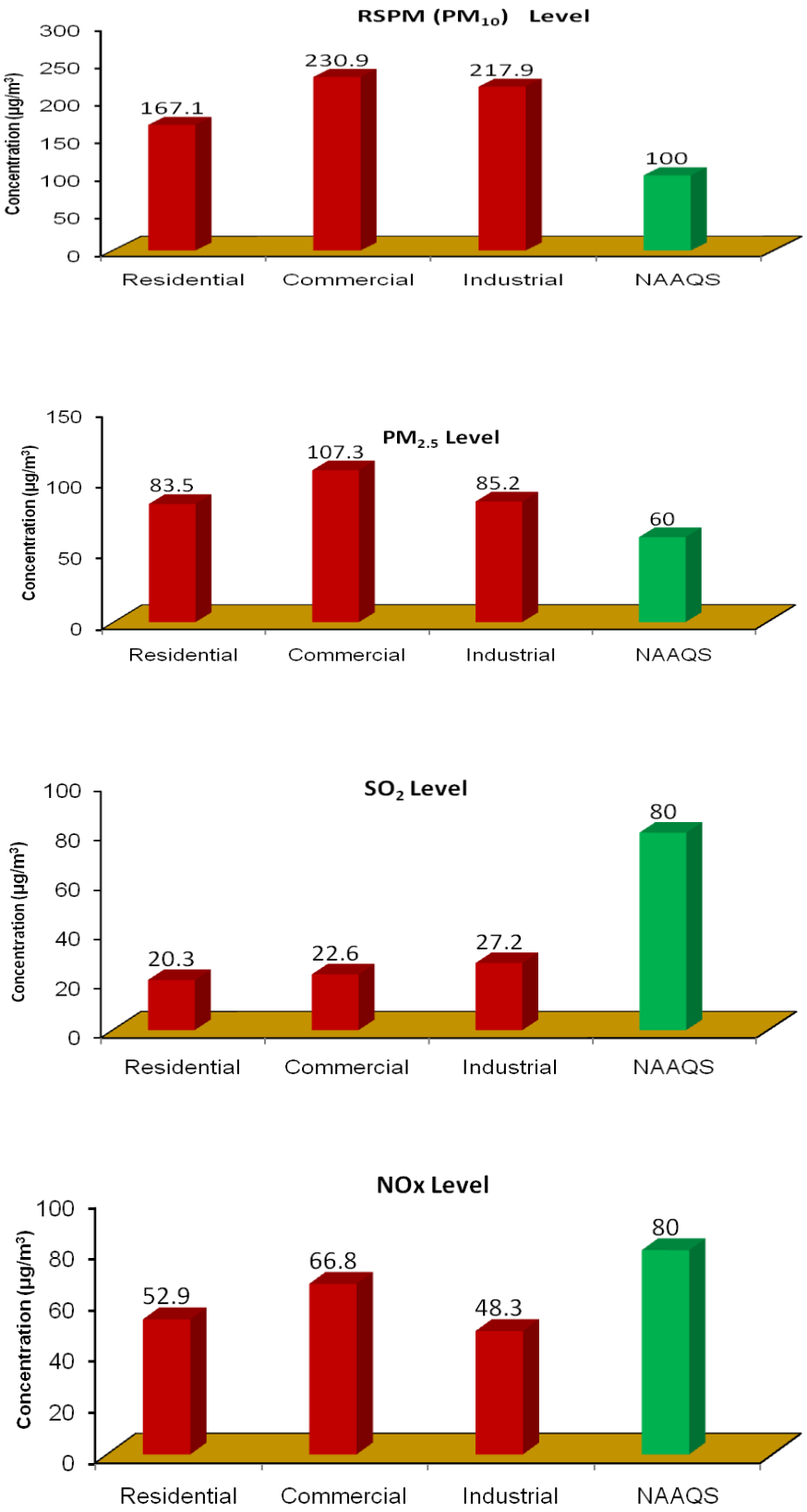

Fig 1: Concentration (µg/m^3) of PM_{10}, $PM_{2.5}$, SO_2 and NO_x in different areas of Lucknow city during post monsoon season (2012) and compared with prescribed National Ambient Air Quality Standard (NAAQS)

1.3.5 Noise

The monitoring data recorded during the post monsoon period (October, 2012) is presented in Table 10.

In residential areas, the day and night time noise levels were recorded between 60.5 to 65.7 and 53.7 to 58.4 dB(A) respectively. All the values were 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 70.5 to 72.5 and 54.3 to 67.4 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 69.3 and 64.7 dB (A) respectively. Noise levels at industrial location in the day and night time was found below the prescribed limit of 75.0 and 70.0 dB(A) respectively.

Table 10. Noise Level dB (A) during Day and Night Time

Sl. No.	Area	Location	Noise level dB(A)	
			Day	**Night**
1.	**Residential**	Aliganj	60.5	53.7
		Vikas Nagar	62.2	54.4
		Indira Nagar	65.7	58.4
		Gomti Nagar	62.8	53.8
		Standard	**55.0**	**45.0**
2.	**Commercial**	Charbagh	72.5	67.4
		Alambagh	70.6	62.3
		Aminabad	71.6	54.3
		Chowk	70.5	57.8
		Standard	**65.0**	**55.0**
3.	**Industrial**	Amausi	69.3	64.7
		Standard	**75.0**	**70.0**

1.4 TRENDS OF AMBIENT AIR QUALITY IN LUCKNOW CITY

The observed PM_{10}, SO_2 and NO_x for 3 last years and $PM_{2.5,}$ for last two years data have been compared to find out the prevailing trend of air pollution in Lucknow city (Fig. 2-5). The slight decrease or increase in the values may be attributed to some local environmental and climatic factors.

1.4.1 Respirable Suspended Particulate Matter (RSPM or PM_{10})

In all the locations in residential areas, lower values were found compared to the previous year except in Gomti Nagar. Among the commercial areas, PM_{10} values showed increasing trend at all the four locations than the last year. Amausi under industrial area showed higher value over the last year. All the values are higher than the NAAQS (Fig. 2).

1.4.2 Fine Particulate Matter ($PM_{2.5}$)

In all the locations in residential areas, lower values were found compared to the previous year except in Gomti Nagar. Among the commercial areas, $PM_{2.5}$ values showed higher values in Alambagh and Aminabad than the last year. Amausi under industrial area showed little lower value over the last year. All the values are higher than the NAAQS (Fig. 3).

1.4.3 Sulphur dioxide (SO_2)

In residential areas, slightly higher concentration was found compared to the previous year except Vikas Nagar. Among the commercial areas, SO_2 values showed lower values than the last year. Amausi under industrial area showed little lower value over the last year. All the values were found to be lower than the NAAQS (Fig. 4).

1.4.4 Oxides of Nitrogen (NO_x)

The level of NOx during post monsoon since 2009 is presented in Fig. 5 for all the locations. Among the residential, commercial and industrial areas all the locations showed increasing trend when compared with the previous year data except Charbagh. All the values of the present study were found to be lower than the NAAQS (Fig.5).

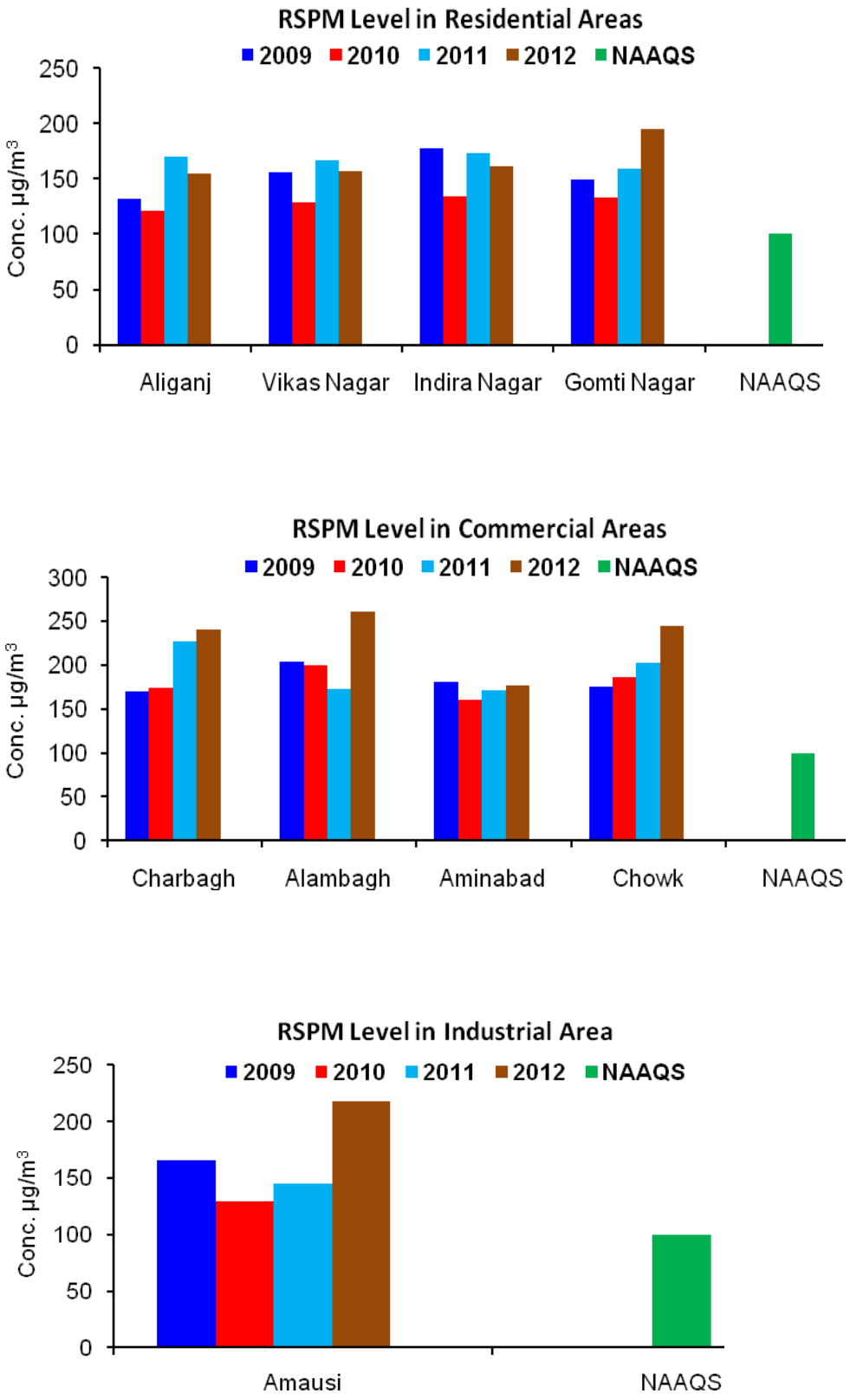

Fig 2: Concentration (µg/m^3) of PM_{10} **(**RSPM**)** in Residential, Commercial and Industrial areas of Lucknow city during 2009 to 2012 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

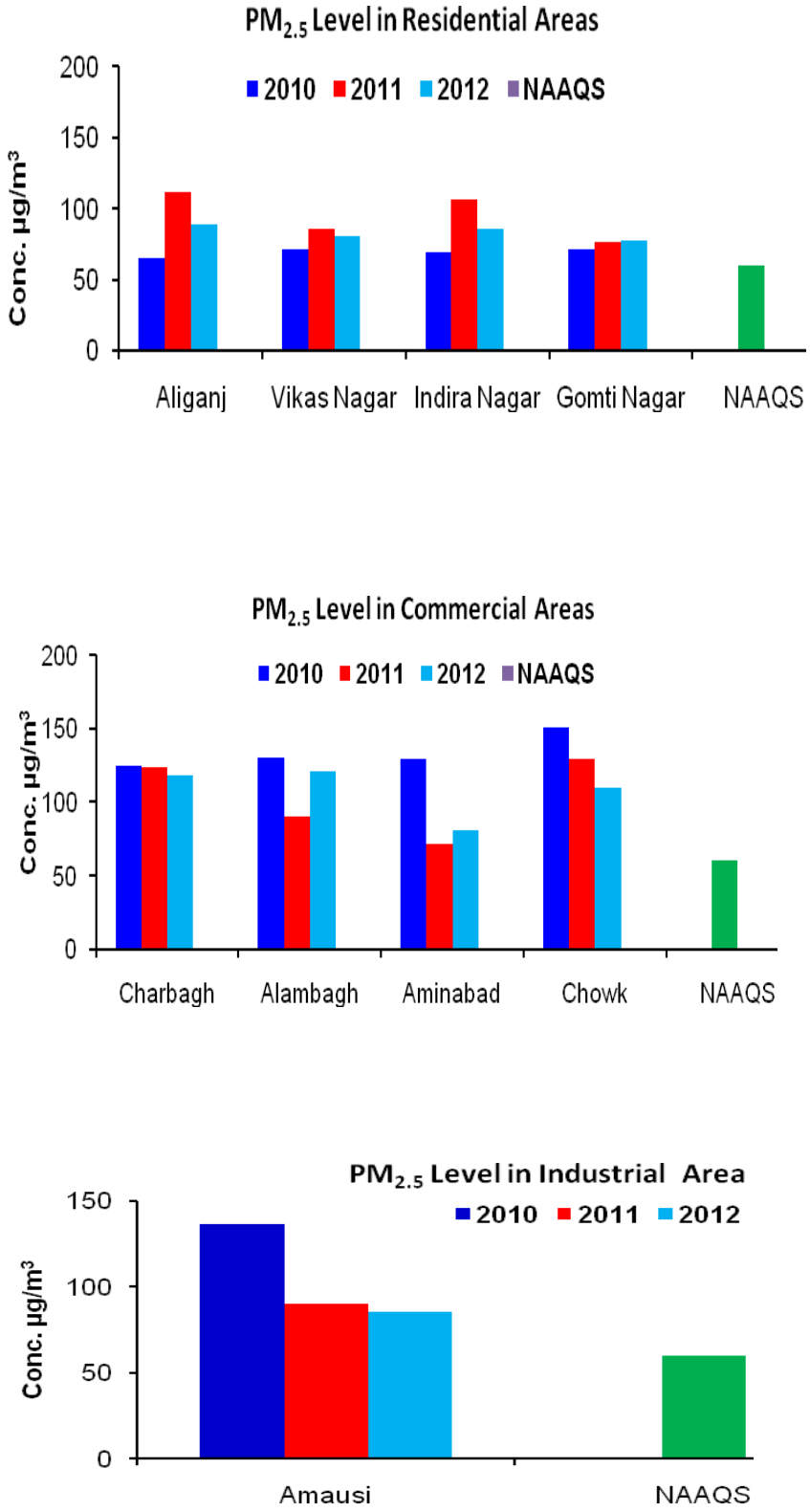

Fig 3: Concentration (µg/m^3) of $PM_{2.5}$ in Residential, Commercial and Industrial areas of Lucknow city during 2010 to 2012 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

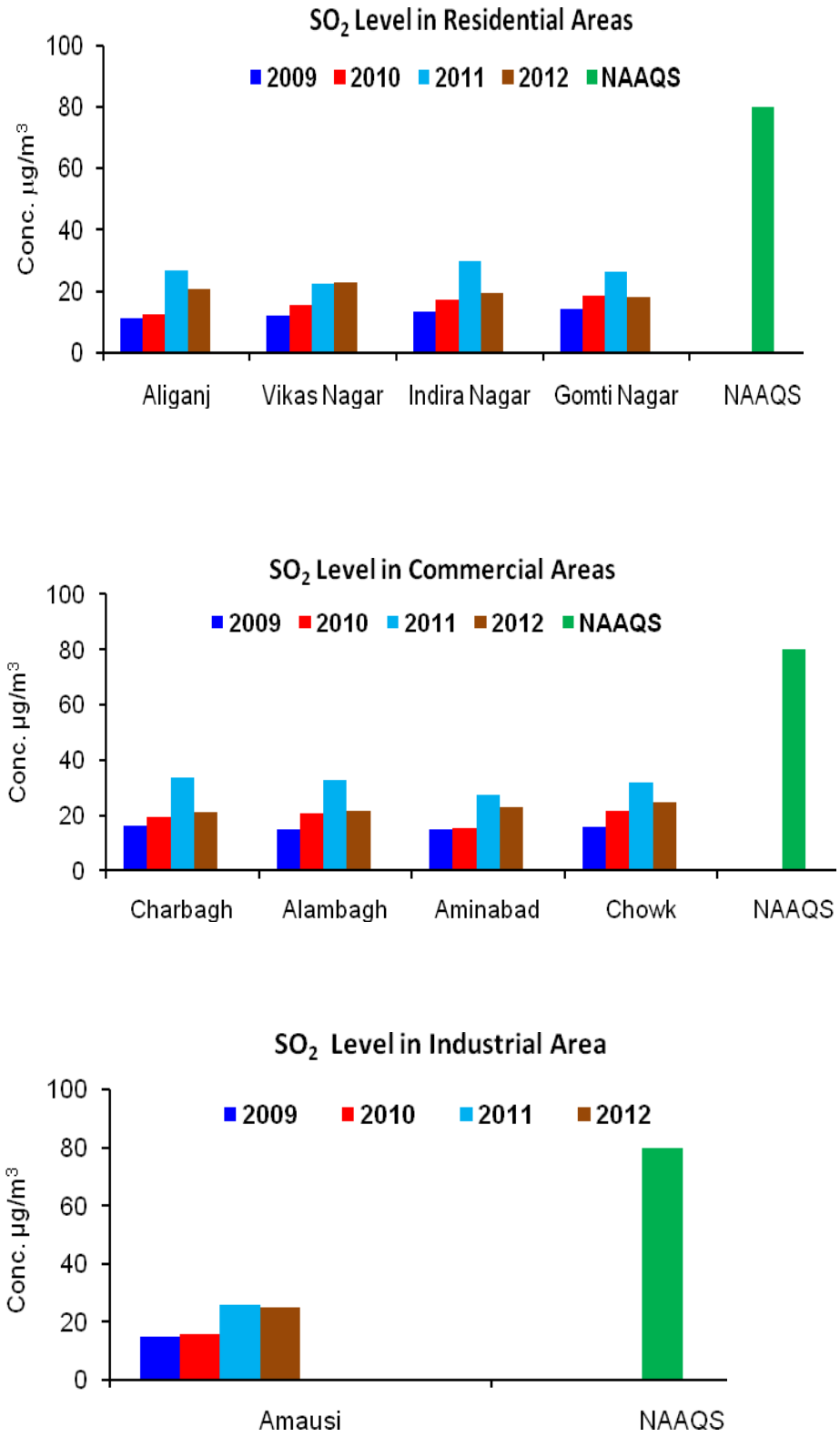

Fig 4: Concentration (µg/m^3) of SO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2009 to 2012 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

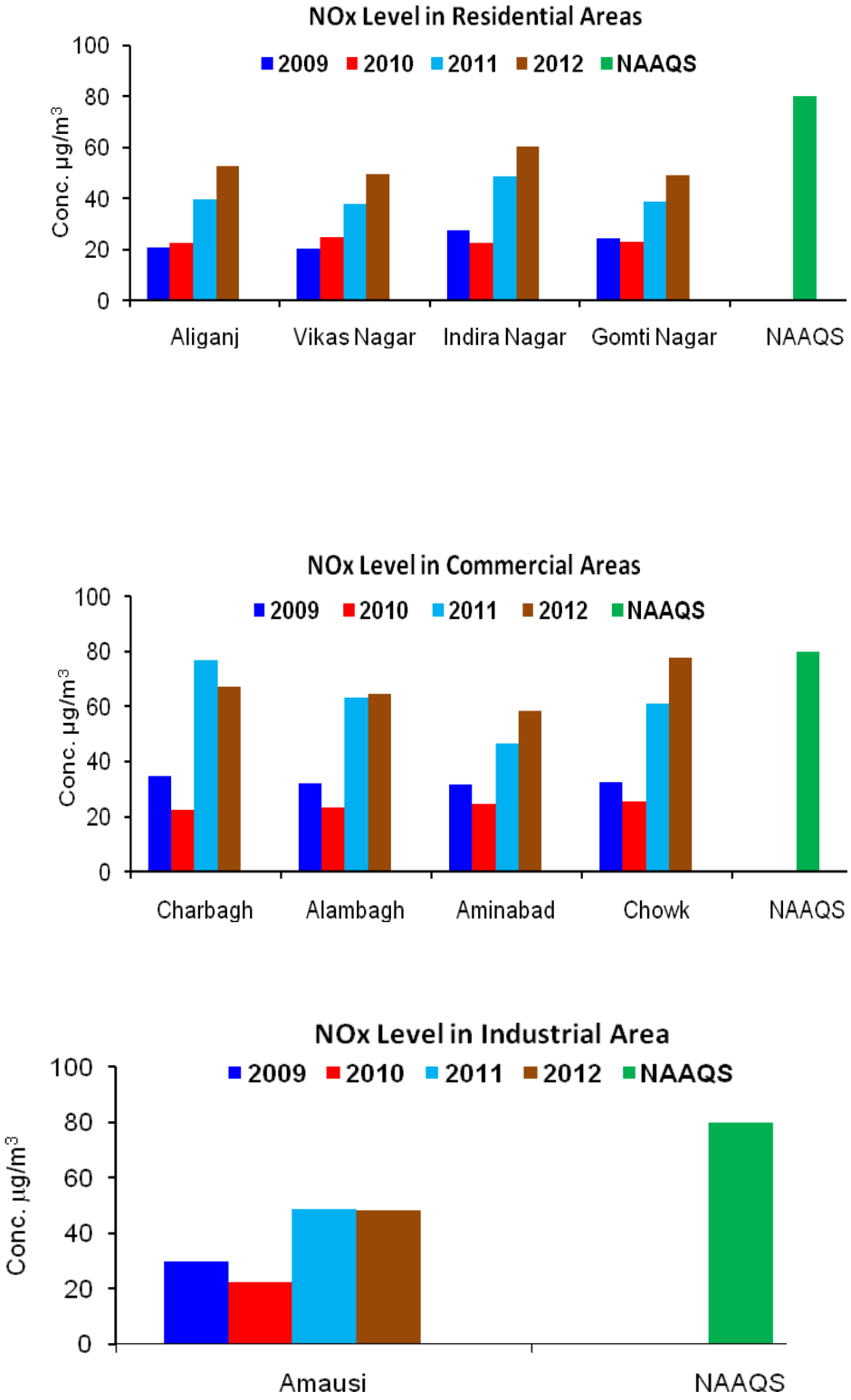

Fig 5: Concentration (µg/m^3) of NO_x in Residential, Commercial and Industrial areas of Lucknow city during 2009 to 2012 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

1.4.5 Noise Level

Current year's noise data has been compared with the corresponding data of the previous three years and are presented in Fig. 6 and 7. The comparative noise level in residential, commercial and industrial areas are described below:

1.4.5.1 Day time Noise Level

In residential areas all the locations showed slightly increasing trend over the previous year. In commercial cum traffic areas noise level was slightly on the higher side at all locations were recorded compared to the previous year. In industrial area, Amausi the noise level was higher than the previous year. The comparative data are presented in (Fig.6.).

1.4.5.2 Night time Noise Level

Residential areas showed slightly higher trend than the last year level. Commercial and industrial areas also showed higher values except Aminabad (commercial area) than the previous year. The comparative data are presented in (Fig. 7).

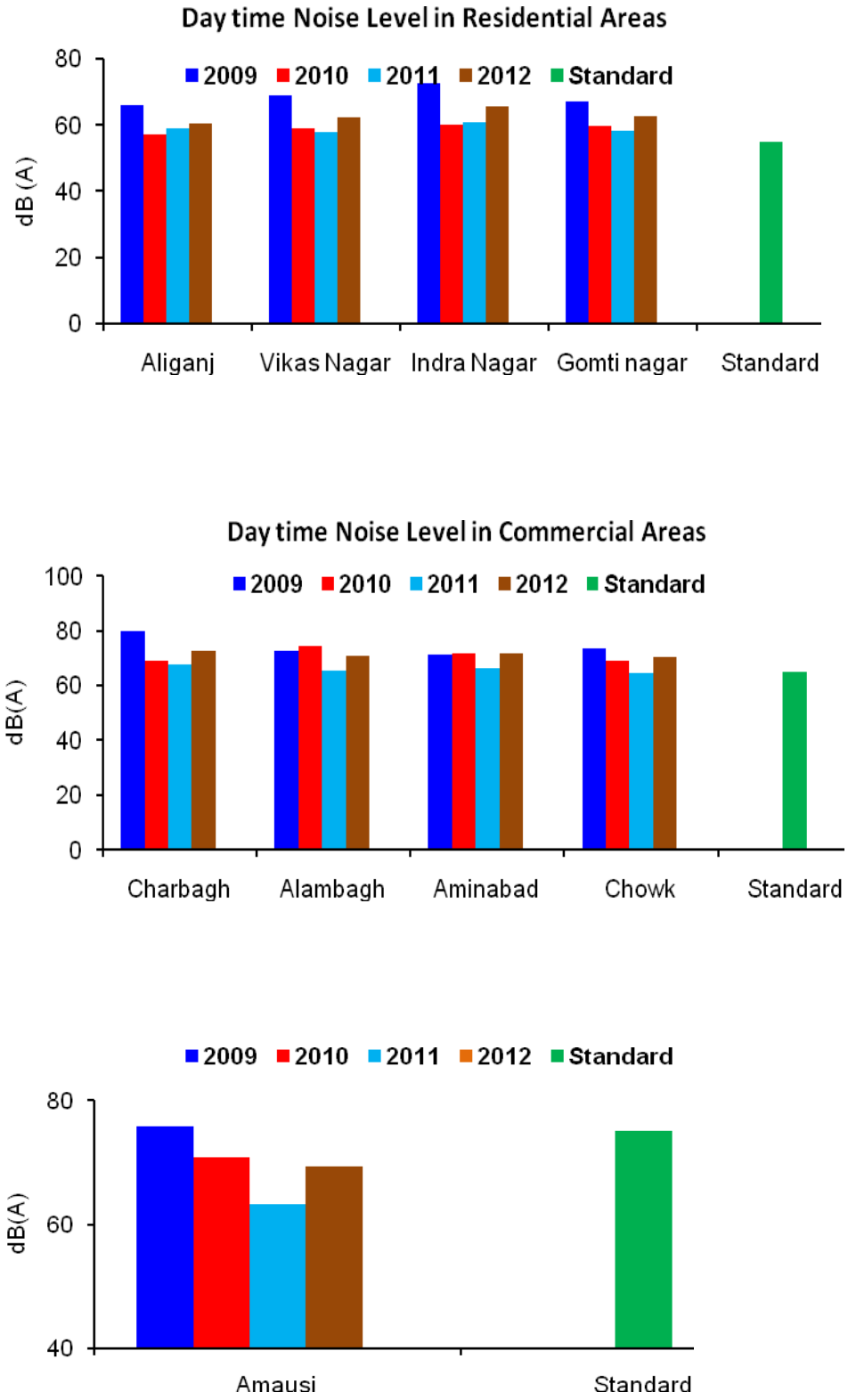

Fig 6: Comparison of day time Noise Level dB(A) in different areas of Lucknow city (2009-2012)

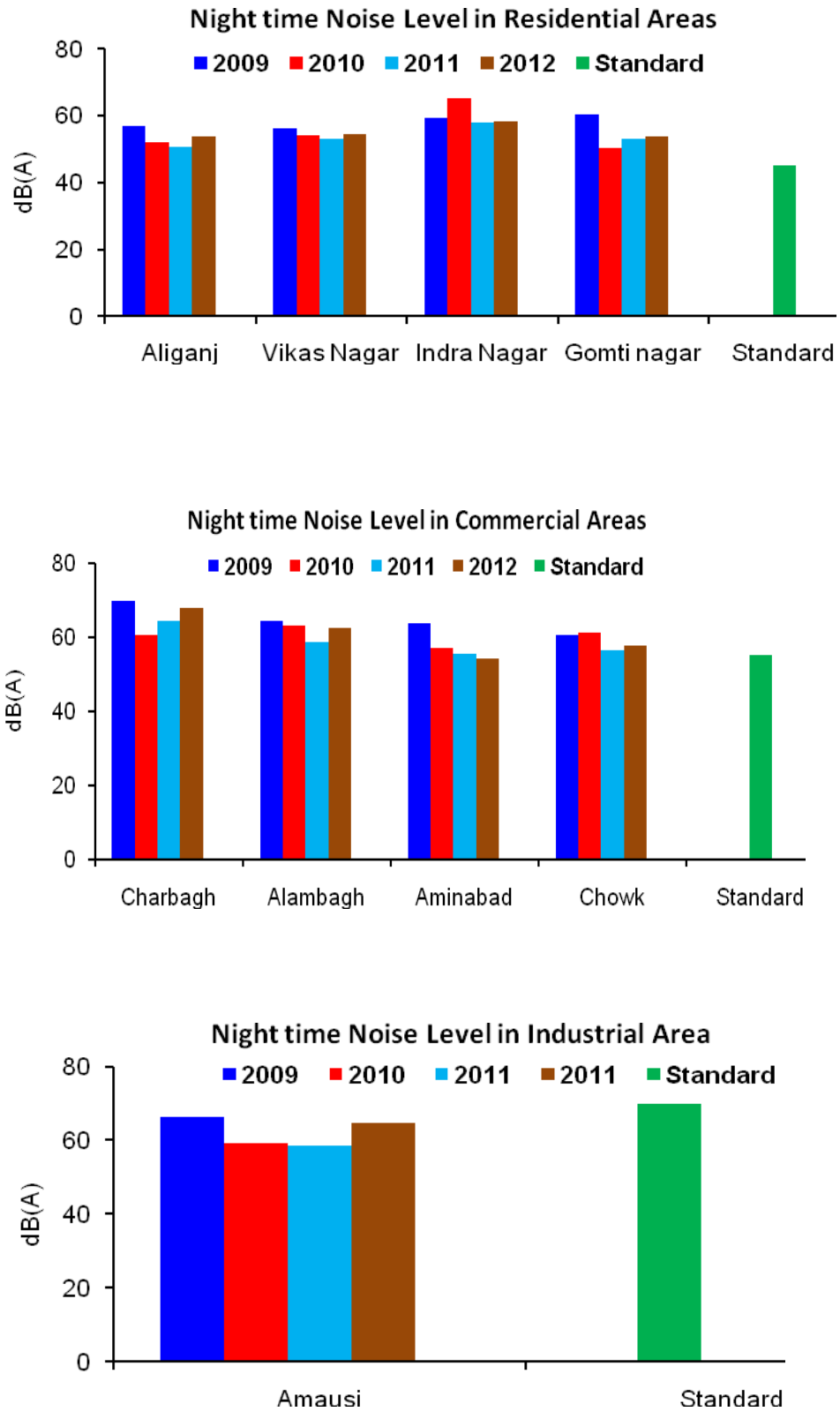

Fig 7: Comparison of night time Noise Level dB(A) in different areas of Lucknow city (2009-2012)

1.5 HEALTH EFFECTS

At elevated levels, all the pollutants including metals have adverse effects on human and environmental health. Accumulation of pollutants in the human body through inhalation of air is an important route. Results of the present study revealed that higher level of particulate matter especially the PM_{10} and $PM_{2.5}$ at all the monitoring locations are 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. It is reported that the total daily mortality increased by approximately 1% for every 10 $\mu g/m^3$ increase in PM_{10} concentration.

Human exposure to particulate air pollution has been identified as a risk factor for human mortality and morbidity and many countries have revised the limits for PM_{10} as previously defined and set up new quantitative standards for $PM_{2.5}$. Nevertheless, PM thresholds levels to which exposure does not lead to adverse effects on human health have not yet been clearly identified and there is a substantial inter-individual variability in exposure and in the response and it is difficult to establish a standard or guideline value that will lead to a complete protection of every individual against all possible adverse health effects of particulate matter.

The effect of PM depends on the mass and number concentration, shape and size and the composition and concentration of other inorganic and organic pollutants associated with it.

In the present study, the concentration of SO_2 and NOx were found to be below permissible limit (80 $\mu g/m^3$) of NAAQS (MoEF 2009), but there are several reports that gaseous pollutants are related with respiratory diseases and reproductive and developmental effect even at low concentration. Vehicular traffic and NO_2 are associated with significantly higher risk of lung cancer.

1.6 CONCLUSIONS

We have monitored air pollutants such as PM_{10}, $PM_{2.5}$, SO_2 and NOx for assessment of ambient air quality. Besides, we also monitored noise level during day and night time at 9 locations during post monsoon (October), 2012 and our data showed the following-

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

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

- The concentration of gaseous pollutants, SO_2 and NO_x were well below the prescribed NAAQS (80 $\mu g/m^3$) at all the locations.

- Increasing trend for the PM_{10} was found at all the commercial and industrial areas when compared to the previous year.

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

Unlimited growth of number of vehicles, their technological development and release of invisible tailpipe pollutants emission are serious debatable issues even for the policy maker. Use of different types of fuels namely petrol, diesel and CNG make the environment more complex regarding the air quality and their synergistic effects on the human health. Overall, continuous accumulation of different types of pollutants and their exposure to human being needs emergency attention of the policy maker, researchers and regulatory agencies.

The present study suggests that it is necessary to monitor the air quality as well as the health effects at regular intervals at strategic locations. Our pre monsoon monitoring survey might be of help to focus on the pollution level in Lucknow city and its probable consequences. Our database since 1997 will help the planners for sustainable development of the city.

1.7 RECOMMENDATIONS

- Subsidized public mass transport must be strengthened to minimize use of personal vehicles.
- Improvement in the traffic management.
- Encroachment should be removed for smooth flow of traffic.
- 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 vehicles.
- Restore foot path for pedestrian.

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