ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY

(POST- MONSOON 2013)

FINDINGS OF A RANDOM SURVEY

PRESENTED ON 48th CSIR-IITR FOUNDATION DAY

CSIR- INDIAN INSTITUTE OF TOXICOLOGY RESEARCH

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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
- **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 31/03/2013** : 14,24,478
- **Growth of Vehicle over 2011-2012** : 8.35%
- **Total No. of Filling Stations (Petrol/Diesel/CNG)** : 100
- **Consumption of Petrol** : 1,28,440 KL
- **Consumption of Diesel** : 1,36,870 KL
- **Consumption of CNG** : 2,38,11,473 Kg
- **Major Source of Pollution** : Automobiles, D. G. sets, Civil Constructions
- **Parameters Monitored** : PM_{10}, SO_2, NO_X, Trace metals and Noise
- **Study Conducted by** : Environmental Monitoring Division CSIR-IITR, Lucknow

ASSESSMENT OF AMBIENT AIR QUALITY OF LUCKNOW CITY DURING POST-MONSOON, 2013

Environmental Monitoring Division
CSIR- Indian Institute of Toxicology Research
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1.0 SUMMARY

The study was carried out during the month of October, 2013 to see the status of air quality by monitoring and assessment of some selected air pollutants namely Respirable Particulate Matter (RSPM or PM_{10}), 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} was in the range of 101.2 to 365.9 µg/m^3 with an average of 203.9 µg/m^3. The average values of PM_{10} irrespective of locations were found to be above the permissible limit (PM_{10} =100 µg/m^3) prescribed by MoEF. 24 hours concentration of SO_2 and NOx were found in the range of 7.9 to 31.3 and 30.7 to 89.6 µg/m^3 with an average concentration of 15.9 and 54.8 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 62.2 to 74.5 dB(A) and 54.2 to 71.5 dB (A) which was above the respective permissible limits (day and night time noise levels in residential area are 55 and 45 dB(A) and corresponding values for commercial area are 65 and 55 dB(A) respectively) except in industrial area which is 68.9 and 65.5 dB (A) during day and night time respectively. .

1.1 INTRODUCTION

Urban air pollution has emerged as an acute problem in recent years because of its detrimental effects on health and living conditions. Air pollutants exert a wide range of impacts on biological, physical, and economical systems. Their effects on human health are of particular concern. High concentration of pollutants is causing adverse health effect and even premature deaths among sensitive groups such as asthmatics and elderly people.

Air pollution is a mixture of solid particles and gases in the air. National Ambient Air Quality Standard (NAAQS-2009) listed standards for twelve common and harmful air pollutants which have documented widespread health threats. The most important of these particulate matter (PM) consists of a heterogeneous mixture of very small particles and liquid droplets suspended in air. The size of particles in PM is directly linked to their potential to cause health problems. Particles with diameter ≤ 10 μm are the particles that generally pass through the throat and nose and enter the lungs. Then, they can affect various body organs, especially the heart and lungs, and may cause serious health effects. Based on particle size, particle pollution is grouped into inhalable coarse particles (which have a diameter of 2.5 μm to 10 μm, and are found near roadways and industries) and fine particles (< 2.5 μm in diameter such as those found in smoke and haze; they can form when gases emitted from power plants, industries and automobiles react in the air). Sulfur dioxide (SO_2) is a gas formed when fuel containing sulfur, such as coal and oil, is burned, and when gasoline is extracted from oil or metals are extracted from ore. Nitrogen oxides (NOx) are a group of highly reactive gases containing various levels of nitrogen and oxygen. Lead is usually emitted from motor vehicles and industrial sources. Other stationary sources are waste incinerators, utilities, and lead-acid battery manufacturers. In addition to exposure to lead in air, other major exposure pathways include ingestion of lead in drinking water and lead-contaminated food as well as incidental ingestion of lead-contaminated soil and dust. Lead-based paint remains a major exposure pathway in older homes. Some toys might contain considerable amounts of lead that would be harmful for children's health. The high level of Pb can induce severe neurological and hematological effects on the exposed population especially children, whereas Ni are known for inducing carcinogenic effects in humans through inhalation.

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.

Lucknow, the capital city of Uttar Pradesh, also figures in the list of most polluted cities and presently, faces the twin challenge of managing the demands of a growing city while still maintaining the quality of the environment. As per the records the area of city is about 310 km^2, which is projected to be increased up to 1000 km^2 as per planned development of the city. The areas developed in the outskirts have four lane roads. In the absence of suitable public transport systems in newly developed areas people staying there mostly use own vehicles (car/bikes). This also adds vehicular load on the main city roads, thus will add more air pollution to the city levels

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 health of human being. The number of different category of vehicles registered with RTO (Regional Transport Office) Lucknow is 14,24,478 as on 31.03.2013 which is 8.35% 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 31.03.2013 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 1,28,440 and 1, 36,870 KL as on 31-03-2013. It is observed that petroleum sale have been increased by 2.91% whereas sale of diesel has increased by 4.98%. (Table 4). In

Lucknow there are six CNG filling stations and consumption of CNG in last year was approximately 2,38,11,473 Kg (2012-13) which was 11.06% higher than the previous year (2011-12) (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), 2013 with respect to PM_{10}, SO_2, NO_x and Noise level with the following aims and objectives.

- *To assess the ambient air quality with respect to PM_{10}, SO_2 , NOx. Trace metals and Noise.*
- *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 2011-12 and 2012-13

Sl. No.	Type of Vehicle	Number of Registered Vehicles on 31st March		% Change
		2011-12	2012-13	
1	Multi Articulated	2520	2770	9.92
2	Light, Medium and Heavy weight Vehicles (Four wheeler)	15593	17142	9.93
3	Light commercial vehicles (Three wheeler)	3022	3170	4.90
4	Buses	3098	3181	2.68
5	Taxi	6195	7089	14.43
6	Light Motor Vehicles (Passenger)	7195	7246	0.71
7	Two wheelers	1052717	1136822	7.99
8	Car	183288	201628	10.01
9	Jeep	16932	19612	15.83
10	Tractor	19012	20417	7.39
11	Trailors	1361	1421	4.41
12	Others	3772	3980	5.51
Total		**13,14,705**	**14,24,478**	**8.35**

Source: RTO, Lucknow

Table 2. Details of Lucknow city bus service, 2013

Sl. No.	Route No.	To and Fro	No. of Buses
1	11	BBD -Chinhat-Gomti Nagar-Alambagh	40
	11 A	Malhaur railway station-Gomtinagar-Dalibagh-Charbagh	
	11B	Charbagh-Alambagh-Avadh hospital-SGPGI	
	11C	Charbagh- Alambagh -Sardar Patel Dental college	
	11AC	BBD-Chinhat- Avadh hospital	
	11D	Charbagh- Alambagh- BBAU	
	11E	Charbagh-Alambagh- Gopesh Kunj-Kalindi Park	
	11f	Khargapur-patrakarpuram-Alambagh	
2	12	BBD- Chinhat- Charbagh- Alambagh-Scooter India	23
	12 A	Samarpan college- Chinhat-Charbagh- Alambagh- Scooter India	
	12 B	BBD-Charbagh- Alambagh- Paasi Kila	
3	23	Gudamba – Vikasnagar- Alambagh- Rajnikhand	28
	23C	Gudamba –Badshanagar – Avadh hospital	
4	24	Engineering College-Indiranagar-Charbagh-Alambag-Paasi Kila	20
	24 A	Manas Bihar colony- Scooter India	
	24C	Munshipulia- Alambagh-Kasiram Yajuna-Avadh hospital	
5	25	Charbagh-Alambagh-Chandraval	7
	25 A	Charbagh-Aurangabad-Maati	
6	31	Alambagh – IIM	2
7	33	Engineering College-Charbagh-Alambagh-Scooter India	23
	33 Secretariats	Engineering College -Alambagh Goal chauraha	
	33 AC	Engineering College-Charbagh-Alambagh-Amousi Airport	
8	45	Virajkhand-Gomtinagar-Charbagh-Alambagh-Paasi Kila	17
		Total	160

Source: UPSRTC, Lucknow

Table 3. Fuel Outlets in Lucknow City

Sl. No.	Agency	Number of outlets
		31st March 2013
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. 11 to Mar. 12	Apr. 12 to Mar. 13	% Change	Apr. 11 to Mar. 12	Apr. 12 to Mar. 13	% Change	Apr. 11 to Mar. 12	Apr. 12 to Mar. 13	% Change
1	IOC	67849	71217	4.96	71351	75456	5.75	--	---	
2	BPCL	32456	33172	2.21	27121	28234	4.10	--	---	
3	HPCL	24500	24051	-1.83	31900	33180	4.01	--	---	
4	Green Gas	--	--	--	--	--	--	2,14,39,460	2,38,11,473	11.06
Total		**124805**	**128440**	**2.91**	**130372**	**136870**	**4.98**	**2,14,39,460**	**2,38,11,473**	**11.06**

*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
		2012-2013
1	Auto Rickshaws	4343
2	Tempo Taxi	2534
3	Buses (UPSRTC)	260
4	Buses (Private)	36
5	School Buses	878
6	School Van	753
7	Private Vehicles	83
8	Private Cars	5788

Source: Green Gas Limited, 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}	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 161.6 to 197.8 µg/m^3 with an average of 178.1 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad

and Chowk) the average concentrations of PM_{10} were in the range of 218.5 to 248.8 µg/m^3 with an average of 223.9 µg/m^3 respectively. In industrial area (Amausi), the average concentrations of PM_{10} were 226.97 µg/$m^{3.}$

The maximum 24 hours mean concentration of PM_{10} was observed in Gomti Nagar (197.8 µg/m^3) in residential area and Chowk (248.82 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 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 14.8 to 15.7 µg/m^3 with an average of 13.9 µg/m^3. In commercial area (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of SO_2 were in the range of 12.3 to 22.7 µg/m^3 with an average of 17.4 µg/m^3. In industrial area (Amausi) the average concentration of SO_2 was 18.0 µg/m^3.

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

1.3.3 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 39.7 to 66.7 µg/m^3 with an average of 50.6 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of NO_X were found in the range of 48.4 to 73.2 µg/m^3 with an average of 60.3 µg/m^3. In industrial areas (Amausi) the average concentration was 49.9 µg/m^3

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

1.3.4 Trace Metals in Ambient Air (RSPM or PM_{10})

The trace metals (Ni and Pb) were estimated in ambient air associated with PM_{10} at 9 monitoring locations. The results are present in Table 9. The 24 hr mean concentration of metals were found to be Ni = 12.7, (5.1-19.7) ng/m^3 and Pb = 163.1 (10.5- 517.5) ng/m^3.

Table 8: Concentration (µg/m^3) of RSPM, SO_2 and NOx during Post monsoon 2013

Location	RSPM (PM_{10})			SO_2			NOx		
Residential	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Aliganj	101.2	315.0	161.6	8.4	20.2	14.8	37.1	58.7	48.0
Vikas Nagar	103.4	257.0	175.0	8.9	17.2	12.9	45.5	65.7	39.7
Indira Nagar	126.2	290.4	178.2	13.8	19.3	15.7	56.8	70.4	66.7
Gomti Nagar	139.3	306.8	197.8	9.8	14.3	12.4	39.9	58.9	48.1
Commercial									
Charbagh	170.0	318.2	218.5	16.4	23.9	19.8	65.4	83.6	73.2
Alambagh	130.0	341.2	226.7	15.5	31.3	22.7	43.4	76.1	57.5
Aminabad	112.2	296.1	201.6	7.9	17.1	12.3	38.6	55.9	48.4
Chowk	119.7	365.9	248.8	11.5	17.6	14.9	46.9	89.8	62.3
Industrial									
Amausi	176.5	310.1	226.9	13.1	22.5	18.0	30.7	69.6	49.9
NAAQS	100			80			80		
WHO Guidelines	50			20			40*		

N=4, *= Annual average and rest 24 hours, NAAQS=National Ambient Air Quality Standards

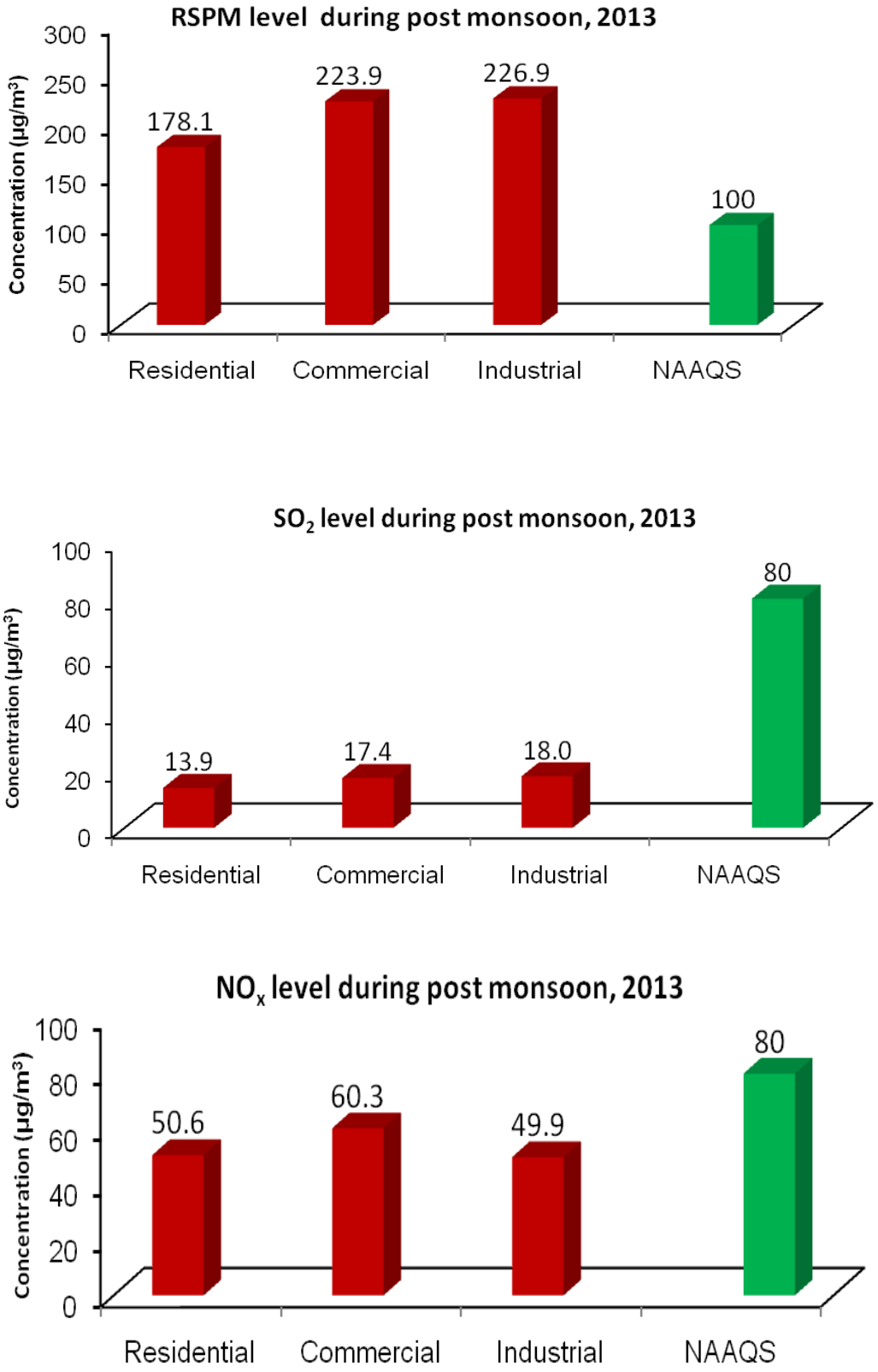

Fig 1: Concentration (µg/m^3) of PM_{10}, SO_2 and NO_x in different areas of Lucknow city during post monsoon season (2013) and compared with prescribed National Ambient Air Quality Standard

Table-9.: Metal Concentration in ng/m^3 associated with PM_{10}

Location	Pb	Ni
Residential Area		
Aliganj	25.22	9.99
Vikas Nagar	23.89	7.63
Indira Nagar	10.54	12.19
Gomti Nagar	19.49	10.99
Average	**19.78**	**10.20**
Commercial Area		
Charbagh	262.00	19.71
Alambagh	146.00	5.066
Aminabad	331.65	19.51
Chowk	131.62	14.51
Average	**217.81**	**14.6**
Industrial Area		
Amausi	517.50	14.78
NAAQS	**1000.0**	**20**

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N= 1

1.3.5 Noise

The monitoring data recorded during the post monsoon period (October, 2013) is presented in Table 10.

In residential areas, the day and night time noise levels were recorded between 62.2 to 68.4 and 54.2 to 60.2 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 heavy traffic area, the day and night time noise level were recorded between 68.2 to 74.5 and 58.3 to 71.5 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 68.9 and 65.5 dB (A) respectively. Noise levels 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 10. Noise Level dB (A) during Day and Night Time

Sl. No.	Area	Location	Noise level dB(A)	
			Day	**Night**
1	**Residential**	Aliganj	62.2	58.3
		Vikas Nagar	63.3	55.4
		Indira Nagar	68.4	60.2
		Gomti Nagar	64.5	54.2
		Standard	**55.0**	**45.0**
2	**Commercial and Traffic**	Charbagh	74.5	71.5
		Alambagh	68.2	64.2
		Aminabad	70.3	58.3
		Chowk	71.6	59.2
		Standard	**65.0**	**55.0**
3.	**Industrial**	Amausi	68.9	65.5
		Standard	**75.0**	**70.0**

1.5 TRENDS OF AMBIENT AIR QUALITY IN LUCKNOW CITY

The observed PM_{10}, SO_2 and NO_x for 3 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 Respirable Suspended Particulate Matter (RSPM or PM_{10})

In all the locations in residential areas, higher values were found compared to the previous year. Among the commercial areas, PM_{10} values showed a mixed trend Among the four locations Aminabad and Chowk were found to be little higher values than the previous 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 Sulphur dioxide (SO_2)

Lower concentration was found compared to the previous year at all the residential commercial and industrial areas except Alambagh in commercial. All the values were found to be lower than the NAAQS (Fig. 3).

1.4.3 Oxides of Nitrogen (NO_x)

The level of NOx during post monsoon since 2010 is presented in Fig. 5 for all the locations. All the locations of the residential and industrial areas showed increasing trend when compared with the previous year data. Whereas in commercial area all the location showed lower values than the last year except Charbagh. All the values of the present study were found to be lower than the NAAQS (Fig.4).

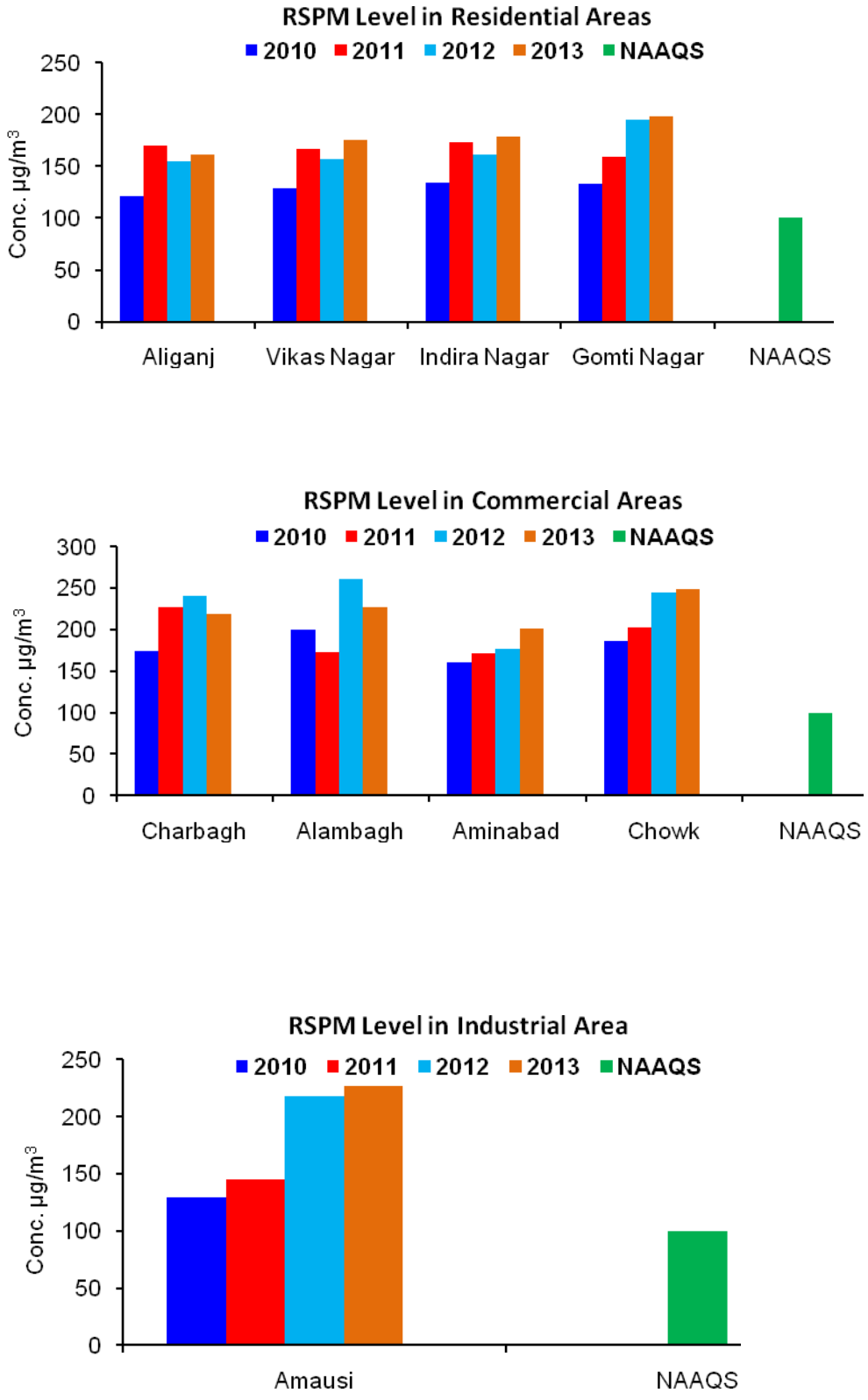

Fig 2: Concentration (µg/m^3) of PM_{10} **(**RSPM**)** in Residential, Commercial and Industrial areas of Lucknow city during 2010 to 2013 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

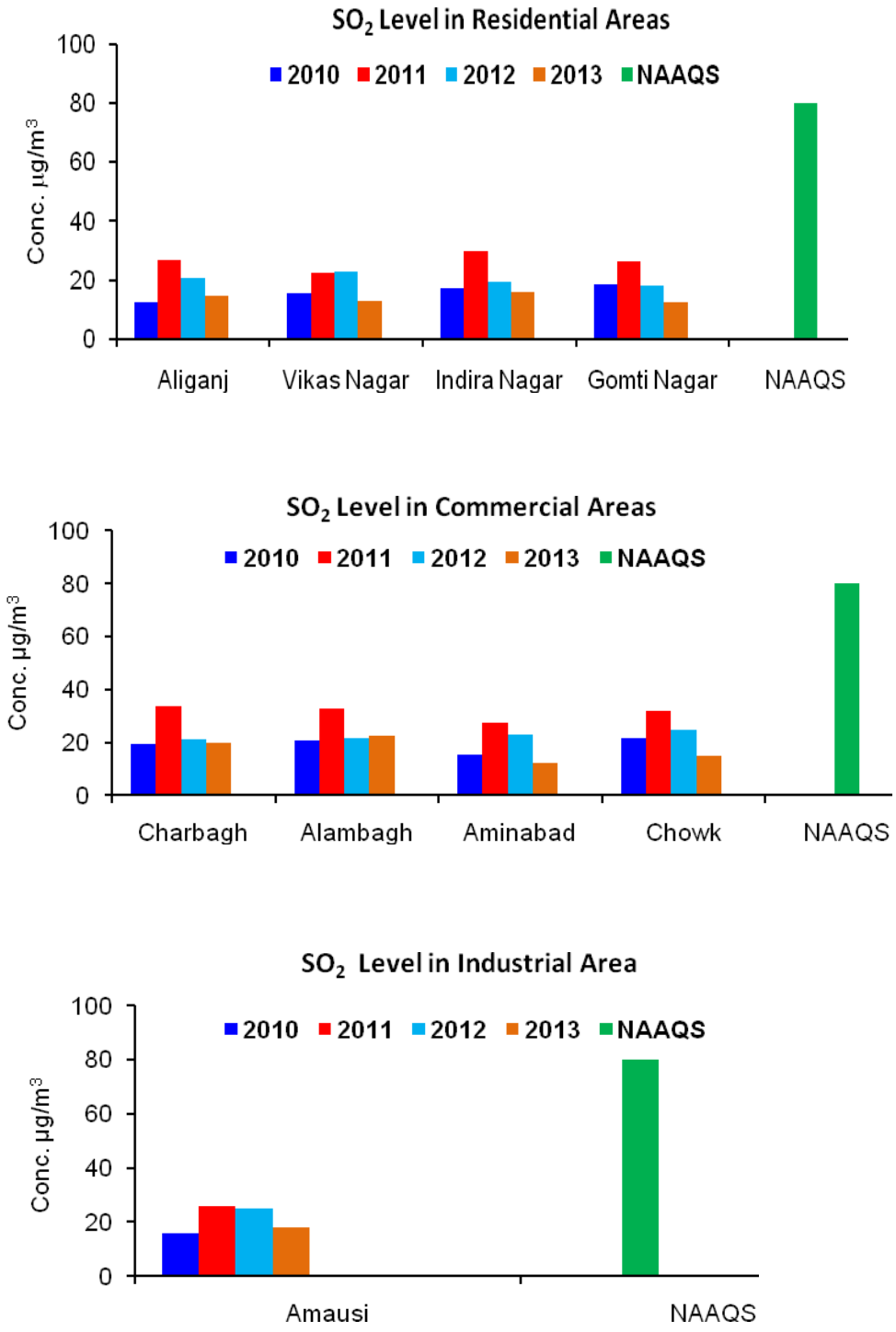

Fig 3: Concentration (µg/m^3) of SO_2 in Residential, Commercial and Industrial areas of Lucknow city during 2010 to 2013 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

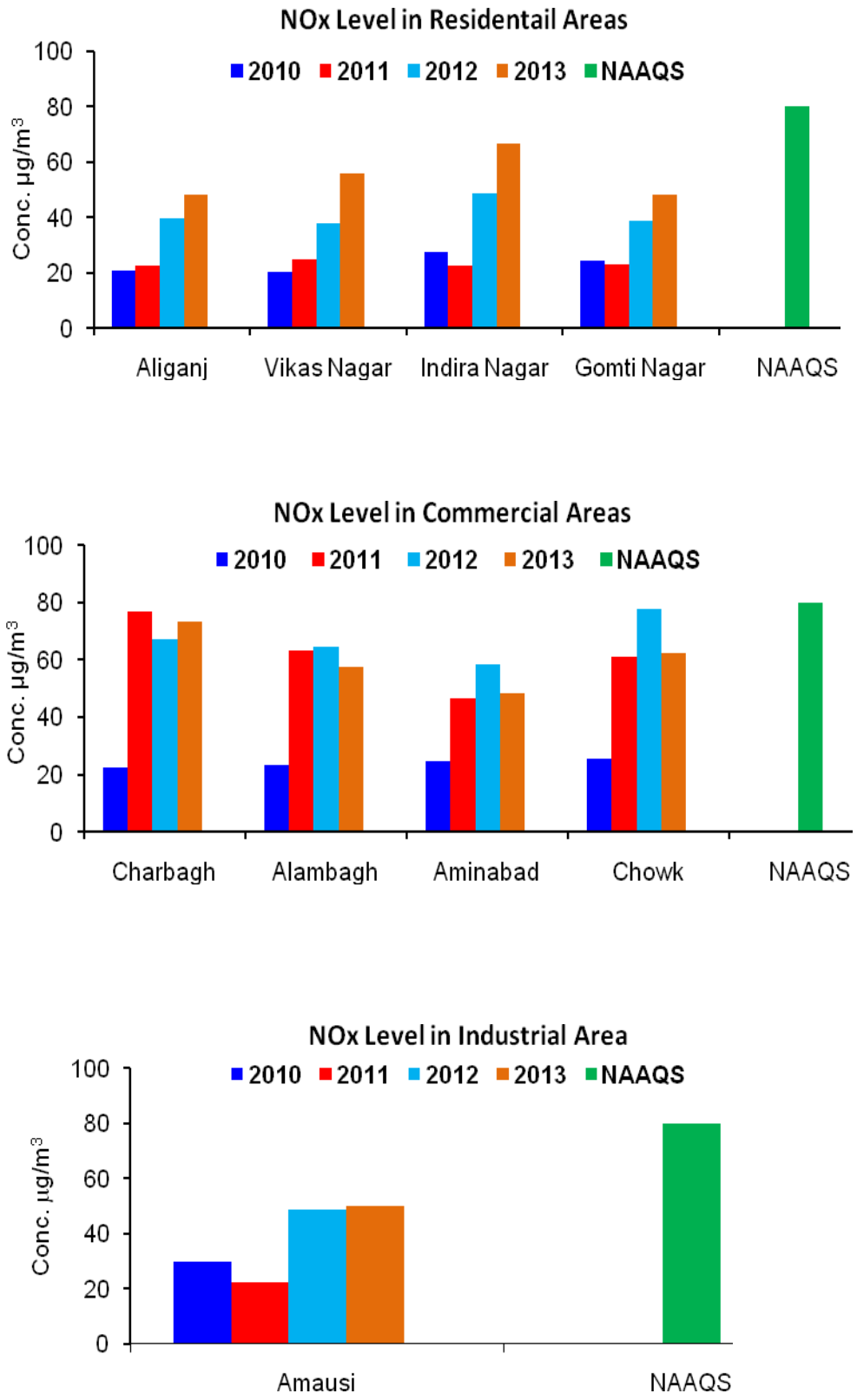

Fig 4: Concentration (µg/m^3) of NO_x in Residential, Commercial and Industrial areas of Lucknow city during 2010 to 2013 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

1.4.4 Noise Level

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

1.4.4.1 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 Charbagh and Chowk were recorded compared to the previous year. In industrial area, Amausi the noise level was slightly lower than the previous year. The comparative data are presented in (Fig.5.).

1.4.4.2 Night time Noise Level

Residential and Commercial areas showed slightly higher trend than the last year level. The industrial areas also showed slightly lower value than the previous year. The comparative data are presented in (Fig. 6).

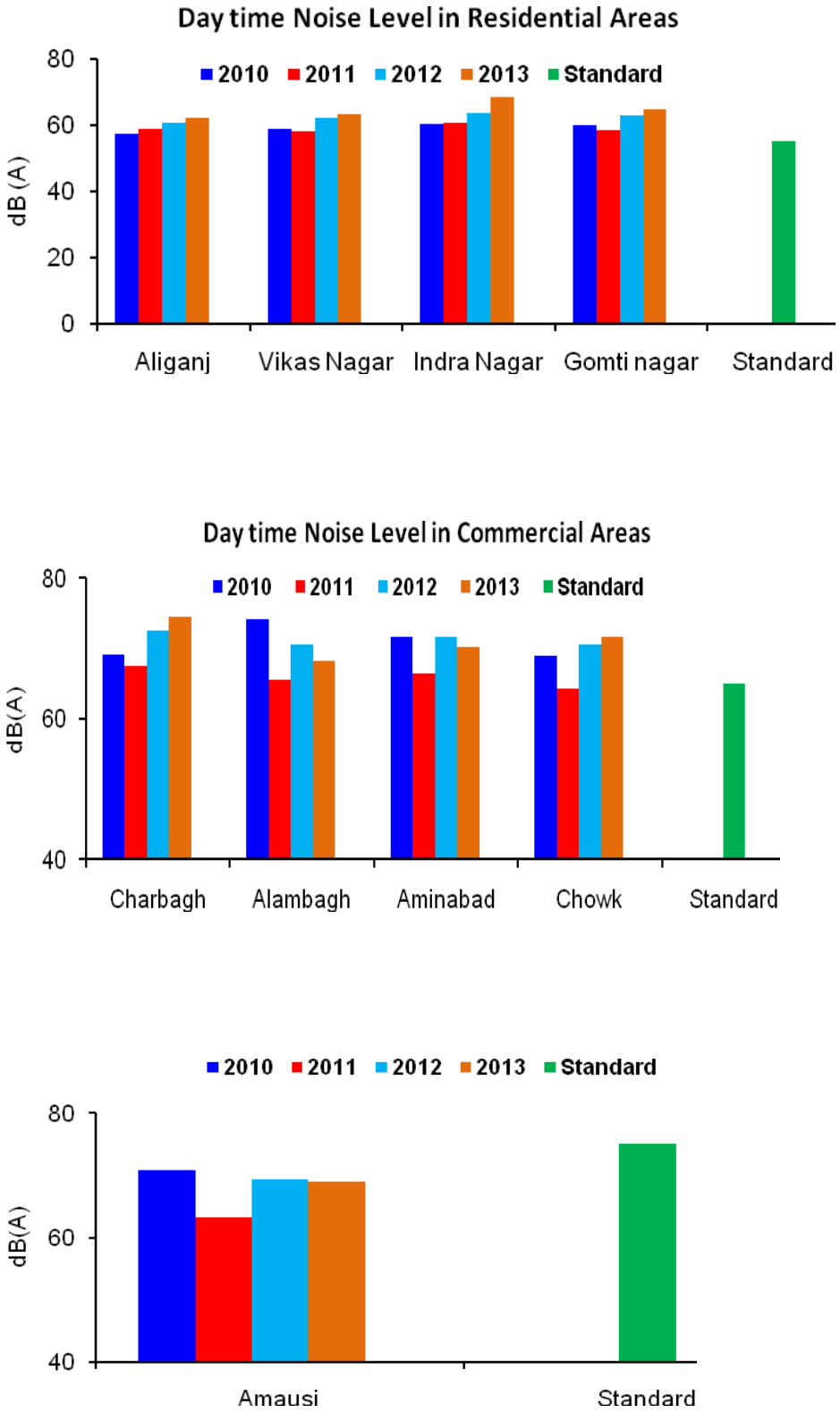

Fig 5: Comparison of day time Noise Level dB (A) in different areas of Lucknow city (2010-2013)

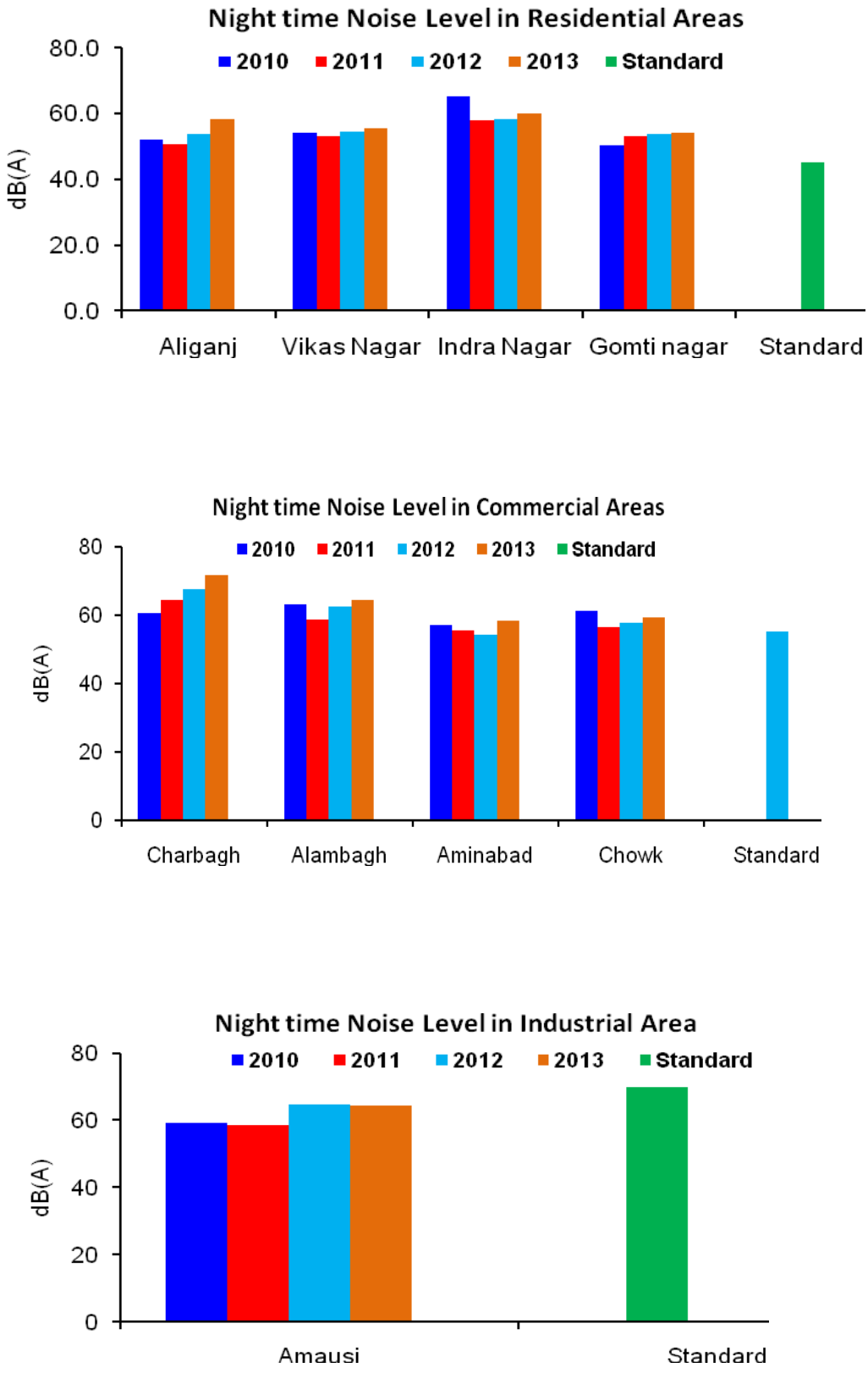

Fig 6: Comparison of night time Noise Level dB (A) in different areas of Lucknow city (2010-2013)

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} 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 difficult to established 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.

Noise pollution is now worldwide recognized as a major problem for the quality of life in urban areas. Noise pollution can have adverse effects varying from hearing loss to annoyance. Noise produces both temporary (short period) and permanent

hearing loss (long period). Damages caused by noise pollution can range from the bursting of the eardrum, permanent hearing loss cardiac and cardiovascular changes, stress fatigue, dizziness, lack of concentration, cause of accident, irritation, inefficiency, nausea, interference with tasks, headaches, insomnia and loss of appetite etc. It also adversely affects future generations and has sociocultural, aesthetic, and economic effects.

1.6 CONCLUSIONS

We have monitored air pollutants such as PM_{10}, 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), 2013 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.
- 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.

Rapid 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 post 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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