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

FINDINGS OF A RANDOM SURVEY

Presented on
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CSIR-INDIAN INSTITUTE OF TOXICOLOGY RESEARCH
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Salient Features of the Study

❖ **Geographical Position** : 26° 52' N Latitude
                                           80° 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 31/03/2013** : 14,24,478

❖ **Growth of Vehicle over 2012-2013** : 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, and trace metals

❖ **Study Conducted by** : Environmental Monitoring Division CSIR- IITR, Lucknow

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

1.0 SUMMARY

The study was carried out during the months of March-May, 2013 to assess 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), Oxides of Nitrogen (NOx) and Trace metals-Lead (Pb) and Nickel (Ni) 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} to be in the range of 111.6 to 326.7 $\mu g/m^3$ with an average of 221.0 $\mu g/m^3$. The average values of PM_{10} irrespective of locations were found to be above the permissible limit (100 $\mu g/m^3$ prescribed by MoEF). 24 hours concentration of SO_2 and NOx were found in the range of 13.2 to 32.9 and 26.8 to 68.5 $\mu g/m^3$ with an average concentration of 20.4 and 47.7 $\mu g/m^3$ respectively and all the values were below the permissible limits (80 $\mu g/m^3$). The mean level of trace metals were found Ni = 17.7, and Pb = 233.5 ng/m^3. Noise levels during day and night time were found in the range of 63.8 to 71.57 dB (A) and 55.9 to 67.4 dB (A) which was above the respective permissible limits except in industrial area.

1.1 INTRODUCTION

The adverse effects of elevated air pollutants on environment and human health are well known. A large number of urban people is at the verge of health risk due to detoriating air quality. Among the different sources of air pollutants, tail pipe emission from the vehicle is one of the main sources of air pollutants. Pollutants like Particulate Matter (PM), Sulphur dioxide (SO_2), Oxide of nitrogen (NOx), Poly aromatic hydrocarbon (PAH) and trace elements etc. are also present in the urban air and their levels are on the increase because of vehicular pollution thus affecting the human health. Due to change of technology and use of different fuels the composition of the air quality is one of areas of concern.

Several scientific studies are going on in the different parts of the world and in India. Studies revealed that almost all major cities including Lucknow are polluted. Some criteria pollutants are above the prescribed permissible limit, especially the Particulate Matter (PM).

PM_{10}, an ambient air criteria pollutant, has size ranging from nanometer to 10 μm and can be aspirated into the lung airways. Smaller PM causes 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. At elevated levels, both the categories may increase mortality and morbidity of human population.

The effect of SO_2 on ecosystem and human health is well known. At elevated level SO_2 can contribute to respiratory illness, particularly for children and elderly people and aggravate existing heart and lung diseases.

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.

The sources of heavy metals in urban areas include vehicle emissions, industrial discharges, street dust and other activities. At elevated concentrations, all the metals are harmful to living beings. Exposure can occur through a variety of routes; among which inhalation of particles (<10 μm) is one of the important routes. The inorganic components constitute a small portion by mass of the particulates; however, it contains some trace elements which are human or animal carcinogens even in trace amounts.

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.

In view of the 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. The number of different categories 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 has 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 the 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 pre monsoon (March-May), 2013 with respect to PM_{10}, SO_2, NO_x, Trace metals and Noise level with the following aims and objectives.

- *To assess the ambient air quality with respect to PM_{10}, SO_2, NOx, and trace metals (Ni and Pb) associated with PM_{10}.*

- *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		% Change
		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	
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.	Trace Metals - (Pb & Ni)	24 hour	AAS method after sampling on EPM 2000.
5	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 181.9 to 242.16 µg/m^3 with an average of 205.8 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of PM_{10} were in the range of 203.7 to 253.6 µg/m^3 with an average of 235.3 µg/m^3 respectively. In industrial area

(Amausi), the average concentrations of PM_{10} was 224.9 µg/m^3.

The maximum 24 hours mean concentration of PM_{10} was observed in Vikas Nagar (242.1 µg/m^3) in residential area and Charbagh (253.6 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 16.3 to 22.5 µg/m^3 with an average of 19.2 µg/m^3. In commercial area (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of SO_2 were in the range of 18.3 to 23.6 µg/m^3 with an average of 21.0 µg/m^3. In industrial area (Amausi) the average concentration of SO_2 was 22.7 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 35.8 to 50.1 µg/m^3 with an average of 41.9 µg/m^3. In commercial areas (Charbagh, Alambagh, Aminabad and Chowk) the average concentrations of NO_X were found in the range of 41.2 to 58.4 µg/m^3 with an average of 51.4 µg/m^3. In industrial areas Amausi) the average concentration was 55.9 µg/m^3

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

Table 8: Concentration (μg/m³) of PM₁₀, SO₂ and NOx during Pre monsoon 2013

Location	RSPM			SO₂			NOx		
Residential	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Aliganj	142.26	289.58	181.99	14.70	18.07	16.37	38.90	44.3	40.14
Vikas Nagar	151.14	292.58	242.16	16.39	23.52	18.89	26.80	44.10	35.87
Indira Nagar	163.01	263.39	196.10	15.00	26.21	22.52	38.70	67.25	50.19
Gomti Nagar	150.12	250.89	203.13	14.39	22.72	19.21	31.90	52.56	41.56
Commercial									
Charbagh	152.44	287.00	253.66	18.80	26.80	23.62	46.80	68.51	58.42
Alambagh	170.36	324.48	244.83	16.46	26.46	21.14	42.68	65.36	54.06
Aminabad	155.60	258.60	203.71	13.18	24.53	18.35	32.58	45.25	41.23
Chowk	191.05	300.66	238.85	15.62	27.39	21.12	39.56	62.85	51.94
Industrial									
Amausi	111.63	326.78	224.29	15.16	32.95	22.78	38.95	67.22	55.92
NAAQS	100			80			80		
WHO Guidelines	50			20			40*		

N=6, *= Annual Average, NAAQS=National Ambient Air Quality Standards

Mean Level of PM$_{10}$ in different locations

Mean Level of SO$_2$ in different locations

Mean Level of NOx in different locations
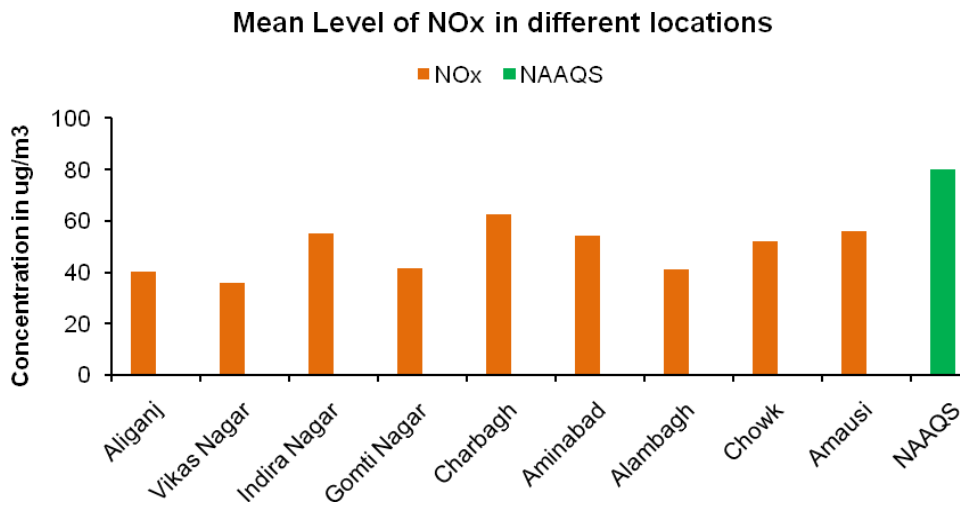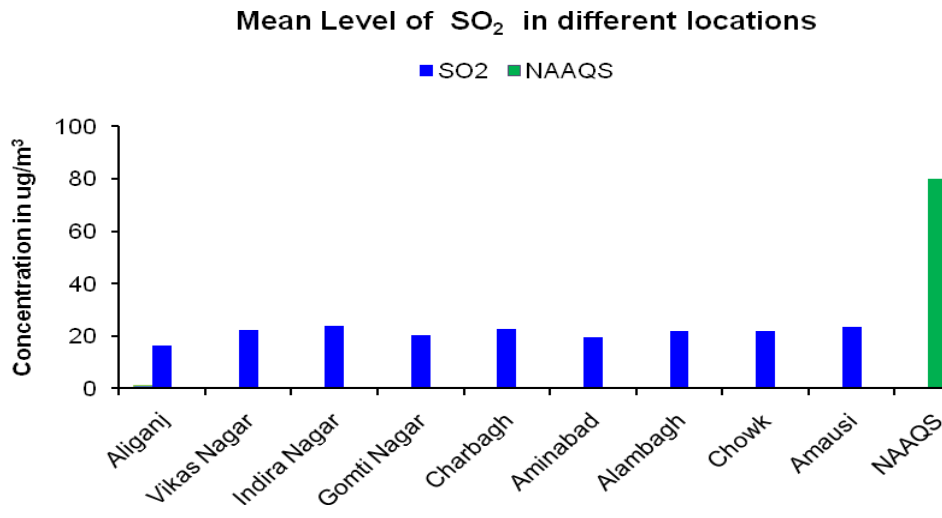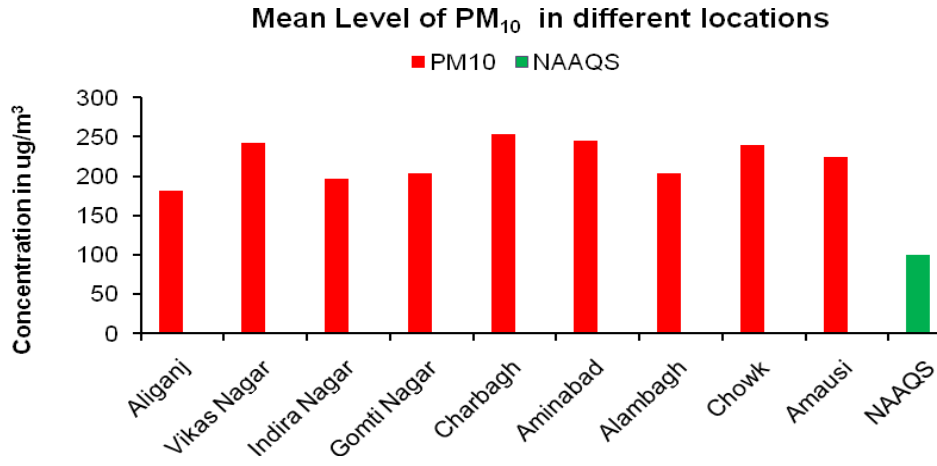
Fig 1: Concentration ($\mu g/m^3$) of PM$_{10}$, SO$_2$ and NO$_x$ in different areas of Lucknow city during pre monsoon season (2013) and compared with prescribed National Ambient Air Quality Standard (NAAQS)

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1.3.4 Trace Metals in Ambient Air (RSPM)

The trace metals (Pb and Ni) 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 Pb = 233.57 (43.69 -809.78) and   Ni = 17.75 (3.63- 38.13) ng/m^3.

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

Sl. No.	Location	Lead	Nickel
1	Aliganj	43.69	3.63
2	Vikas Nagar	100.99	8.03
3	Indira Nagar	58.27	9.68
4	Gomti Nagar	182.79	38.13
5	Charbagh	423.83	19.36
6	Alambagh	90.82	16.82
7	Aminabad	211.59	7.85
8	Chowk	180.43	32.52
9	Amousi	809.78	23.72
Mean		**233.57**	**17.75**
NAAQS		**1000**	**20***

N= 1, *=Annual Average

1.3.5 Noise

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

In residential areas, the day and night time noise levels were recorded between 63.8 to 68.3 and 56.2 to 60.3 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 66.8 to 69.5 and 55.9 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 71.5 and 66.3 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	64.6	56.8
		Vikas Nagar	63.8	59.1
		Indira Nagar	68.3	60.3
		Gomti Nagar	64.3	56.2
		Standard	**55.0**	**45.0**
2	**Commercial**	Charbagh	69.5	67.4
		Alambagh	66.8	64.7
		Aminabad	68.6	55.9
		Chowk	67.8	62.3
		Standard	**65.0**	**55.0**
3	**Industrial**	Amausi	71.5	66.3
		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 years data have been compared to find out the prevailing trend of air pollution in Lucknow city (Fig. 2-4). A slight change 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 the residential areas, higher values were found in Vikas Nagar and Indira Nagar whereas lower values were observed in Aliganj and Gomti Nagar when compared to the data of the previous year. Among the commercial areas, PM_{10} values showed decreasing trend except at Charbagh as compared to the last year. Amausi, under industrial area showed slightly lower value over that of the last year. All the values are higher than the NAAQS (Fig. 2).

1.4.2 Sulphur dioxide (SO$_2$)

The level of SO$_2$ during pre monsoon since 2010 is presented in Fig. 3 for all the locations.

In residential areas, higher concentration of SO$_2$ was found as compared to that of the previous year at all the locations. Among the commercial areas, SO$_2$ values showed increasing trend except at Alambagh than the last year. Amausi, industrial area showed increasing trend over the last year. All the values of the present study were found to be lower than the NAAQS (Fig. 3).

1.4.3 Oxides of Nitrogen (NO$_x$)

The level of NOx during pre monsoon since 2010 is presented in Fig. 4 for all the locations. Among the residential, commercial and industrial areas all the locations showed increasing trend when compared with the previous year data. All the values of the present study were found to be lower than the NAAQS (Fig. 4).
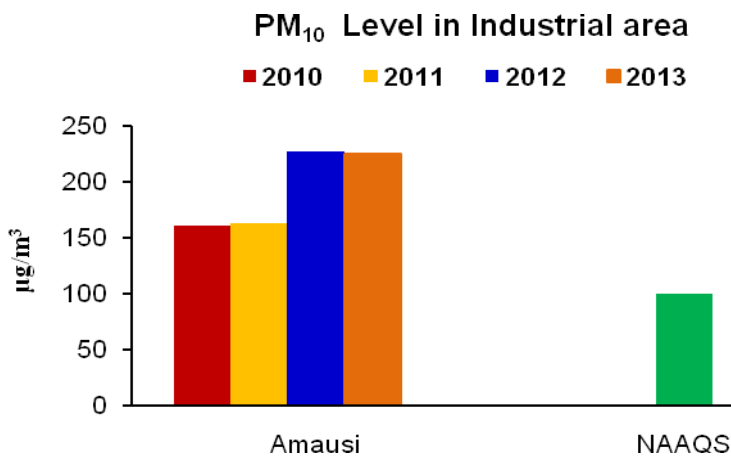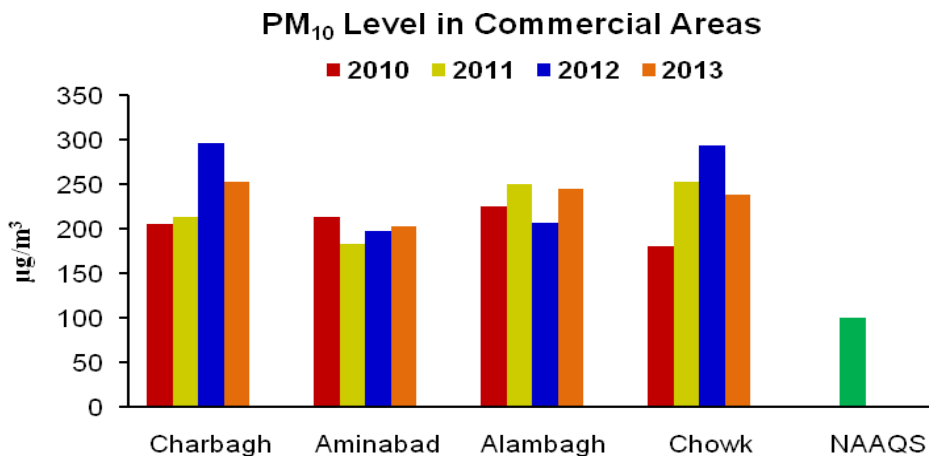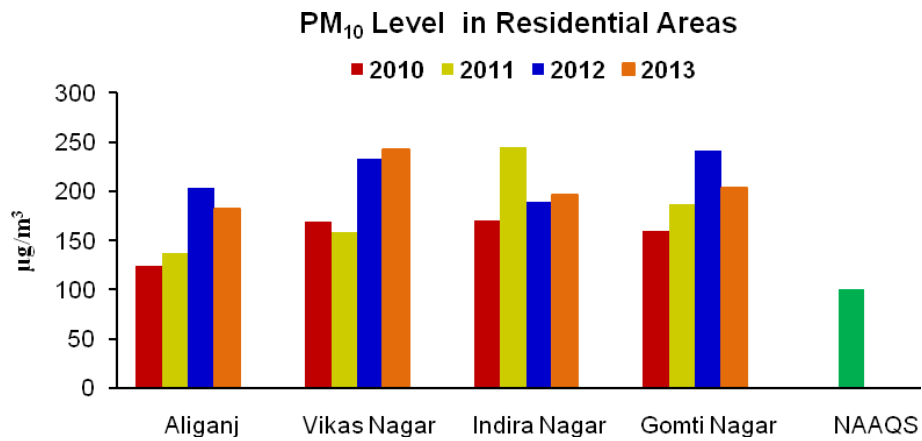
Fig 2: Concentration (μg/m³) of PM₁₀ (RSPM) in Residential, Commercial and Industrial areas of Lucknow city during 2010 to 2013 and compared with prescribed National Ambient Air Quality Standard (NAAQS)
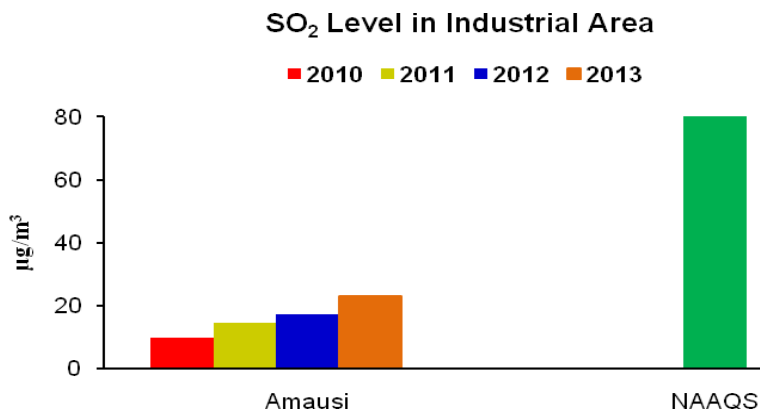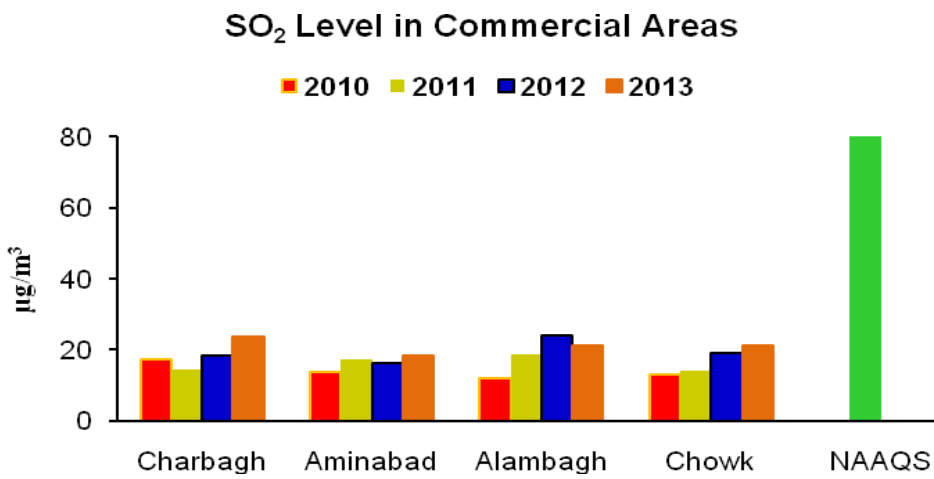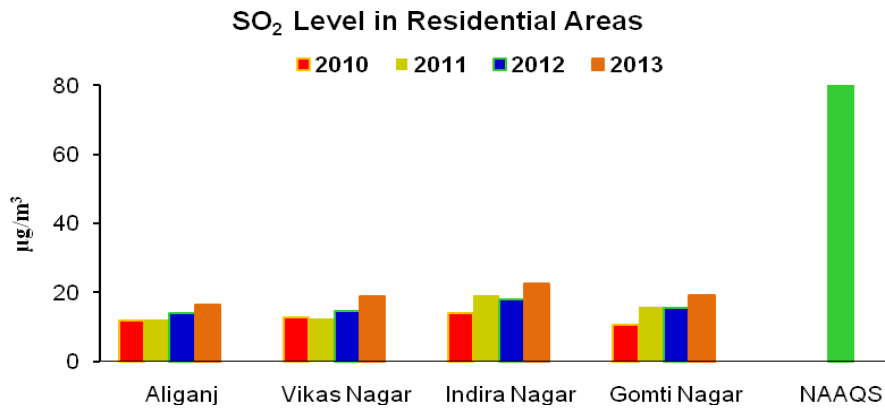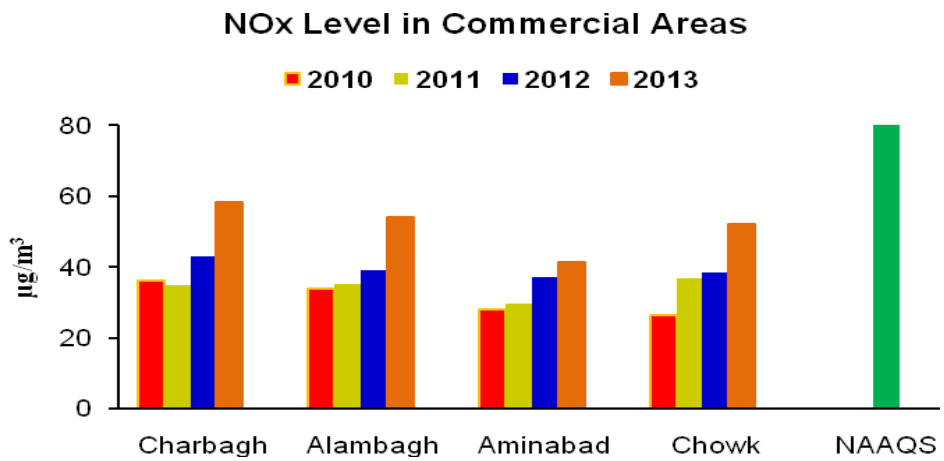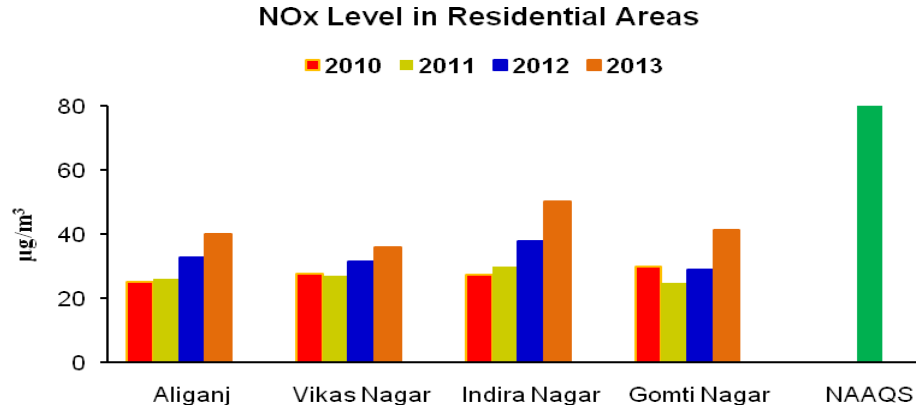
Fig 3: Concentration (μg/m^3) of SO$_2$ in Residential, Commercial and Industrial areas of Lucknow city during 2010 to 2013 and compared with prescribed National Ambient Air Quality Standard (NAAQS)
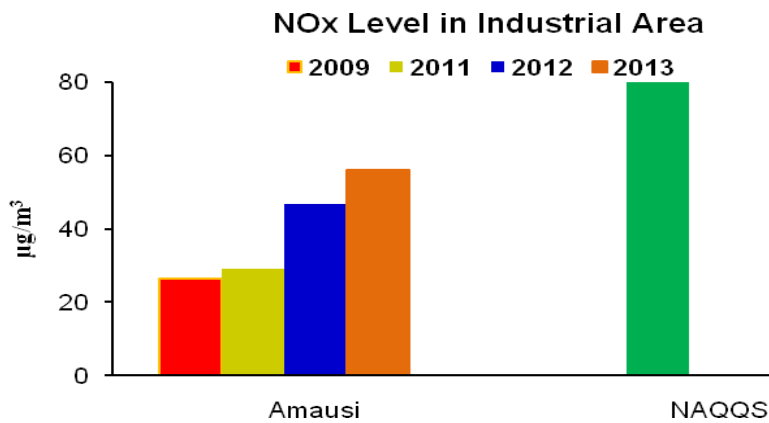
Fig 4: Concentration (µg/m^3) of NO$_x$ in Residential, Commercial and Industrial areas of Lucknow city during 2010 to 2013 and compared with prescribed National Ambient Air Quality Standard (NAAQS)

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 that of the previous year except Vikas Nagar. In commercial cum traffic areas noise level was found to be slightly on the lower side at all the locations were recorded compared to the previous year. In industrial area, Amausi the noise level was lower than the previous year. The comparative data are presented in (Fig.5).

1.4.4.2 Night time Noise Level

Residential areas showed slightly higher level than the last year level. Commercial and industrial areas also showed higher values than the previous year. The comparative data are presented in (Fig. 6).
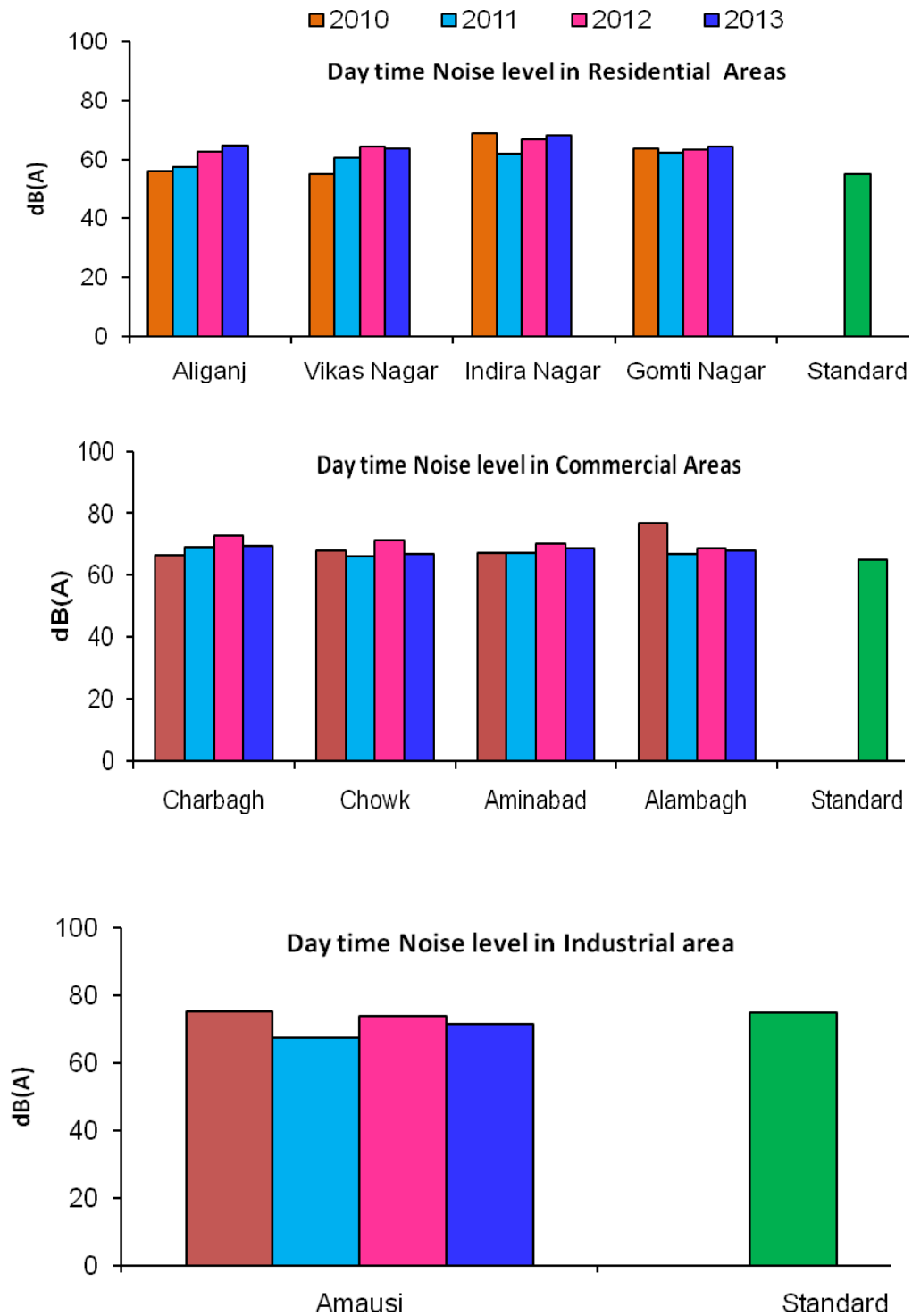
Fig 5: Comparison of day time Noise Level dB(A) in different areas of Lucknow city (2010-2013)
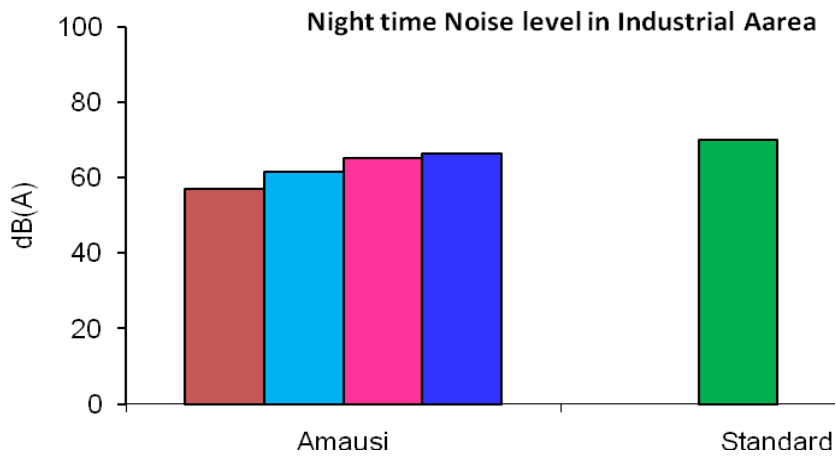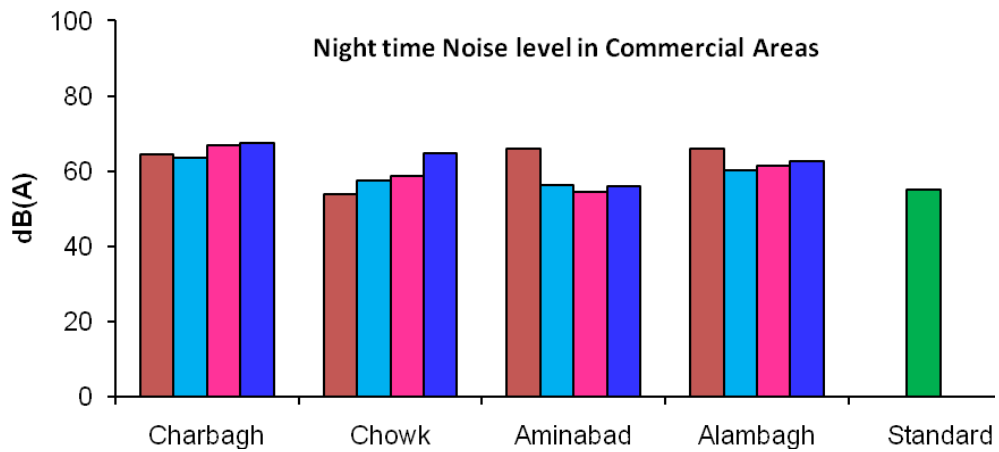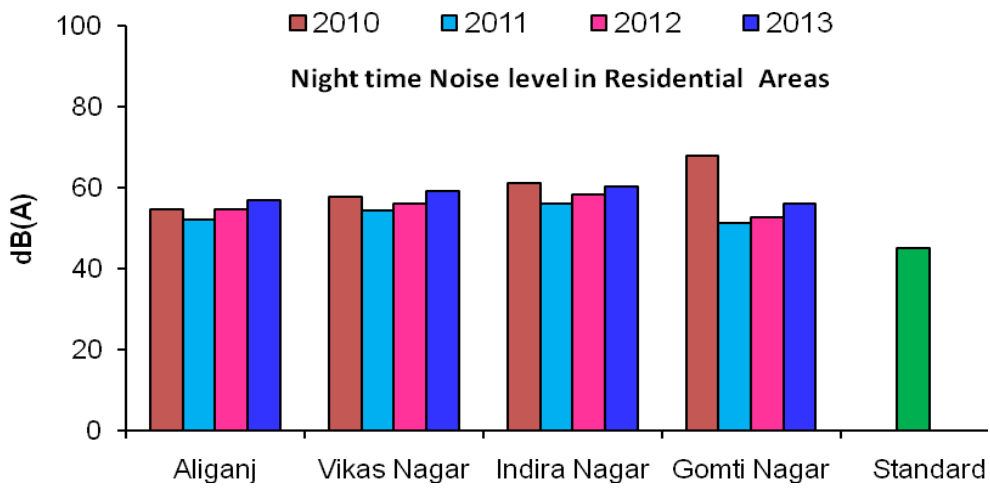
Fig 6: Comparison of night time Noise Level dB(A) in different areas of Lucknow city (2010-2013)

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 (PM_{10}) at all the monitoring locations are responsible for several cardiovascular and respiratory diseases such as asthma, bronchitis, reproductive development, increased risk of preterm birth and even mortality and morbidity rate

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}. 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 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. We also estimated the trace metals associated with PM_{10}. The inorganic components constitute a small portion by mass of the particulates; however, it contains some trace elements such as As, Cd, Ni, Pb etc. which are human or animal carcinogens even in trace amounts. 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. Occupational exposure to Cd is a risk factor for chronic lung diseases.

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}, SO_2, NOx and trace metals for assessment of ambient air quality. Besides, we also monitored noise level during day and night time at 9 locations during pre monsoon (March-May), 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 below the prescribed NAAQS (80 $\mu g/m^3$) at all the locations but showed increasing trend.

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

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

Unlimited growth of number of vehicles, their technological development and release of invisible tailpipe pollutants emission are serious debatable issues even for the policy makers. Use of different types of fuels namely petrol, diesel, LPG 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 beings 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 (Metro, Monorail etc.) must be introduced/strengthened to minimize use of personal vehicles.
- Improvement in the traffic management.
- Encroachment should be removed for the smooth flow of traffic.

- Public awareness programme for reduction of 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