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AIR QUALITY INDEX FOR UTTAR PRADESH WITH A FOCUS ON LUCKNOW

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ABSTRACT

This paper presents air quality data interpretation and air quality index (AQI) prevailing in 13 districts of Uttar Pradesh during period of 2001 to 2009. The mathematical function for calculating sub-indices is based on IND-AQI and USEPA. A maximum operator calculation mode is used to determine the overall AQI. The air pollutants included in the AQI are SO_2, NO_2, SPM, PM_{10}, $PM_{2.5}$, NH_3, CO, C_6H_6, O_3, Pb, Hg, Ni, As and benzopyrene. The data show that air quality is worst in winter months because of SPM, PM_{10} and $PM_{2.5}$. Air Quality generally improves in monsoon months because of washout of air pollutants with rainfall. Maximum AQI variation is found in Ghaziabad, Agra and Firozabad whereas minimum AQI variation is found in Anpara, Gajraula and Jhansi.

INTRODUCTION

Air pollution has emerged as a major challenge, particularly in urban areas. The problem becomes more complex due to the multiplicity and complexity of the air polluting source mix (e.g., industries, automobiles, generators, domestic fuel burning, road side dusts, construction activities, etc.) [1]. A human need air for respiration. An adult at rest breathes 16 respirations per minute- approximately 5 m^3/h (lungs volume 4-6 L), with harder work the rate is 3-6 times more (15-30 m^3/h). Poor air can have adverse impact on our quality of life and can damage the fabric of building and sensitive flora and fauna. Air pollution is the accumulation of hazardous substances into the atmosphere that danger human life and other living matter [2]. Outdoor PM air pollution is estimated to be responsible for about 3% of adult cardiopulmonary disease mortality, about 5% of trachea, bronchus and lung cancer mortality, and about 1% of mortality in children from acute respiratory infection in urban areas worldwide. This amounts to about 0.80 million (1.2%) premature deaths and 6.4 million (0.5%) lost life years [3]. The World Health Organization reports that in 2012 around 7 million people died - one in eight of total global deaths – as a result of air pollution exposure confirming that air pollution is now the world's largest single environmental health risk. Reducing air pollution could save millions of lives [4]. High PM_{10} level in air may cause chronic and acute effects on human health, particularly the pulmonary function, as they can penetrate deep into the lungs and cause respiratory problems. Association with high levels of NO_2 etc. may further exaggerate such effect. High concentration of PM_{10}, sulfate and SO_2 would cause respiratory mortality in several situations [5]. Air quality within a region is affected by emission quantities and meteorological conditions. Good air quality is essential to human health, plants and animals, buildings and to the environment as well. Poor air quality adversely impacts our quality of life and can damage the fabric of building and sensitive flora and fauna. Ambient air monitoring stations measure air pollutant concentrations which not only determine existing air quality, but also help in evaluation of the effectiveness of air pollution control program and to identify areas in need of restoration and their prioritization. Air quality index (AQI) is designed to inform the public about the air quality in their surroundings. AQI is a very useful tool for evaluating the pollution hazards of a particular area on a particular day and can be very helpful to citizens of that area, because

it can show them whether or not they need to take precautions while going out. With AQI, one can describe ambient air in terms of pollution level and quality of the air at a certain time and area by single number or color code. Awareness of the air quality is also important for the people who suffer from illness caused by air pollution.

According to USEPA (1999) [6], Environmental Protection Agency (EPA) developed a uniform AQI in 1976 and primarily it was known as pollutant standard index, for the use of state and local agencies to assess urban air quality in USA. AQI may be defined as a single number for reporting the air quality with respect to its effect on human health. In most elaborate form it combines many air pollutant concentrations in some mathematical expression to arrive at a single number for air quality [2]. One of the earliest AQI was proposed by the Green in 1966 based on two pollutants SO_2 and COH (coefficient of haze). This index did not include any other pollutants and was applicable only for winter season [7]. In 1967 Rich developed a consumption product index. The index was having the advantage of requiring few actual measurements of air quality relying instead on the assumption that the severity of pollution is directly related to the quantity of fossil fuel burned and inversely related to the atmospheric mixing volume overhead. There are several other AQIs developed in the past such as: Combustion Product Index 1967, Ontario Air Pollution Index 1970, Extreme Value Index 1972, Environmental Quality Index 1976, Dosage Population Product 1978. Oak Ridge AQI 1971 was based on the 24 hr average concentration of pollutant variables (SO_2, NO_x, PM, CO and Photochemical Oxidants). The Greater Vancouver AQI (GVAQI, 1997) was based on Canadian Federal Government air quality objectives. This index was based on six pollutants (SO_2, NO_2, O_3, TSP, COH and PM_{10}) and relates public health to environment. Index values (25, 50 and 100) were divided into three ranges (Federal Desirable, Acceptable and Tolerable respectively). The GVAQI value was determined by calculating a sub-index for each pollutant measurement and averaging time. The particular pollutant responsible for the maximum sub-index is called the index pollutant with the index value greater than 25. Index was based on the assumption that the combined effect of a number of air pollutants was related to the highest concentrations relative to air quality objectives. Alberta's AQI is based on 24 hr average concentration of O_x, NO_x, CO and suspended particulates. Pindex is combined index designed for synergistic effect of air pollution and is based on particulate matter, sulfur oxides, nitrogen oxides, carbon monoxide, hydrocarbons, oxidant, solar radiation and particulate sulfur-oxide synergism. Inhaber's AQI was developed by Inhaber and was based on root-mean-square method of averaging and combining of sub-indices. Pollution Standard Index was based on SO_2, NO_2, CO, PM, O_3. CityAIR index was developed for urban area and was based on concentration of CO, NO_2, O_3, C_6H_6 and PM_{10}. ORAQI, GVAQI, GI and MURCI are modified according to Indian conditions (index is modified for three pollutants) [8]. These modified indices gave contradictory result for the same set of data for three cities (Delhi, Mumbai and Howrah). Most of the indices developed after 1990 were based on the maximum value of sub-index.

METHODOLOGY

Calculation of AQI is based on number of pollutant variable, calculation method (mathematical functional relationship between pollutant concentration and index), calculation mode and description categories (good, moderate, unhealthy for sensitive people, unhealthy, Very unhealthy, Hazardous). Minimum three pollutants (SO_2, NO_2, and SPM) are sufficient to develop an AQI, although all the pollutants are not necessary, but desirable [8]. The reference scale of the AQI with the corresponding categories varies in the range 0-500. To relate the air quality and its effect on human health, the index scale 0-500 is divided in six categories (Table 1) to provide description of index value depending on the break point concentration of each pollutant. The basis of breakpoint for the proposed AQI is based on USEPA, IND-AQI [9, 10, 11] and report of review of ambient air quality standards [12] (Table 2). The AQI value of 50 defines the prevailing National Ambient Air Quality Standards (NAAQS) for each pollutant and 500 as hazardous level.

Table 1: Categories and break point concentration of AQI System

Index	Descriptor Categories	Health Effects
0-50	Good	No effect on human health and on environment
51-100	moderate	Unusually sensitive people may experience respiratory symptoms
101-150	Unhealthy for sensitive people	Increasing likelihood of respiratory symptoms and breathing discomfort in active children and adults and people with lung disease, such as asthma
151-200	Unhealthy	Greater likelihood of respiratory symptoms, increased aggravation of heart and lung disease
201-300	Very Unhealthy	significant increase in respiratory symptoms, significant aggravation of heart and lung disease, premature mortality in people with cardiopulmonary disease and significant increase in respiratory symptoms
301-500	Hazardous	Severe respiratory symptoms and serious aggravation of heart and lung disease, premature mortality in people and serious effect of respiratory symptoms in general people

Table 2: National Ambient Air Quality Standards (NAAQS) [13]

S. No.	Pollutants	Time Weighted Average	Concentration in Ambient Air	
			Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (notified by Central Government)
1.	Sulphur Dioxide (SO_2), µg/m^3	Annual	50	20
		24 Hours	80	80
2.	Nitrogen Dioxide (NO_2), µg/m^3	Annual	40	30
		24 Hours	80	80
3.	Particulate Matter (Size <10µm) or PM_{10}, µg/m^3	Annual	60	60
		24 Hours	100	100

4.	Particulate Matter (Size <2.5 µm) or $PM_{2.5}$, µg/m^3	Annual	40	40
		24 Hours	60	60
5.	Ozone (O_3), µg/m^3	8 Hours	100	100
		1Hour	180	180
6.	Lead (Pb), µg/m^3	Annual	0.50	0.50
		24 Hours	1.0	1.0
7.	Carbon Monoxide (CO), mg/m^3	8 Hours	02	02
		1Hour	04	04
8.	Ammonia (NH_3), µg/m^3	Annual	100	100
		24 Hours	400	400
9.	Benzene (C_6H_6), µg/m^3	Annual	05	05
10.	Benzo(a)Pyrene (BaP) particulate phase only, ng/m^3	Annual	01	01
11.	Arsenic (As), ng/m^3	Annual	06	06
12.	Nickel (Ni), ng/m^3	Annual	20	20

Study Area

Study area for the calculation of AQI is Uttar Pradesh where ambient air quality is monitored in 13 districts. Uttar Pradesh is situated between 24°N-30°N and 77°E-84°E with a population of 200 million people. The state is spread over a total area of 243,286 km^2. Three dominant seasons, summer (March-June), monsoon (July-October) and winter (November-February) are observed in the study area with maximum temperature in summer (more than 45°C) and minimum temperature in winter (less than 1°C) [13, 14, 15]. The state receives average annual rainfall of 1,025 mm in monsoon season.

National Ambient Air Quality Monitoring in India started in 1984 and presently ambient air quality is monitored in 13 cities of Uttar Pradesh (UP). A total of 39 ambient air quality monitoring stations are maintained by UP Pollution Control Board (UPPCB) and Central Pollution Control Board (CPCB) in these 13 districts covering various land use patterns (Table 3).

Table 3: Details of Air Quality Monitoring Stations in Study Area

S. No.	Districts	Location of Monitoring Station	Land Use Pattern	Monitoring Days	Monitoring Agency
1	Agra	Tajmahal	Sensitive	Sunday, Monday, Tuesday, Wednesday, Thursday, Saturday	CPCB
		Regional Office Bodla	Residential	Monday, Thursday	UPPCB
		Nunhai	Industrial	Tuesday, Friday	UPPCB
		DIC Nunhai	Sensitive	Wednesday, Saturday	CPCB
		Itmad-ud-daulah	Sensitive	Tuesday, Friday	CPCB
		Rambagh	Sensitive	Monday, Thursday	CPCB
2	Allahabad	Square Crossing	Residential	Monday, Thursday	UPPCB
		Bharat Yantra Nigam	Residential	Monday,Thursday	UPPCB
3	Anpara	Anpara Colony	Industrial	Tuesday, Thursday	UPPCB
		Renusagar Colony	Industrial	Monday,Wednesday	UPPCB
4	Firozabad	CDGI	Industrial	Tuesday, Friday	UPPCB
		Tilak Nagar	Residential	Wednesday,Saturday	UPPCB
		Raza Ka Tal	Residential	Monday, Thursday	UPPCB
5	Gajraula	Indira Chowk	Residential	Friday, Sunday	UPPCB
		Raunaq Auto Ltd.	Industrial	Tuesday, Friday	UPPCB
6	Ghaziabad	Atlas Cycles Ind. Ltd.	Industrial	Tuesday, Friday	UPPCB
		Bulandshahar Road	Industrial	Monday, Thursday	UPPCB
7	Jhansi	Jail Chauraha	Residential	Tuesday, Thursday	UPPCB
		Veeranga Nagar	Residential	Saturday, Tuesday	UPPCB
8	Kanpur	Fazalganj	Industrial	Saturday,Wednesday	UPPCB
		Jajmau	Industrial	Tuesday, Friday	UPPCB
		Deputy Ka Parao	Residential	Tuesday, Friday	UPPCB
		Dabauli	Residential	Monday, Thursday	UPPCB
		Vikas Nagar	Residential	Monday, Tuesday, Thursday, Friday	CPCB
		Kidwai Nagar	Residential	Monday, Thursday	UPPCB

9	Khurja	CGCRI	Industrial	Sunday, Thursday	UPPCB
		Ahirpara	Residential	Tuesday, Saturday	UPPCB
10	Lucknow	Talkatora	Industrial	Monday, Thursday	UPPCB
		Mahanagar	Residential	Tuesday, Thursday	UPPCB
		Kapoor Hotel Hazratganj	Residential & Commercial	Tuesday, Friday	UPPCB
		Chandganj	Residential	Monday,Wednesday	UPPCB
		Aminabad	Residential	Tuesday,Wednesday, Friday	UPPCB
11	Meerut	Begum Bridge	Residential	Tuesday, Friday	UPPCB
		Thana Railway Road	Residential	Wednesday, Friday	UPPCB
12	Noida	R.O. UPPB	Residential	Tuesday, Thursday	UPPCB
		GEE-PEE	Industrial	Monday, Thursday	UPPCB
13	Varanasi	Regional Office	Residential	Monday, Thursday	UPPCB
		Shivpuri	Residential	Friday, Tuesday	
		Sigra	Residential	Tuesday, Friday	UPPCB

Computation of AQI

To calculate AQI, first step is the calculation of sub-indices (I_1, I_2,....I_n) for n pollutant variables (X_1, X_2, ... X_n) and is carried out using sub-indices functions that are based on air quality standards and health effect. Each sub-index value represents a relationship between pollutant concentrations and health effect. Mathematically

$I_i = f(X_i)$, $\quad i = 1, 2.....n$

Function used to convert concentration to AQI value is given below

$$I_p = \frac{I_{HI} - I_{LO}}{BP_{HI} - BP_{LO}}(C_P - BP_{LO}) + I_{LO}$$

Where,

I_p = the index for the pollutant p

C_p = the actual concentration of pollutant p

BP_{HI} = the break point in the Table 4 that is greater than or equal to Cp

BP_{LO} = the break point in Table 4 that is less than or equal to C_p

I_{HI} = the air pollution index value corresponding to BP_{HI} of the pollutant p

I_{LO} = the air pollution index value corresponding to BP_{LO} of pollutant p

In the second step, aggregation of sub-indices I_i is used with mathematical function to calculate overall index (I).

$I = F(I_1, I_2.....I_n)$

In second step aggregation function F may be summation or multiplication operation or maximum operator. In this study, maximum operator system has been adopted as follows:

$AQI = Max(I_1, I_2.....I_n)$

In third step maximum operator function is used for AQI value. It is free from the eclipsing (situation when pollutant is underestimated by AQI) and ambiguity (situation when pollutant is overestimated by AQI) problems. Drawback of the maximum operator function is that synergistic effect of pollutants is not known.

Mathematical function that is used to calculate AQI value is a segmented linear function. Same function is also adopted by various countries (GVAQI and ORAQI etc.). This function is used to calculate AQI value of each pollutant. A pollutant that gives the maximum value, considered as a responsible pollutant and sub-indices value considered as AQI value. Good category lies in index value that is NAAQS for each pollutant.

RESULTS AND DISCUSSION

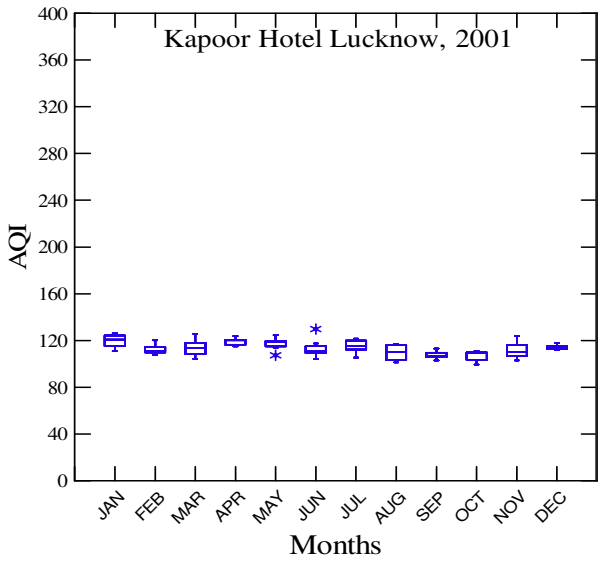
The pollutants included in the air quality index are SO_2, NO_2, SPM, RSPM, Pb, As, Ni, C_6H_6, BaP, O_3, NH_3 and CO. AQI for all monitoring stations existing in 13 districts has been calculated. The monthly variation, seasonal variation, yearly variation, rainfall impact and responsible pollutant of Lucknow city are presented in detail in this paper and for other cities are mentioned briefly.

Monthly Variation of AQI

The monthly variation of AQI at all five monitoring stations of Lucknow city (Talkatora, Mahanagar, Kapoor Hotel Hazratganj, Aminabad and Chandganj Nagar) based on available data for the period 2001 to 2009 is shown in Figure 1. AQI category in Lucknow was 'unhealthy to sensitive people' at all locations except Talkatora, where it was 'unhealthy' category during 2001-02. Index value at Mahanagar lies at moderate category during 2001. At Talkatora maximum and minimum in AQI was found in March and December during 2001-02. During 2004-09 maximum AQI was found in December, January and February in all the locations. At Kapoor Hotel during 2001-09 maximum AQI was found in November, December, January, February and May. During 2001-09 at Mahanagar maximum AQI was found in April, May, June, November, December, and January. During 2005-09 at Chandganj Nagar and Aminabad maximum AQI was found in November, December, January, February and April. Minimum AQI at all the locations was found in August and September and sometimes July (at Aminabad, Chandganj Nagar and Kapoor Hotel, 2005). During 2001 Maximum variation of AQI are shown in March, June and September at Talkatora and Mahanagar and rest of the locations shown in December except in year 2009 where it was in June and January and minimum variation are shown in August and September.

Table 4: Breakpoint Concentrations of the Air Quality Index

Index value	Category	PM_{10} (μg/m^3) 24 hrs	CO (mg/m^3) 8 hrs	SO_2 (μg/m^3) 24 hrs	NO_2 (μg/m^3) 24 hrs	SPM (μg/m^3)	O_3 (μg/m^3) 8 hrs	NH_3 (μg/m^3) 24 hrs	$PM_{2.5}$ (μg/m^3) 24 hrs	Pb (μg/m^3) 24 hrs	As (ng/m^3) Annual	Ni (ng/m^3) Annual	C_6H_6 (mg/m3) Annual	BaP (ng/m^3) Annual
0-50	Good	0-100	0-2	0-80	0-80	0-200	0-100	0-60	0-60	0-.001	0-6	0-20	0-.005	0-1
51-100	Moderate	101-150	3-10	81-366	81-565	201-300	101-165	61-90	60-65.4	>.001-.01	>6-6.6	>20-25	.005-.02	2-4
101-150	Unhealthy for sensitive people	151-250	11-14	367-575	566-1129	301-500	166-204	91-105	65.4-150.4	>.01-.03	>6.6-9	>25-50	>.02-81	5-36
151-200	Unhealthy	251-350	15-18	576-785	1130-2260	501-700	205-243	106-210	150.5-250.4	>.03-.1	>9-66	>50-250	>81-162	36-273
201-300	Very Unhealthy	351-420	19-37	786-1570	2261-3000	701-840	244-300	211-250	250.5-500	>.1-1.5	>66	>250	>162-325	273-40,000
301-500	Hazardous	421-600	37-61	>1570	>3000	841-1200	>300	>250	>500	>1.5			>325-812	>40,000


Kapoor Hotel Lucknow, 2001
AQI
Months
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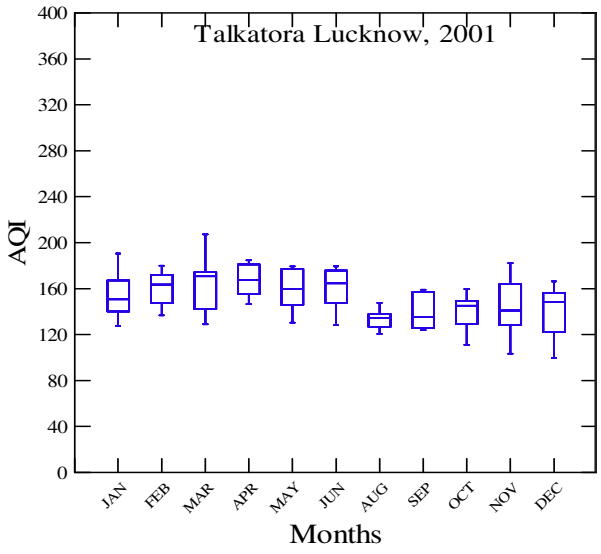
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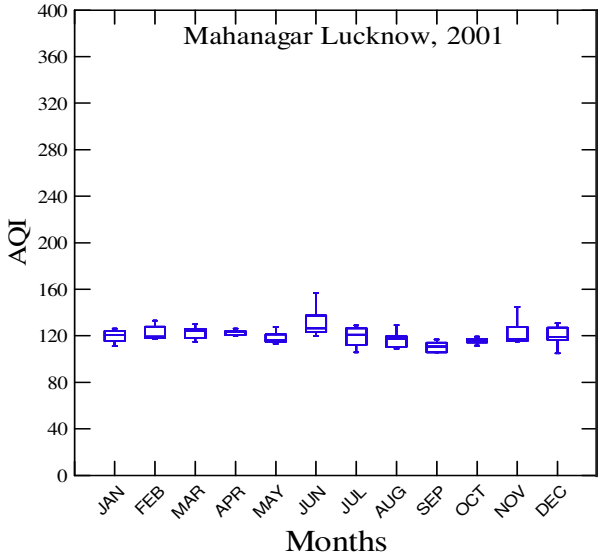
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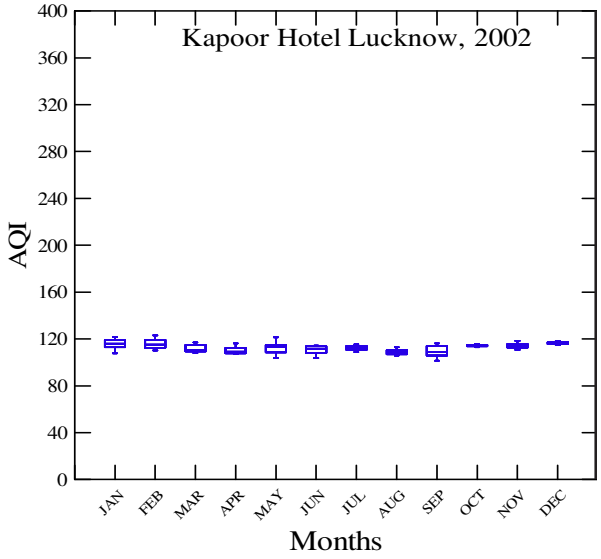
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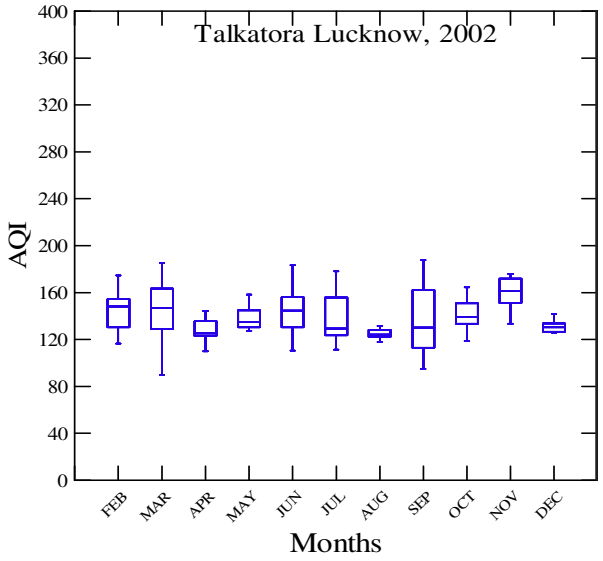
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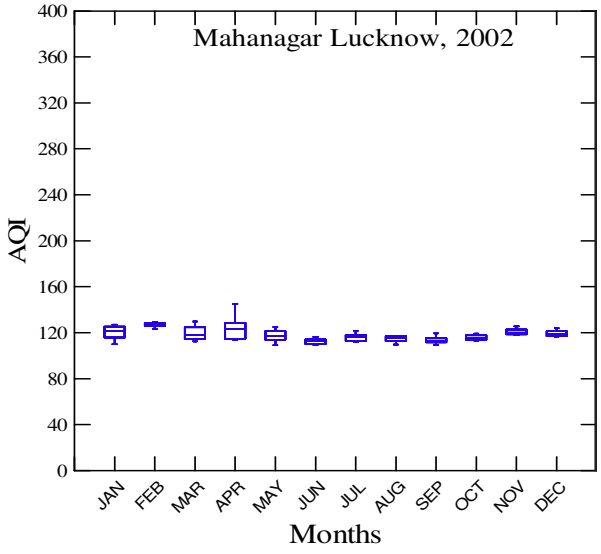
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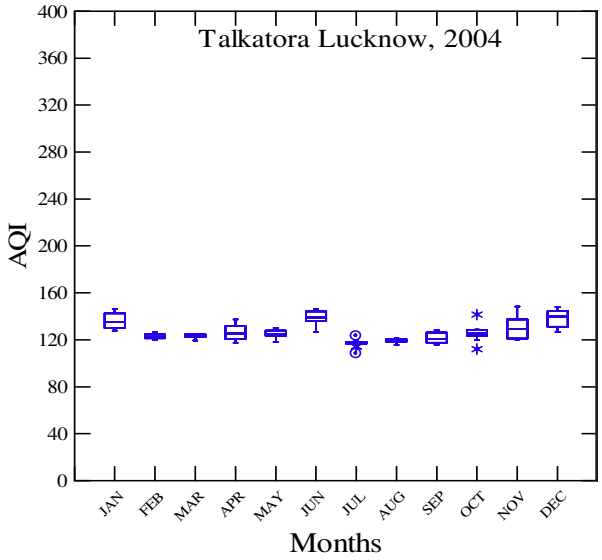
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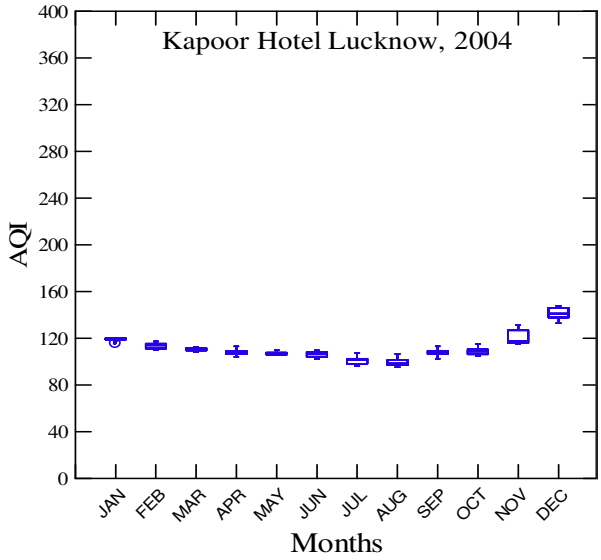
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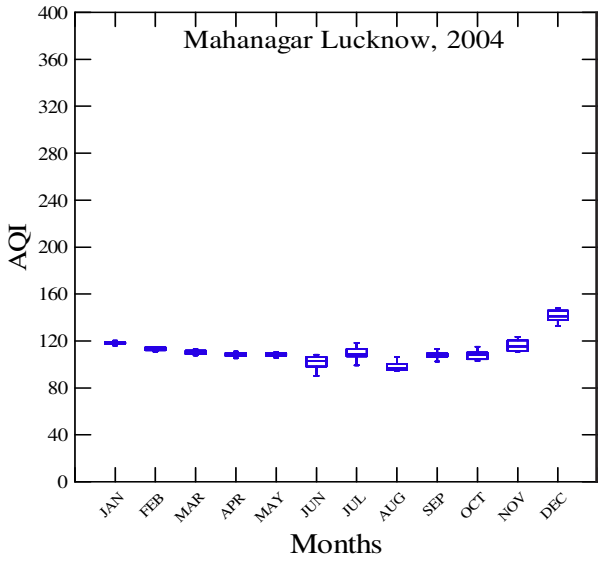
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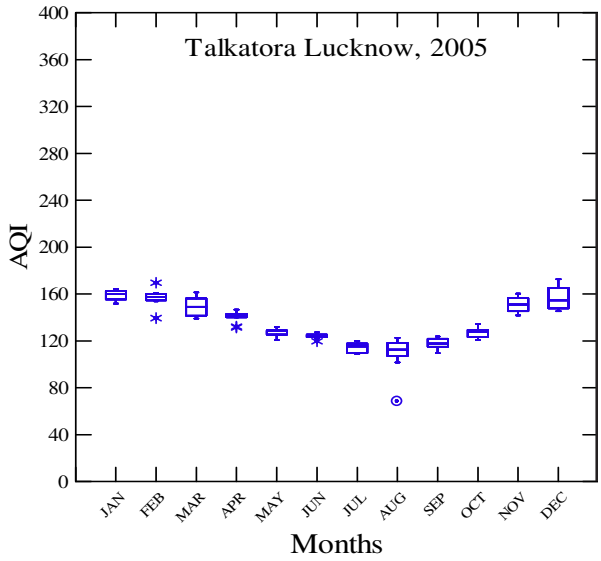
Talkatora Lucknow, 2005
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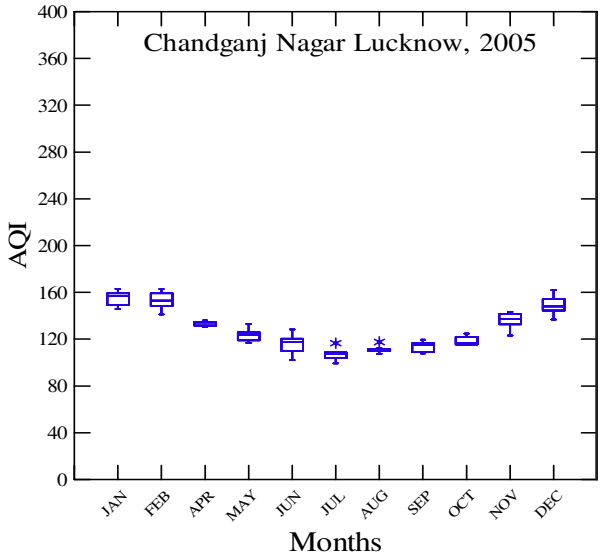
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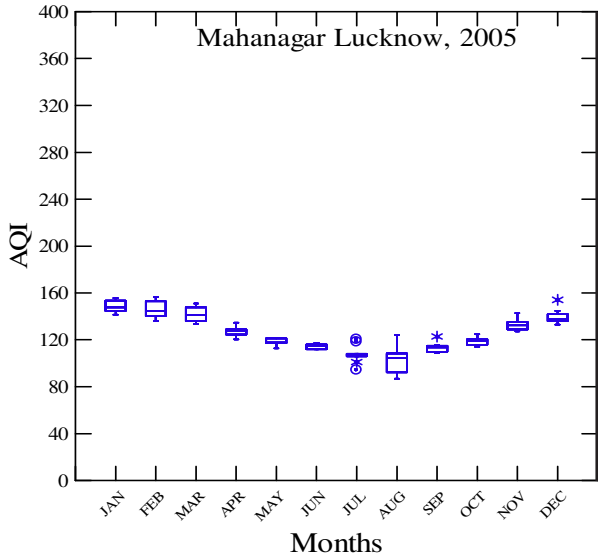
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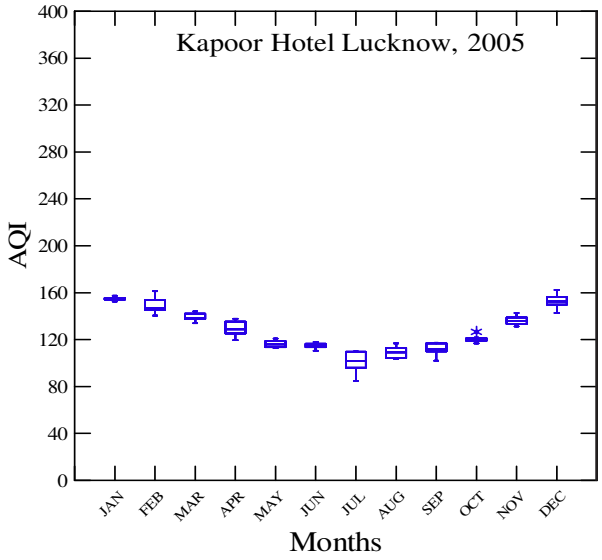
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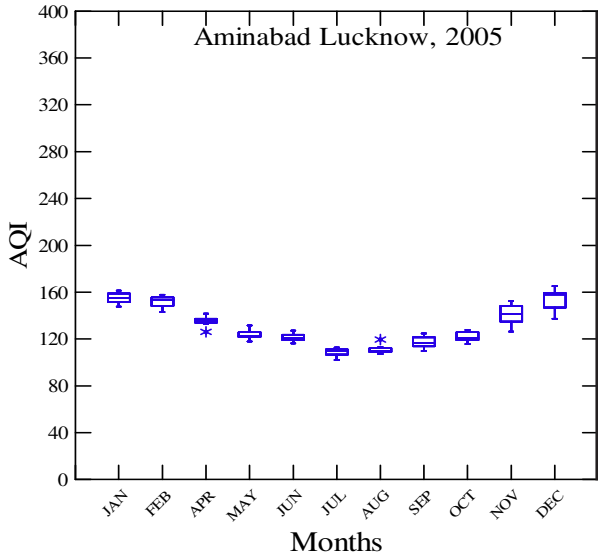
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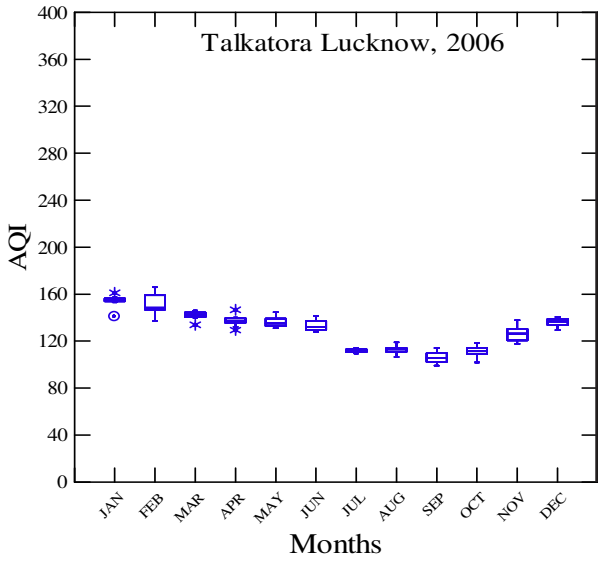
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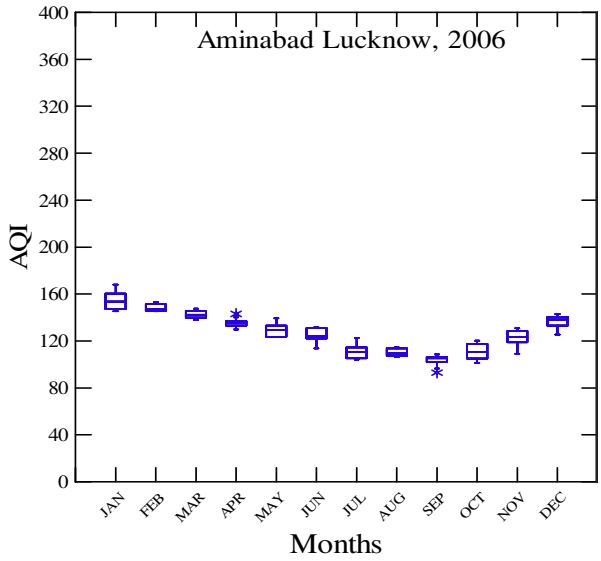
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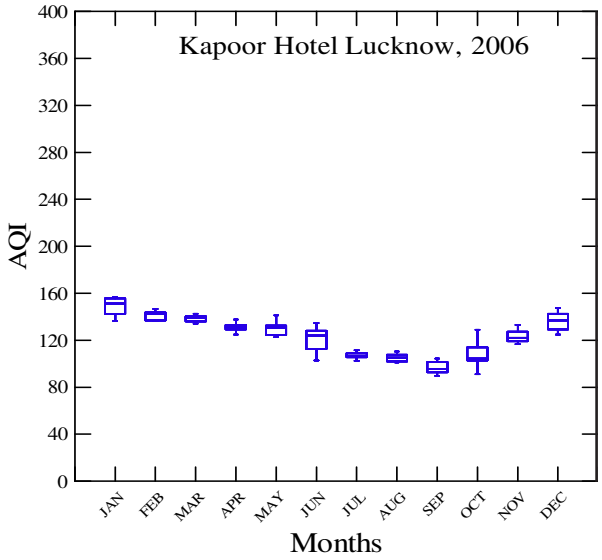
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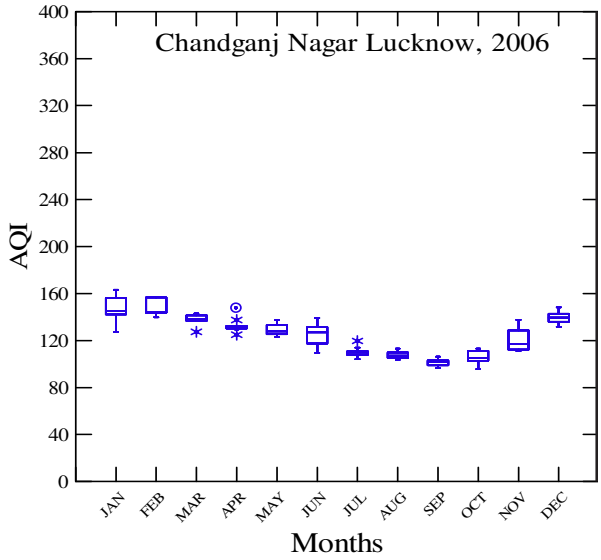
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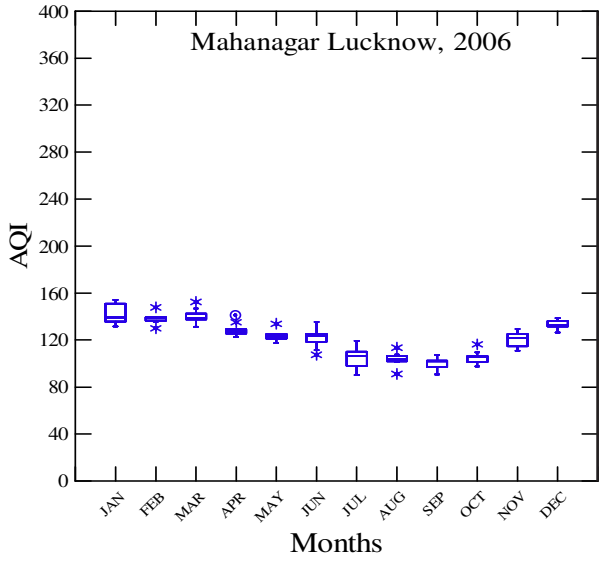
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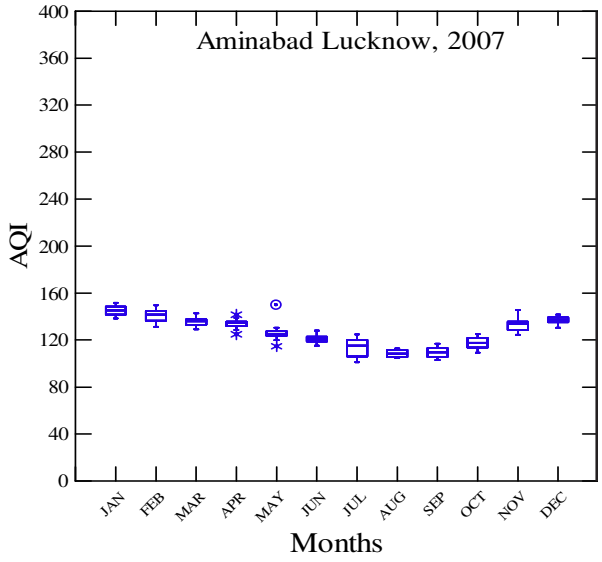
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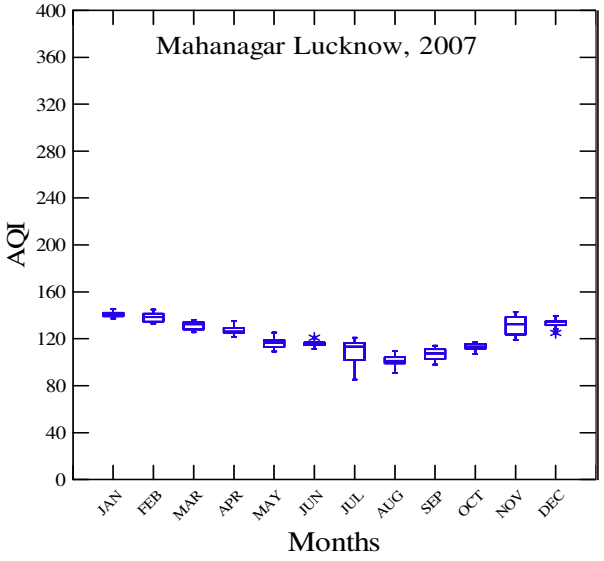
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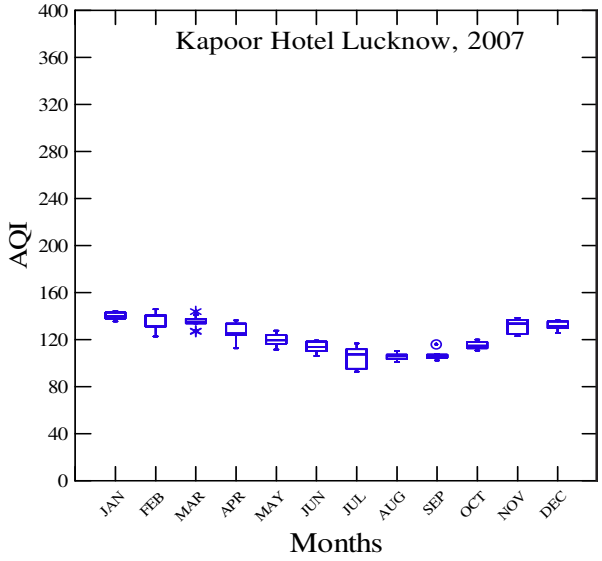
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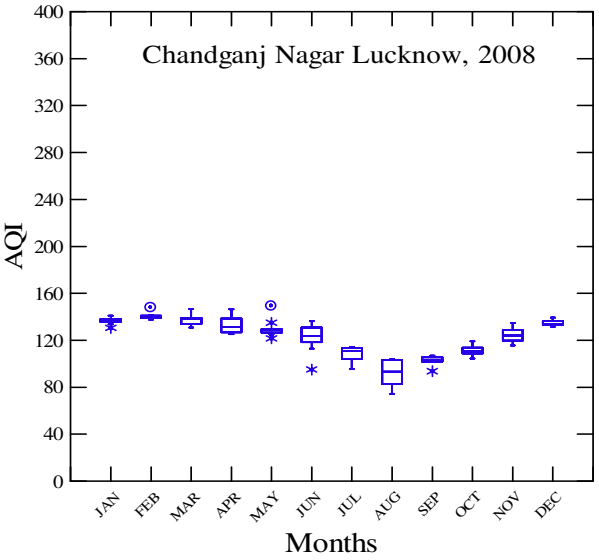
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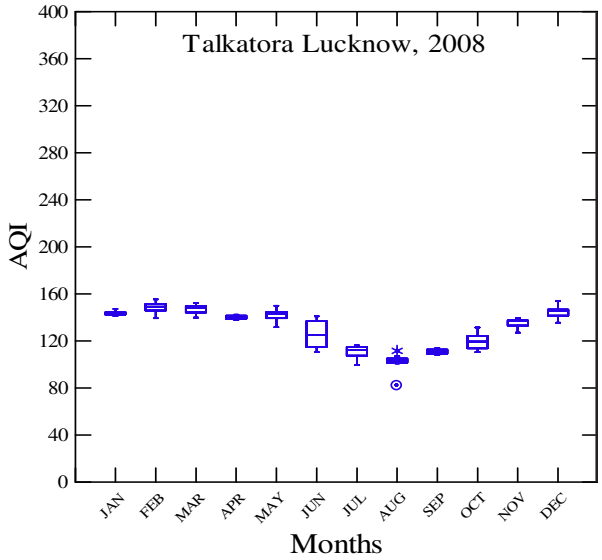
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Months
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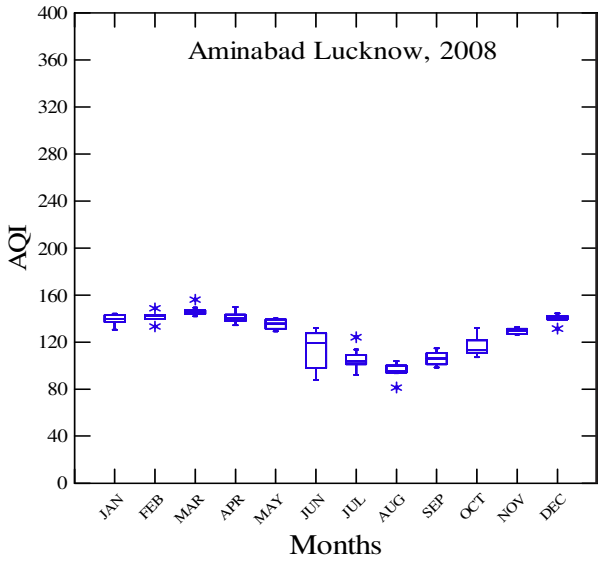
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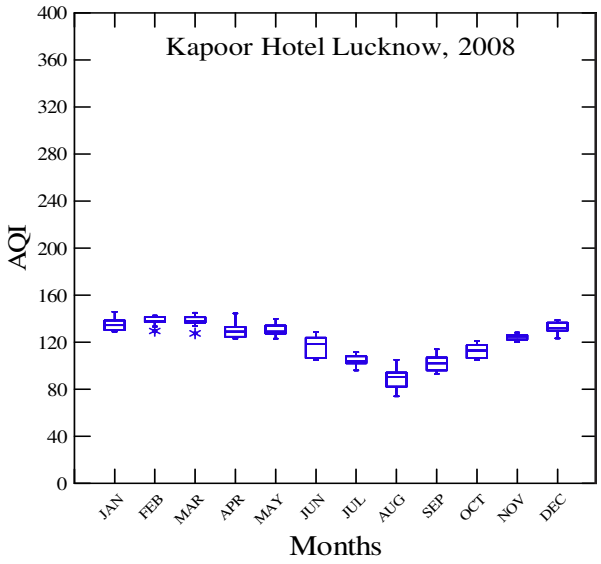
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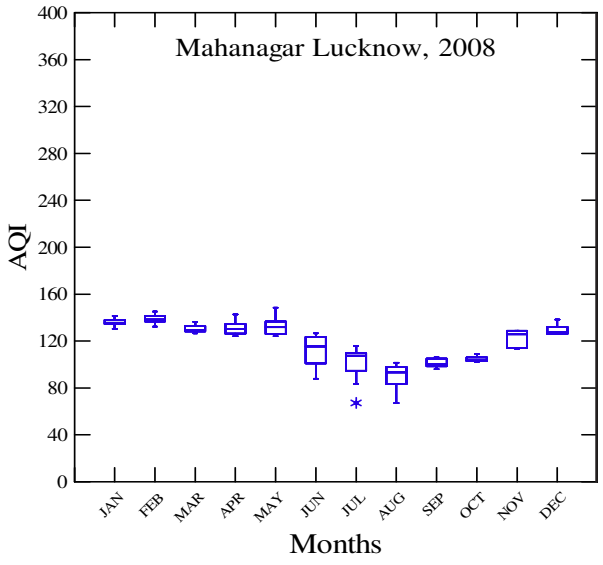
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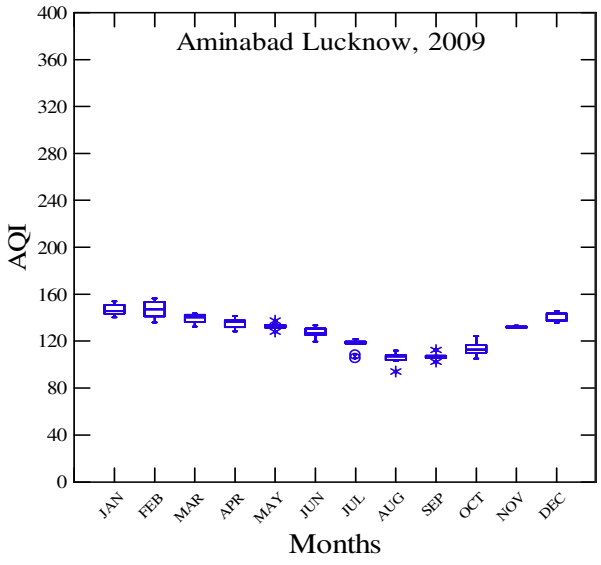
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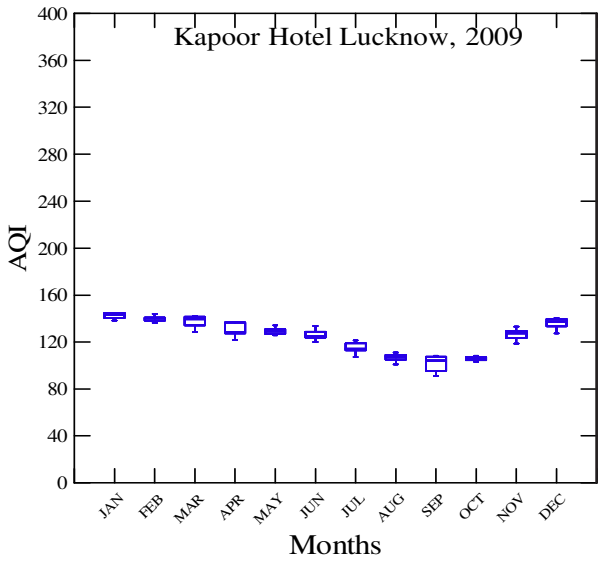
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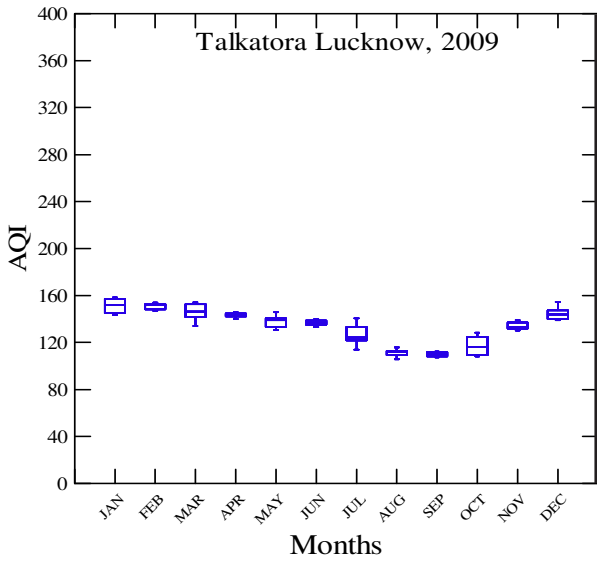
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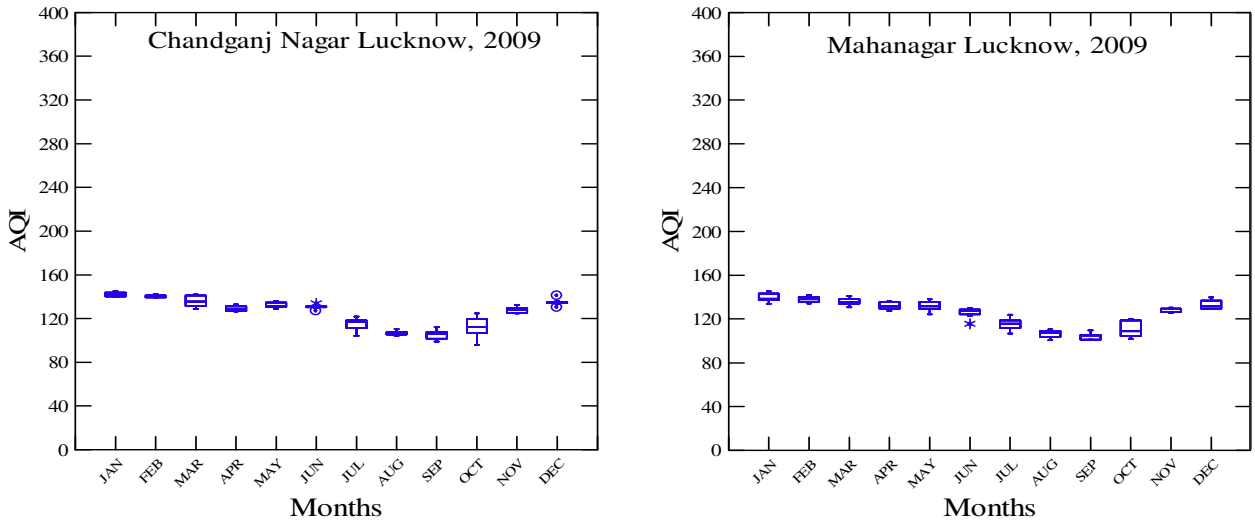
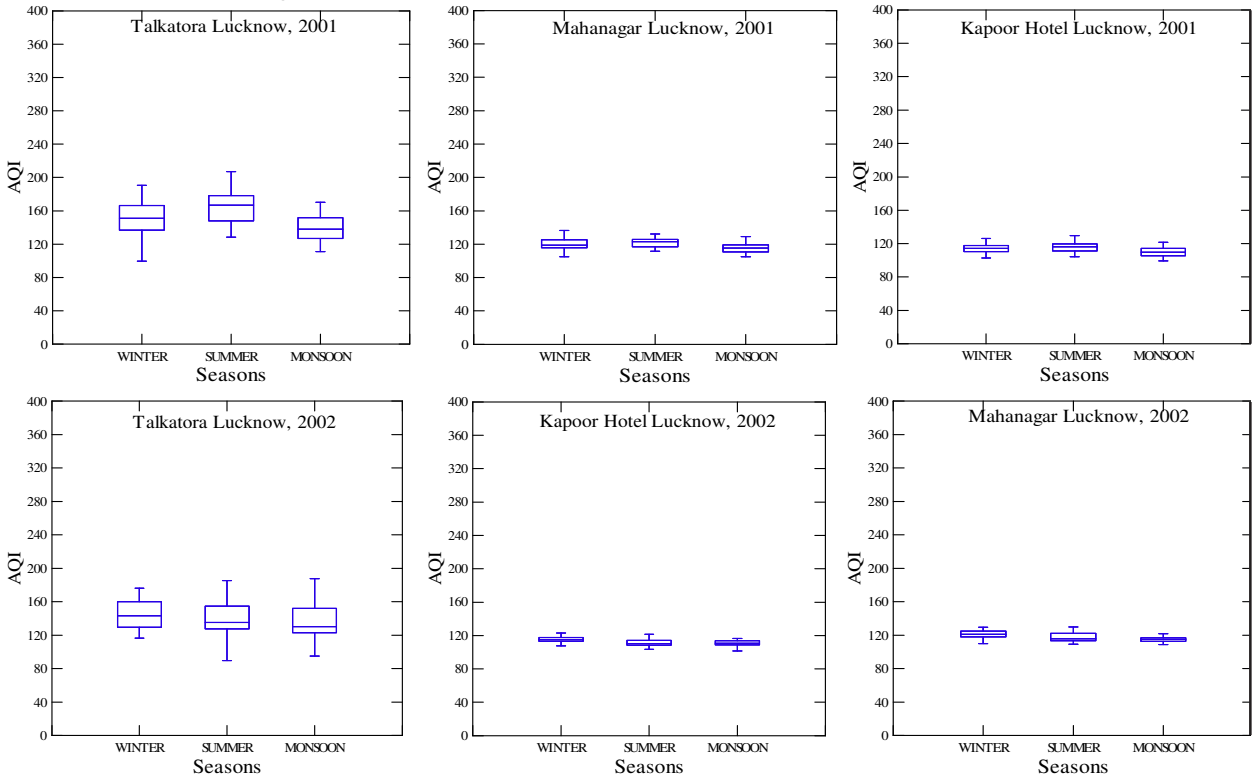


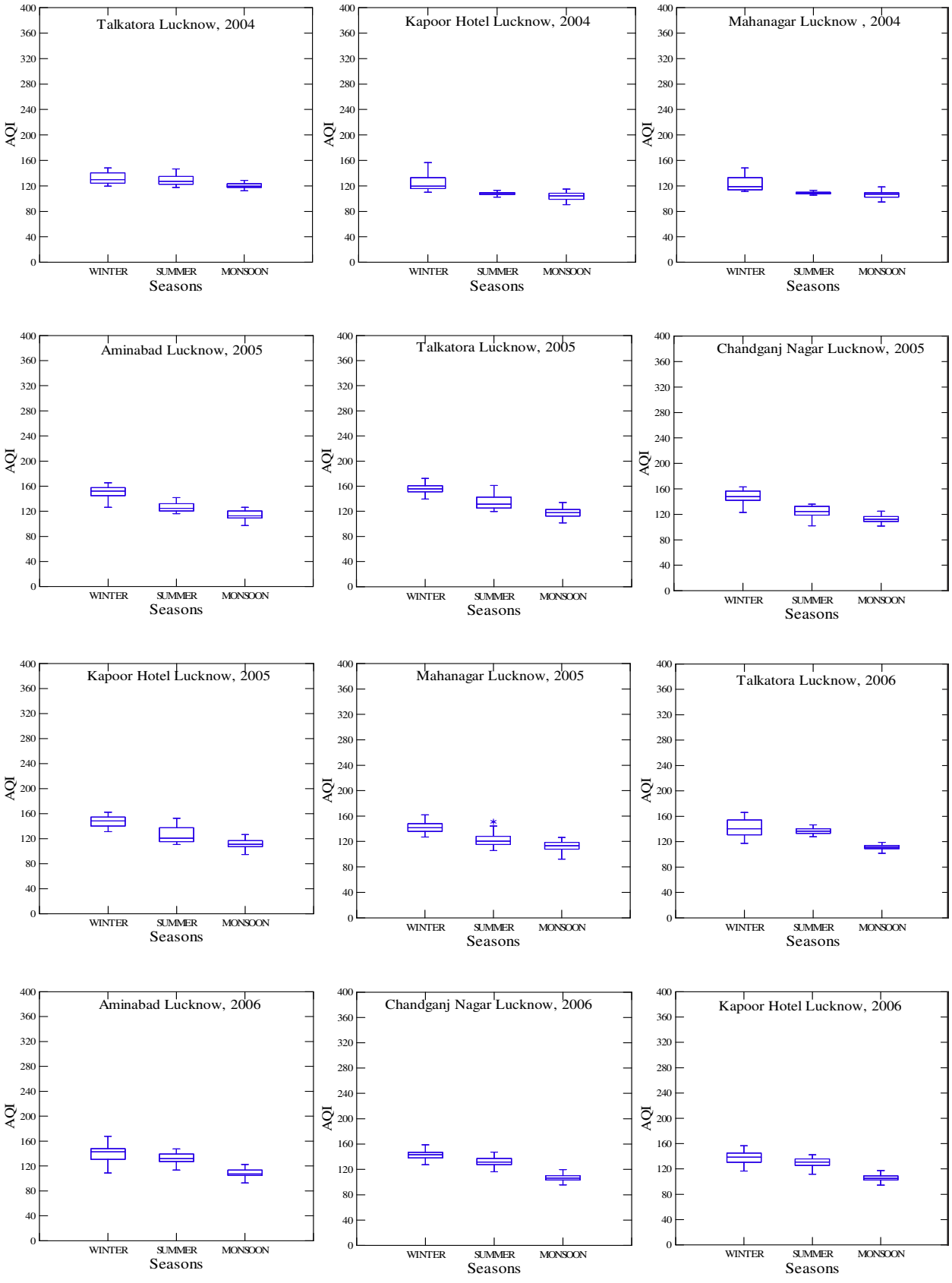
Figure 1: Monthly variation of AQI at Lucknow during 2001-09

Overall at all 13 districts of Uttar Pradesh, AQI value decreases from July to October and lies in good to moderate category due to rain whereas AQI value increases from November to February and lies in 'unhealthy for senstive people' category to 'unhealthy' category in most of the cities as calm condition prevails in these months compared to other months. AQI values from March to June are indicating 'unhealthy for senstive people' category to 'unhealthy' category due to dust storms. Maximum monthly AQI vaiation is found in Ghaziabad, Agra, Firozabad. Minimum AQI variation is found in Anpara, Gajraula, Jhansi.

Seasonal variation of AQI

Figure 2 shows seasonal variation of AQI at all five monitoring stations of Lucknow city based on available data for the period 2001 to 2009.




Talkatora Lucknow, 2004
Kapoor Hotel Lucknow, 2004
Mahanagar Lucknow , 2004
Aminabad Lucknow, 2005
Talkatora Lucknow, 2005
Chandganj Nagar Lucknow, 2005
Kapoor Hotel Lucknow, 2005
Mahanagar Lucknow, 2005
Talkatora Lucknow, 2006
Aminabad Lucknow, 2006
Chandganj Nagar Lucknow, 2006
Kapoor Hotel Lucknow, 2006
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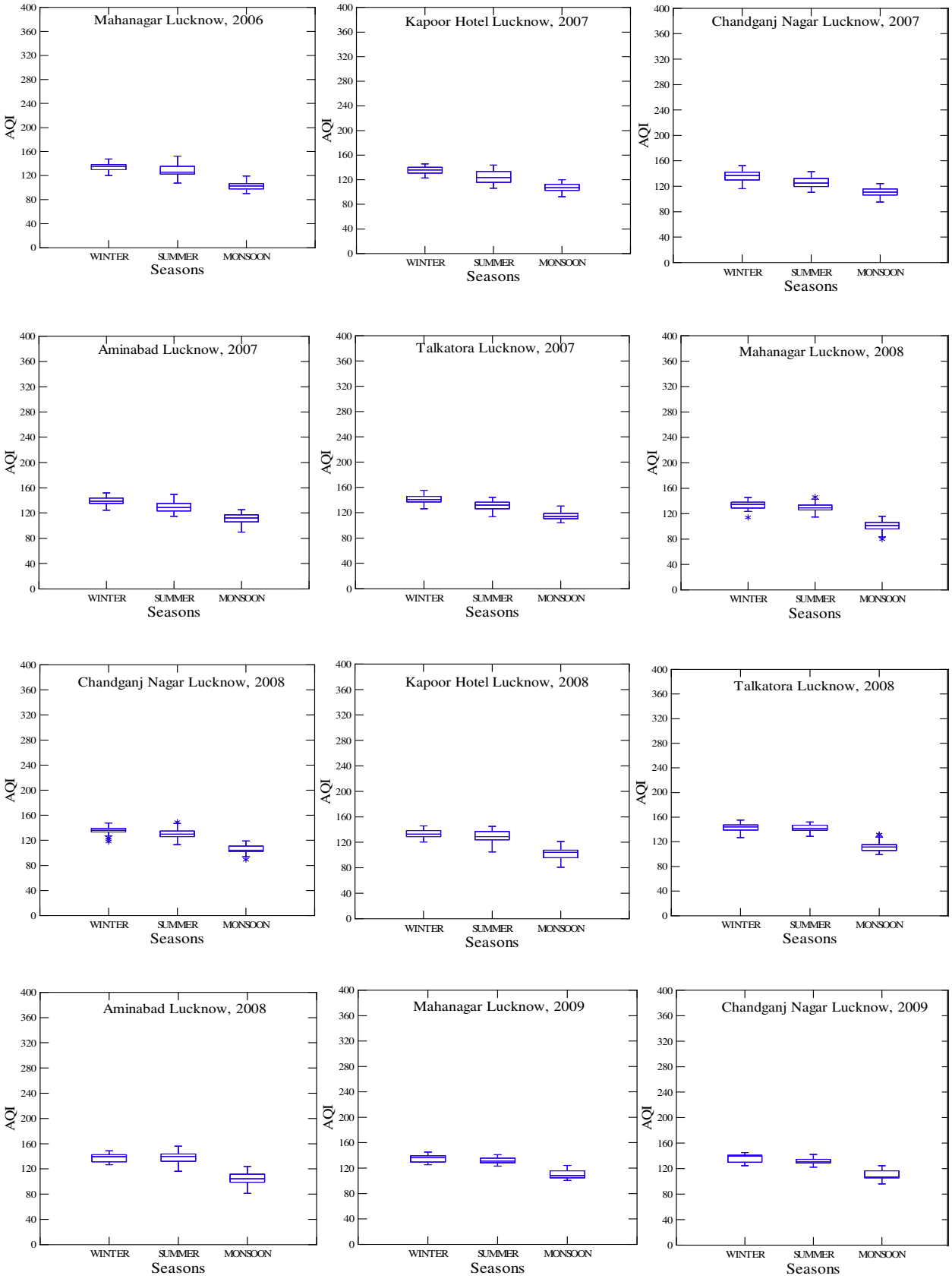
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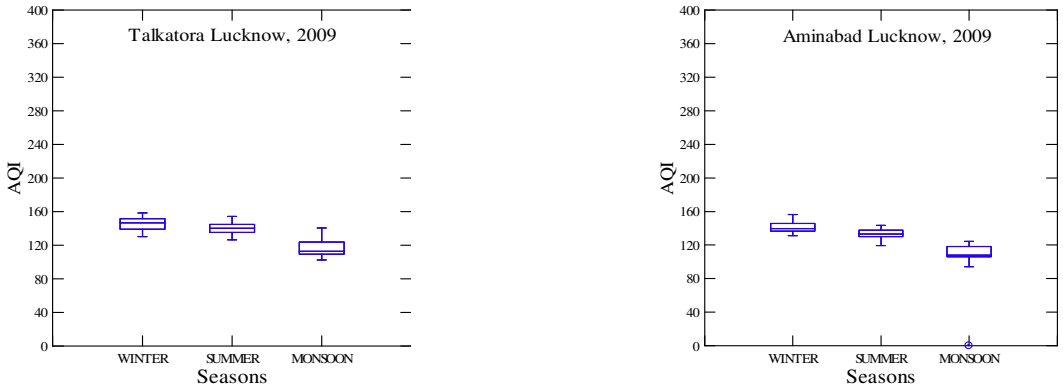

Figure 2 Seasonal variation of AQI at Lucknow during 2001-09

During period of 2001-09, maximum variation of AQI in Lucknow city is found during 2002 at Talkatora, whereas in Kanpur city it is observed during 2005 at Vikas Nagar. The metrological condition and turbulence in the atmosphere are the primary factors affecting pollutant distribution, dispersion pattern and seasonal variations. The air quality generally improves in Monsoon. During Monsoon frequent rain washes down the air borne particulates and gaseous pollutants.

Annual variation of AQI

Annual variation of AQI at all 13 districts of Uttar Pradesh having monitoring stations based on available data for the period 2001 to 2009 has been observed. In Lucknow city, during 2005-09 there is a little variation in AQI at all the locations (Figure 3), whereas during 2001-04, AQI value is low and AQI value increases after 2004.

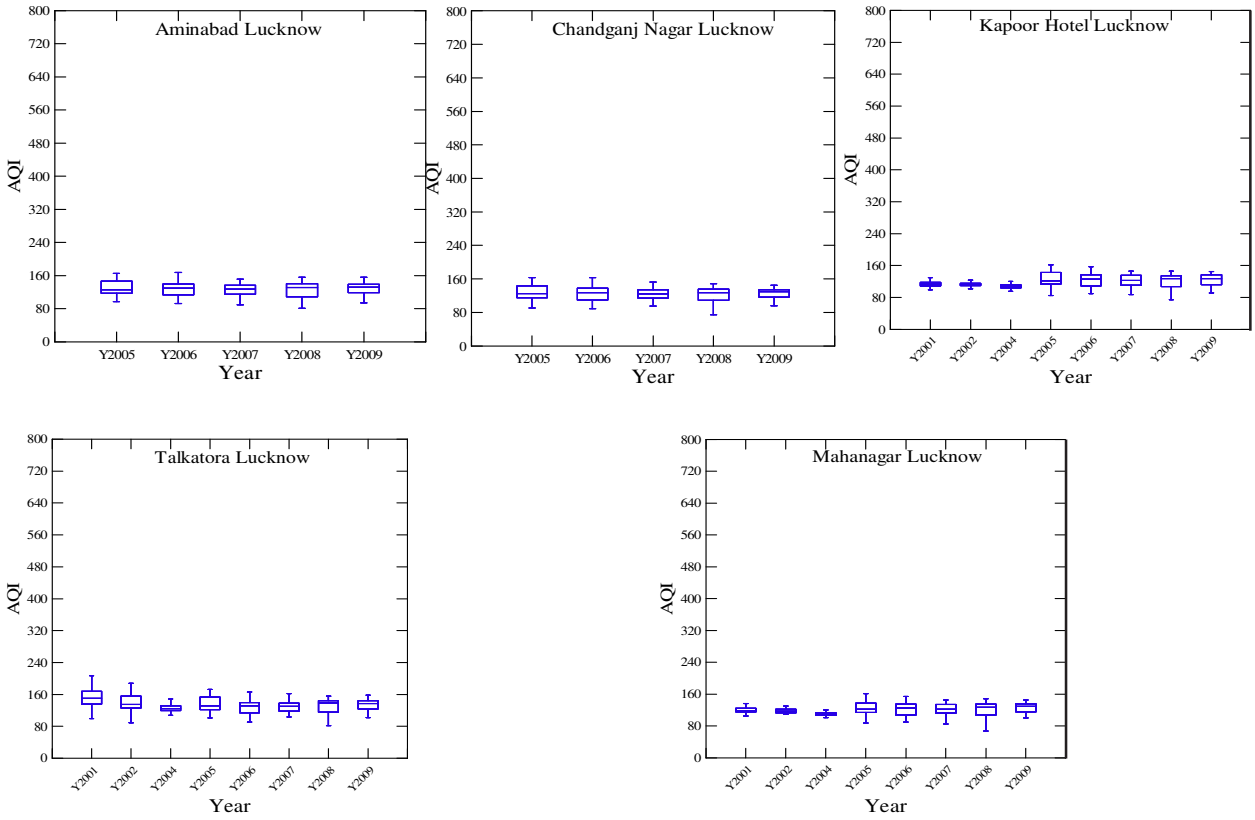

Figure 3 Annual variation of AQI at Lucknow during 2001-09

Responsible pollutant for AQI

The analysis of AQI is based on maximum operator calculation mode, where the maximum sub-index value of pollutants becomes the overall index. It is observed that most of the time SPM and PM_{10} are the responsible pollutant for high AQI value. Thus, to improve the air quality of U.P. concentration of SPM and PM_{10} have to be reduced on priority basis.

CONCLUSION

AQI has been calculated for the 13 districts of U.P. for knowing the status of air pollution with its effect on human health. While comparing all 12 pollutants, it was observed that the concentration of SPM and PM_{10} are higher than the prescribed standards and concentration of SO_2 and NO_2 is lower than NAAQS. The air quality worsens in winter month and also during summer month. The summer month are characterized by dust winds resulting high SPM. The AQI generally improves in monsoon period due to rain, good to moderate. The SPM and PM_{10} have been responsible pollutant for the index. The air quality is giving the holistic view of air pollution levels as clearly exceeded the high air pollution category and has been crossed severe pollution category at many places.

REFERENCES

1. Singh, D., Shukla, S.P., Sharma, M., Behera, S.N., Mohan, D., Singh, N.B. and Pandey, G. (2014). GIS based on-road vehicular emission inventory for Lucknow city. Journal of Hazardous, Toxic, and Radioactive Waste Mgmt, DOI: 10.1061/(ASCE)HZ.2153-5155.0000244.
2. Bishoi, B., Prakash, A. and Jain, V.K. (2009). A Comparative Study of Air Quality Index on Factor Analysis and US-EPA Methods for an Urban Environment, Journal of Aerosol and Air Quality Research, 9(1), 1-17.
3. Cohen, A.J., Anderson, H.R., Ostro, B., Pandey, K.D., Krzyzanowski, M., Künzli, N., Gutschmidt, K., Pope, A., Romieu, I., Samet, J.M. & Smith, K. (2005). The Global Burden of Disease Due to Outdoor Air Pollution, Journal of Toxicology and Environmental Health, Part A: Current Issues, 68(13-14), 1301-1307.
4. WHO (2014). 7 million premature deaths annually linked to air pollution. (http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/) (June 30, 2015)
5. Singh, K.P., Gupta, S., Kumar, A. and Shukla, S.P. (2012). Linear and nonlinear modeling approaches for urban air quality prediction. Science of the Total Environment, 426, 244-255.
6. USEPA (1999). Federal Register, Part III, Environmental Protection Agency, 40 CFR Part 58, Air Quality Index Reporting, Final Rule, 64(149), 42530-42549.
7. Ott, W.R. (1978). Environmental indices theory and practice. Ann Arbor Science Publishers Inc., Ann Arbor, Mich. 48106.
8. Sharma, M., Maheshwari, M. and Pandey, R. (2001). Development of Air Quality Index for data interpretation and public information, Indian Institute of Technology Kanpur, Report submitted to Central Pollution Control Board Delhi.
9. Sharma, M., Pandey, R., Maheshwari, M., Sengupta, B., Shukla, B.P., Gupta, N.K. and Johri, S. (2003). Interpretation of Air Quality data using an air quality index for the city of Kanpur, India, Journal of Environmental Engineering and Science, 2(6), 453-462.
10. USEPA (2006). Guideline for Reporting of Daily Air Quality - the Air Quality Index (AQI), EPA-454/B-06-001, US Environmental Protection Agency, Office of Air Quality Planning and standards, Research Triangle Park, North Carolina 27711.
11. USEPA (2014). Air Quality Index- A Guide to Air Quality and your Health, EPA-456/F-14-002, US Environmental Protection Agency, Office of Air Quality Planning and Standards, Outreach and Information Division, Research Triangle Park, NC.
12. IIT Kanpur (2009). Review of Ambient Air Quality Criteria/ Standards, Report submitted to the CPCB.
13. CPCB (2009). National Ambient Air Quality Standards, Central Pollution Control Board, Notification, New Delhi, the 18th November, 2009. (http://cpcb.nic.in/National_Ambient_Air_Quality_Standards.php) (July 02, 2015)
14. Shukla, S.P. and Sharma, M. (2008). Source apportionment of atmospheric PM_{10} in Kanpur, India. Environmental Engineering Science, 25 (6), 849-861.
15. Shukla, S.P. and Sharma, M. (2010). Neutralization of rainwater acidity at Kanpur, India. Tellus, 62B, 172-180.
16. Shukla, S.P., Singh, N.B. and Sharma, M. (2010). Air quality survey at Kanpur City. Indian Surveyor, 64(1), 74-80.