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Ambient Air Quality Status of Jaipur City, Rajasthan, India

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Abstract

Since 1991, with enactment of the economic liberalization policies, India experienced rapid industrial growth. This rise enabled growth in the resource intensive manufacturing sector and facilitated rate of material use leading to manifold impacts to the environment. Unsystematic utilization of natural resources has lead to environmental pollution. In many Indian Cities, air pollution has resulted in poor urban air quality. The air pollution can be attributed to emissions from transportation, industrial and residential activities. During the study, pollutants like PM10, PM2.5, Nitrogen dioxide, Sulphur dioxide and Carbon monoxide were studied besides meteorological parameters like temperature, relative humidity, wind speed and direction for a period from January 2014 to December, 2014. Monthly and seasonal variations of these pollutants have been monitored. On the basis of the monthly average, the air quality index for the pollutants was determined. It was observed that concentrations of the pollutants were higher in colder season as compared to summer or monsoon season. The results of this study identifies the degree of air pollution and concludes with suggestions for control of air pollution and associated health problems.

Keywords: Air Quality Index, Nitrogen dioxide, Sulphur dioxide, Carbon Mono Oxide, Particulate matter.

Introduction

Rapid and unsystematic industrialization has become a major environmental concern for both developed and developing countries. Long-term and short term effects on human health have been observed due to poor air quality[1,2]. The London fog and the subsequent series of dramatic episodes in industrialized countries lead to extensive studies on health impacts of air pollution in the mid 20th century[3].

In India, ambient air quality have progressively deteriorated due to anthropogenic sources like rapid urbanization, industrialization, uncontrolled increase of vehicles on poor road conditions, construction debris, garbage burning, lack of public awareness, domestic cooking/heating and seasonal causes such as dust storms. Both National and State authorities have taken up necessary regulatory steps and introduced interventions to curb emissions and reduce ambient air pollution, however lack of rational policy as well as unplanned growth across various developmental sectors (construction, transport, industry) has caused hindrance in the efforts.[4]

All the air pollutants are associated with a range of health impacts. Particulate matter is a major cause of all kinds of respiratory problems, increased level of sulphur dioxide and oxides of Nitrogen enhances symptoms of chronic bronchitis and CO in haemoglobin hampers oxygen supply to brain which in some cases is fatal.

An "Air Quality Index" is defined as a numeral used for reporting quality of air with respect to effects on the human health[5]. The concept of Air Quality Index was introduced by the Environmental Protection Agency (EPA) in USA to measure the pollution levels due to major air pollutants. Air Quality Index (AQI) has been used effectively to determine effect of pollution on human health in many developed countries for over last three decades[6-8]. However, not much significant efforts to develop and use AQI in India has been done, primarily due to a major reason that a modest air quality monitoring program started in 1984 and people's unawareness about health impacts due to air pollution.

Air Quality Index values are segmented into ranges and each range is allotted a descriptor and a colour code[9]. There are six degrees of health concern which makes it easier for people to understand pollution load in the air and the corresponding health impacts.

Table-1 below shows various categories of IND-AQI (National Air Quality Index) as approved by CPCB, New Delhi in Oct, 2014.

In this study, a number of pollutants (PM10, PM2.5, SO_2, NO_2 and CO) affecting ambient air quality are measured for specified location in Jaipur city along with the meteorological parameters. During study period from January 2014 to December, 2014, daily, monthly and seasonal variations of the pollutants have been monitored. On the basis of the monthly average, the indexes for each of the pollutants were obtained and cumulative impact of air pollution with meteorological factors was examined in the light of corresponding AQI.

Table-1
Air pollution index and corresponding health impact

Air Pollution Index Values	Remark	Levels of Health Concern
0 to 50	Good	Good
51 to 100	Satisfactory	Moderate
101 to 200	Moderate	Unhealthy for Sensitive Groups
201 to 300	Poor	Unhealthy
301 to 400	Very poor	Very Unhealthy
401 to 500	Severe	Hazardous

Materials and Methods

Study Area: Jaipur is famously known as the "Pink City" and is the capital of Rajasthan, India. Jaipur District has total area of 11,117 sq. km. with an average population density of 470 people per sq. km. Jaipur city lies on the geographical coordinates of 26° 55' 0" N, 75° 49' 0" E and covers an area of 200.4 sq. km. The total population of Jaipur city was found to be 3,073,350 in census 2011. Jaipur city experiences hot and arid climate with highest temperature during May- June to be 42-44^{0}C.

Site description: Vishwakarma Industrial area (VKI) was selected as monitoring site in the study area. A Continuous Ambient Air Quality Monitoring Station (CAAQMS) has been installed in the premises of RSPCB, Regional Office, Road No. 5, V.K.I. Area, which is very much close to Industrial Area (west) and is surrounded by Commercial complexes and Residential area. National Highway 11 runs towards East of the monitoring station.

Monitoring and Analysis: Air pollutants and meteorological parameters were monitored continuously for 24-hours in a day from January 2014 to December 2014. Air pollutant (PM10, PM2.5, SO_2, NO_2) concentrations are expressed in microgram per cubic meter (µg/m^3) and concentration of CO is expressed in milligram per cubic meter (mg/m^3). Wind speed is expressed in meter per second (m/s), wind direction in degree from the north, ambient temperature in degree Celsius (^{o}C), and relative humidity in percentage (%). Table-2 summarizes air pollutant parameters and principles of their measurement.

Several methods and equations are used for determination the AQI[10] in different countries.

AQI can be calculated from concentration of different pollutants using following formula[11-13].

$$I = ((I_{high} - I_{low}) \times (C - C_{low}) / (C_{high} - C_{low})) + I_{low}$$

Where, I = Air Quality Index, C = Concentration of pollutant, C_{low}= Concentration breakpoint that is ≤ C, C_{high}= Concentration breakpoint that is ≥ C, I_{low}= Index breakpoint corresponding to C_{low}, I_{high}= Index breakpoint corresponding to $C_{high.}$

Table-2
Pollutants selected for study and their measurement principle

Parameter	Description	Principle
PM10	Respirable Suspended Particulate Matter (RSPM) <10µm particle size	Beta Ray Attenuation
PM2.5	Respirable Suspended Particulate Matter (RSPM) <2.5µm particle size	
SO_2	Sulphur Dioxide	Pulsed Fluorescence
NO_2	Nitrogen Dioxide	Gas Phase Chemiluminescence
CO	Carbon Monoxide	Non Dispersive Infra Red

Results and Discussion

Concentrations of air pollutant exhibit typical diurnal, weekly and annual cycles due to variation in meteorological parameters and emission of pollutants from their sources[14,15].

Monthly variations among pollutants: Monthly average concentrations of air pollutants viz PM10, PM2.5, NO_2, SO_2 and CO have been depicted in Table-3 for a period from January to December, 2014.

Maximum concentration of PM10 (362.1 µg/m^3) and PM2.5 (163.1 µg/m^3) was observed during winter months. While minimum observed value of PM10 (154.0 µg/m^3) and PM2.5 (51.5 µg/m^3) was recorded in the month of August. During winters, there occurs slow dispersion of pollutants which results in more stable atmospheric conditions. These conditions favour build up of pollutants near to the source of pollution which give rise to higher concentrations. These maximum values for PM10 and PM2.5 are higher than those found in Lucknow (PM10-182.3 µg/m^3 and PM2.5= 89.3 µg/m^3)[16].

During the study (2005-2008) in Ahmadabad, high concentrations of Particulate Matter were observed during winters and low concentrations during monsoon months[17]. Similar observations were reported in Bikaner[18.] Unlike this study, maximum observed values of PM10 and PM2.5 were reported in the month of March and minimum value in the month of February during their study of ambient air quality of

Bhopal city[19]. In the present study, all observed values of PM10 were higher than National Ambient Air Quality Standards. Similarly, PM10 values for Jhansi city[20,] for Dehradun[21] and for Kakinada city[22] were found to exceed prescribed limits as stipulated by CPCB.

Concentration of NO_2 as monthly average was maximum (63.5µg/m3) in January, followed by 58.0 µg/m^3 in October while a minimum was recorded 9.7 µg/m3 in Monsoon season. Observed values of NO_2 was highest (37.04 µg/m^3) in industrial area of Udaipur[23] which is lower than that observed in this study. The present study coincides with the results of study for Rohtak city where high NO_2 concentration was reported in winters and low in monsoon[24].

Highest concentration of SO_2 was obtained in the month of December (24.2 µg/m^3), followed by 23.2 µg/m^3 in November and lowest concentration (5.7 µg/m^3) in monsoon. Captured value of SO_2 may be attributed to congested traffic, garbage burning at nearby Highways and residential areas. Similar observations were observed and it was reported that high value of SO_2 may be likely due to heavy traffic load and stationery fuel combustion[25]. Other than anthropogenic sources, many environmental conditions may also result in the buildup of high SO_2 concentration in the ambient air. Variation of parameters may be associated with dynamics of atmospheric boundary layer and with convective turbulence[26]. In their study for ambient air quality of Jajpur district of Odisha, SO_2 concentration was low during monsoon as compared to concentrations observed in summer and winter months[27], which is in coherence with the present study. Study in Haridwar is also in agreement with results of this study as high SO_2 concentration was reported during winter months[20.]

CO as a pollutant is a result of partial combustion of diesel or gasoline in engines, bush burning and some indoor sources [28]. As concentration of CO in ambient air is strongly related to traffic load as compared to other environmental factors, not much variation in concentration of CO was observed during the study period. CO concentration ranged from 0.40 - 0.76 mg/m^3 throughout the year 2014. However, the results of study indicated a significant downward trend in CO concentrations, with the trend following an exponential pattern. CO variation across the seasons revealed that the condition of ambient air quality during afternoon and evening hours is poor[29].

In contrast to conventional technology vehicles, vehicles produced after 1989 have been equipped with a catalyst which emits 8 to 12 times less CO and 3-6 times less NO_2 depending on the type of catalyst which could be a reason of relationship between traffic and gaseous pollutants[30,31].

Table-3
Monthly average and air quality index of pollutants

Month	PM10		PM2.5		SO_2		NO_2		CO	
	Monthly average (µg/m^3)	AQI	Monthly average (µg/m^3)	AQI	Monthly average (µg/m^3)	AQI	Monthly average (µg/m^3)	AQI	Monthly average (mg/m^3)	AQI
January	336.88	336.9	163.14	271.9	21.02	26.3	63.50	79.4	0.76	19.0
February	268.54	268.5	85.18	142.0	15.39	19.2	39.19	49.0	0.62	15.6
March	272.31	272.3	83.95	139.9	15.94	19.9	31.83	39.8	0.57	14.3
April	304.48	304.5	72.67	121.1	17.13	21.4	25.19	31.5	0.61	15.3
May	309.54	309.5	56.85	94.7	12.86	16.1	17.54	21.9	0.51	12.9
June	269.45	269.5	63.16	105.3	9.15	11.4	12.62	15.8	0.40	10.1
July	183.94	183.9	56.16	93.6	6.36	7.9	9.71	12.1	0.47	11.8
August	154.00	154.0	51.51	85.8	5.74	7.2	14.99	18.7	0.45	11.2
September	157.13	157.1	59.15	98.6	6.47	8.1	20.37	25.5	0.48	12.0
October	295.20	295.2	85.27	142.1	15.32	19.1	58.04	72.5	0.56	14.1
November	362.06	362.1	106.03	176.7	23.24	29.1	26.61	33.3	0.48	12.0
December	330.18	330.1	129.08	215.1	24.18	30.2	29.43	36.8	0.51	12.6

Calculation of Air Quality Index: Air Quality Index (AQI) is referred to as a numerical rank that reflects the composite influence on overall quality of parameters which can be helpful not only to guide general public but also for making decision of systematic urban planning[12,32]. The AQI focuses on health effects sensed for few hours or days after continuous inhaling polluted air[17].

Concentration of air pollutants were monitored and subsequently converted into AQI using following formulae-

$$I = ((I_{high} - I_{low}) \times (C - C_{low}) / (C_{high} - C_{low})) + I_{low}$$

AQI values are then rated to corresponding health impacts of pollutants. Greater value of index reflects high concentration of air pollutants and adverse impact of human health.

Table-3 shows that Air Quality Index for observed PM10 was maximum in November (362.1µg/m^3) followed by January (336.9 µg/m^3) and minimum AQI value 154.0 µg/m^3 was observed in August. AQI highest value for PM2.5 was calculated to be 271.9 in January followed by 215.1 µg/m^3 in December and minimum 85.8 µg/m^3 in August.

Captured values show that maximum AQI for SO2 was observed in December (30.2 µg/m3) and minimum 7.2 µg/m3 was observed in August. In the case of NO2 maximum AQI was observed in January (79.4 µg/m3) and minimum value 12.1 µg/m3 was observed in July. AQI of CO varies from 10.0 - 19.0 mg/m3. The results show good air quality with reference to gaseous pollutants.

From the results of the study, it can be concluded that highest values for AQI was observed in following descending order: PM10> PM2.5>NO_2>SO_2>CO. Thus, the major impact on ambient air quality in study area may be attributed to PM10.

A lot of research work on ambient air quality have been undertaken at various regions of India. AQI values for 24 hourly average of SO_2 and NO_2 concentrations was calculated and categorised as "Good and good to Moderate" during 2009 for Delhi city[33]. However, daily average concentration and AQI value for Particulate matter showed maximum concentration of pollutant during winters and minimum values were depicted in monsoons. The data compiled by MPCB for the year 2013-2014 at 72 AAQM stations shows that PM10 is the main and primary pollutant followed by NO_2 and air quality of 42% of the total observations were found to be "Moderate and below[34]". Overall AQI values fall under "Moderately polluted category" (100-200) for the city of Vapi, India and PM10 was observed to be a critical pollutant[35]. AQI study in industrial areas of Visakhapatnam reveals that PM2.5 was the main responsible pollutant and fall under category of "Very Poor[36]". During the study of Cuddalore, Tamil Nadu, overall AQI for selected stations falls under category of "Moderate to Polluted". Results of the study confirmed that SO_2 levels in comparison to previous studies for the same place have increased which shows concentration of SO_2 is increasing[37]. In case of Hyderabad, it was reported that the biggest threat for any city is decoupling of economic growth from pollution trend. For Hyderabad as study area during 2002-2008, along with growth and development concentration of pollutants are also rising. SO_2 is the only pollutant that has decoupled from growth. This is mainly due to change in energy matrix of the city[38].

Observed value of AQI for PM10 in the present study falls under the range of 154 – 362.1 which shows "Poor" air quality with reference to particulate matter. Overall AQI indicated "Severe air pollution" in Bhopal city[18], "Moderately – Polluted to unhealthy" for Ahmadabad[32]. Unhealthy for sensitive groups" for selected sites of Surat city during December, 2010 to March, 2011[39]. During the present study, AQI calculated for SO2 and NO2 was under "Good to Moderate" with a value of 7.2- 30.2 and 12.1-79.4 respectively.

High AQI for PM10 for study area may be accounted for Automobiles and industries along with other major sources as diesel-powered generators (used in case of electricity supply failures), dust emissions from paved roads, garbage burning in open, use of conventional fuels like wood, cow dung etc. for cooking and other domestic purposes, and some natural sources dominant in semi arid climatic conditions in the city. Motor vehicles generate particulate matter of different particle size from dust produced from brakes, clutch plates, tyre movement and indirectly through re- suspension of particulates on road through mobility of vehicles [40.]

Most of the Indian cities in North are suffering with unusually high concentration of PM10 in ambient environment posing a serious risk to human health[41]. Continuous inhalation of high concentration of PM10 may lead to a number of health ailments such as increased respiratory symptoms viz irritation of the airways, coughing or problem in normal breathing, decreased lung function, aggravated asthma, irregular heartbeat, nonfatal stroke, premature death of people due to heart or lung disease[6]. In order to protect human health and environment from adverse effects of particulate pollution, control measures have to adopted so that emission concentrations of pollutants is within prescribed limits specified by CPCB.

Conclusion

This study reveals that both the particulate pollutants, PM 10 and PM2.5 are mostly above permissible limits at study site. Result of the study for Jaipur city is similar with research for other cities of India as the concentration of particulate matter is also high in other cities. High particulate concentration is due to heavy transport activity in study area, apart from industrial emissions, dust from paved roads, garbage burning in open, use of conventional fuels like wood, cow dung etc for cooking and other domestic purposes. All pollutants were observed to be high in concentration during winters as compared to summer

and monsoon, due to slow dispersion and dilution of pollutants. From the calculation for AQI, it was observed that Particulate pollution is mainly responsible for ambient air pollution in Jaipur city.

It can be summarised that air pollution at the study site is primarily because of traffic. Traffic diversions, provision of alternate routes, restricting heavy vehicles movement through residential roads, arranging for periodic vehicle maintenance and encouraging public transport instead of private vehicles are worthy considerations to control air pollution due to transportation. Regular monitoring for adequacy of pollution control equipments installed at various industries should be undertaken to check emissions from industrial processes. In addition to above, public awareness for environment protection should be adopted and green plantation along highway and within industries should be encouraged. It may, thus be concluded that strict implementation of environmental regulations and adoption of adequate pollution control measures is need of the hour.

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