*International Journal of Theoretical & Applied Sciences* **6**(1): 138-147(2014)

**ISSN No. (Print): 0975-1718**
**ISSN No. (Online): 2249-3247**

# Study of Ambient Air Quality Status on Urban Roads using Air Quality Index -A Case of Jaipur City (Rajasthan, India)

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*(Received 26 March, 2014, Accepted 14 June, 2014)*

**ABSTRACT: An attempt has been made in this investigation to ascertain ambient air quality on major arterial roads of Jaipur city in the form of Air Quality Index (AQI). Monitoring stations were set up at thirty five strategic locations on all arterial roads of the study area after gaining knowledge about their traffic characteristics and analyzed the air samples from various monitoring locations, the results are being compared with permissible standards as specified in Gazette of India Notification Extraordinary Part III, Section-4, Year 2009 and subsequently computed the air quality index. The results reveal that gaseous pollutants such as $SO_2$ and NOx are within the permissible limits and particulate matter is the predominant cause of air pollution in the study area. More than half the total numbers of locations have severe air pollution while another one-third suffer from heavy air pollution.**

**Key Words**: Jaipur City, Ambient air quality, Air quality index

## I. INTRODUCTION

The presence of high density of population and industries in the cities lead to vehicular, domestic, and industrial emissions that subsequently affect the urban environmental conditions adversely. Air quality scenario in most of the Indian cities presents a grim picture as more than 90 per cent of the national monitoring stations have recorded particulate concentrations exceeding the WHO recommended guidelines (TERI 2003). Urban transport is the single largest cause of air pollution in Indian cities (IIR 2006). In the light of the above facts an attempt has been made in this investigation to study the air pollution due to urban transport in Jaipur city.

### *A. Study Area*

Jaipur, the capital city of Rajasthan State in India, is the tenth most populous city of the country. It is located at $26^0$ 54'N latitude and $75^0$49'E longitude and experiences a continental type of climate. The city witness extreme temperatures both in summer as well as in winters and low to moderate relative humidity. The highest mean monthly maximum temperature of 40.6º C is recorded in May and the lowest mean monthly temperature of 8.3º C is recorded in January.

The city is well connected by rail, road, and air transportation network to rest of the country.

The city lies on Ahmedabad rail route of Western railways and is connected with three national highways. While two national highways, i.e., NH-8 and NH-11 pass through the city, NH-12 leading to Jabalpur starts from the city.

The transport system of Jaipur city is mainly road based. The city is served by eleven major arterial spines. Seven out of these eleven arterial roads witness traffic volume in access of the traffic carrying capacity, which implies heavy traffic flow on these roads during peak hours. Heterogeneity of traffic, lack of lane discipline, inadequate public transportation system, and exponential increase in personal modes of transport are some of reasons for congestion on these roads. Two-wheeler is the predominant vehicle mode in Jaipur city and its share in total number of registered vehicles is at 76 per cent, followed by Four-wheelers, which constitute 16 per cent, and buses constitute only one per cent of the total registered vehicles in Jaipur city (CMPJ 2008). The growth trend of registered vehicles in the city reveals that the average annual growth of passenger vehicles stands at 14.26 per cent for the period 2001-2011 (RTO, Jaipur).

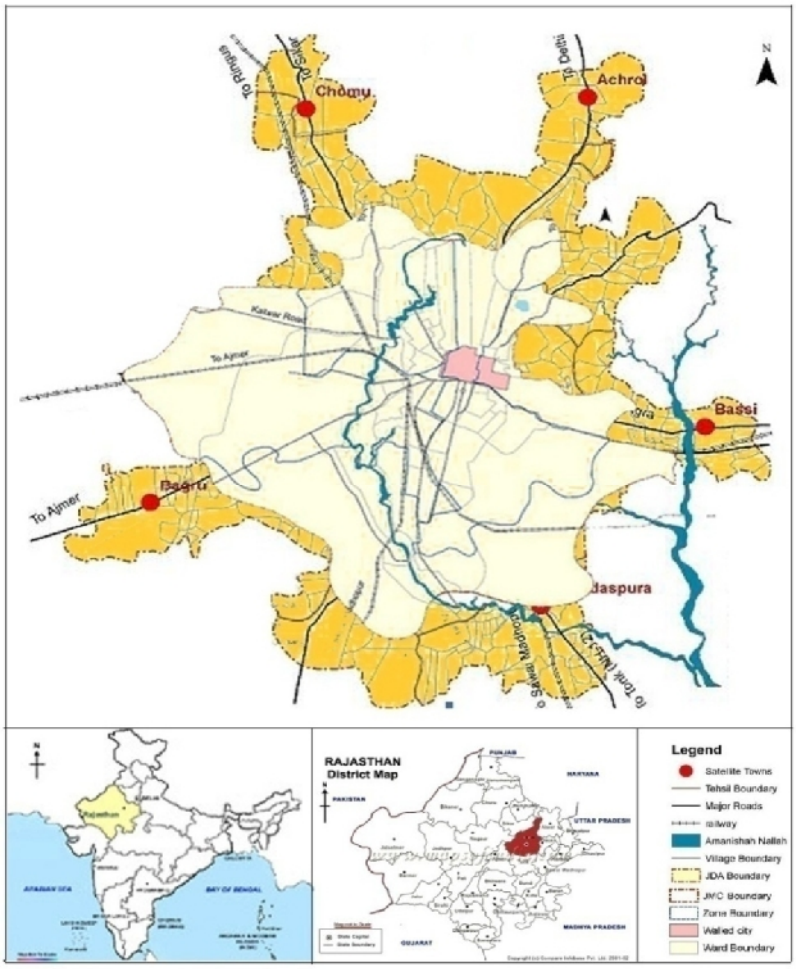


**Fig. 1.** Description of the Study Area.

## II. MATERIALS AND METHODS

Monitoring stations were set up at thirty five strategic locations on all arterial roads of the study area after gaining knowledge about their traffic characteristics. The monitoring was conducted by a team of central laboratory of the State Pollution Control Board of Rajasthan and the investigator being the member of the monitoring team collected and analyzed the air samples from various monitoring locations. Sampling was done in the summer months (March-June 2011 ) with a view to cover the peak traffic hours of morning (9:00AM-1:00PM) and evening (4:00PM - 8:00 PM) of the day. The APM 460 NL respirable dust sampler manufactured by Envirotech Ins. Pvt. Ltd. was used for sampling purpose. The samplers were installed in the breathing zone (1.5 m). The flow rate of air was kept in the range of 1.0 -1.3 m3/min. The size classification of the particulate was achieved through a cyclone installed in the sampler which separates the respirable (PM10) and non-respirable fractions. The particle sized less than10 microns were collected on the filter papers; whereas, SPM larger than 10 microns was collected in the separate sampling bottle, also called as dust collector. Further, the air was passed through the impingers, housed in separate enclosure containing absorbing solution for $SO_2$ and $NO_x$ in series, at a flow rate 1.00 liter/min. A constant temperature was also maintained during sampling with the help of an icebox and samples were stored at a temperature below 5°C. Modified West and Gaeke Method has been used for computing $SO_2$ while Jacob and Hochheiser (Modified Na-Arsenite Method) Method has been used for computing NOx in the collected samples. The air quality parameters such as Suspended particulate matter (SPM), Respirable suspended particulate matter (RSPM), $SO_2$ and $NO_x$ have been studied in this investigation and the results are presented in the subsequent paragraphs, in sequel. The details of locations and the values of air quality parameters along with their air quality index is presented in Appendix-1.

## III. RESUL AND DISCUSSION

*A. Suspended Particulate Matter (SPM)*

Suspended matter is of a major concern and they typically consist of dust, fumes, and smoke. These particles when breathed in cause lung damage and respiratory problems. It is therefore, considered important to study this air quality parameter and the results are presented in Table 1, Fig. 2 and Fig.3. It is evident from the Table1 and Fig. 2 that a little more than half (54 per cent) the total number of locations have SPM level between 200-400 µg/m$^3$ while another two-fifth (43 per cent) locations have SPM level between 400-600 µg/m$^3$ . It is observed further that Transport Nagar has the maximum SPM level of 650 µg/m$^3$ while Figure 3 reveals that there is no location which has SPM level less than or equal to 200 µg/m$^3$. It is therefore important to note that all locations in the study area have SPM level beyond the permissible limits as specified in the standards.

**Table 1: Distribution of SPM Level in Jaipur City.**

| **Serial No.** | **SPM µg/m$^3$** | **No. of Samples** | **Per cent Distribution** |
|---|---|---|---|
| 1 | ≤200 | 0 | 0 |
| 2 | 200-400 | 19 | 54 |
| 3 | 400-600 | 15 | 43 |
| 4 | 600-800 | 1 | 3 |
| **Total** | | **35** | **100** |

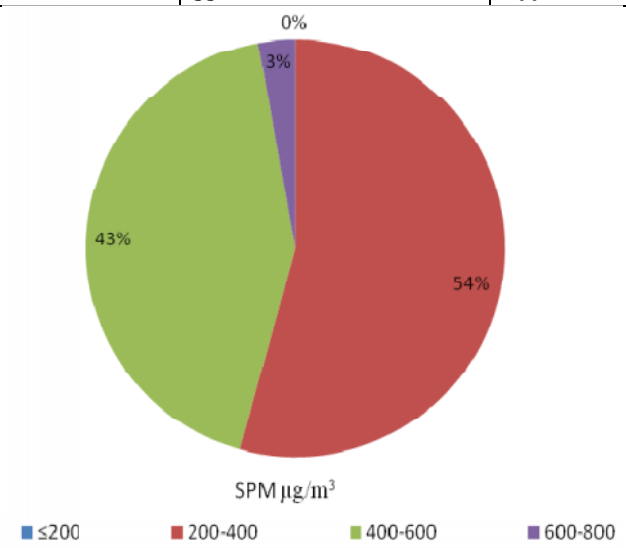


**Fig. 1.** SPM levels and per cent share of samples in Jaipur city.

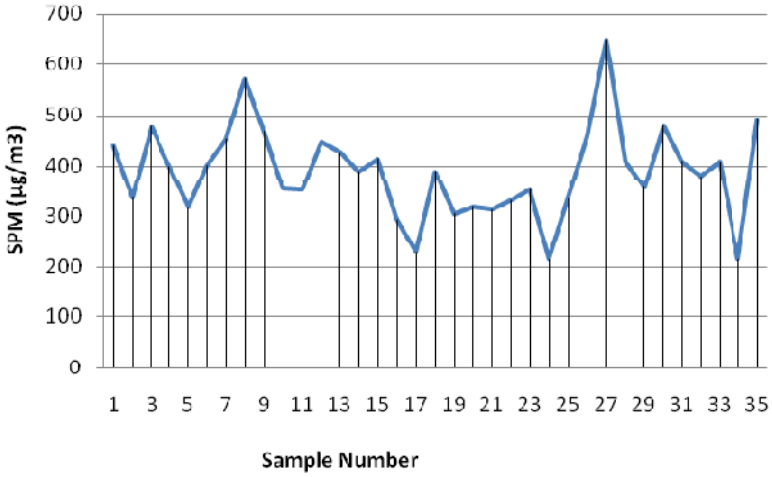


**Fig. 2.** Distribution of SPM levels in Jaipur City.

*B. Respirable suspended particulate matter (RSPM)*

Respirable suspended particulate matter (RSPM) is the suspended particles less than 10 micrometer. As these particulates are small enough to be breathed in readily, they are even more detrimental to human health as compared to suspended particulate matter. The particulate matter less than 2.5 micrometers or less are specifically more harmful as they cannot be expelled from the body, therefore, they cause long-term ailments such as lung cancer, asthma and acute respiratory symptoms, chronic bronchitis, some type of birth defects as well as premature deaths. Given the above facts, it was considered to examine this air quality parameter and the results are presented in Table 2 and Fig. 4 and Fig. 5.

The ambient air of the study area ranged between 101-385 µg/m3. It is observed from the Table 2 and Figure 4 that two-third (66 per cent) of the total locations have RSPM level between 100-200 µg/m3 while another three-tenth (31 per cent) locations have RSPM level between 200 -300 µg/m3 and only one location (Transport Nagar intersection ) has RSPM level more than 300 µg/m3. As per the Gazette of India Notification Extraordinary Part III, Section-4, Year 2009. Standard for respirable suspended particulate matter is 100µg/m3; it is important to note that no location has the RSPM level within the standard while 23 locations of the study areas are having RSPM level twice of the prescribed limit and 12 locations are having three times higher RSPM level than the standards.

**Table 1: Distribution of RSPM Level in Jaipur City.**

| **Serial No.** | **RSPM µg/m$^3$** | **No. of Samples** | **Per cent Distribution** |
|---|---|---|---|
| 1 | ≤100 | 0 | 0 |
| 2 | 100-200 | 23 | 66 |
| 3 | 200-300 | 11 | 31 |
| 4 | 300-400 | 1 | 3 |
| **Total** | | **35** | **100** |

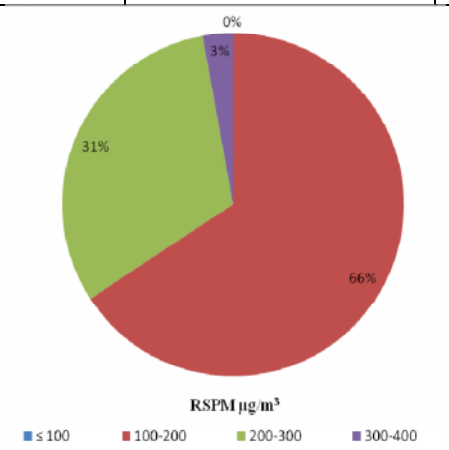


**Fig. 4.** RSPM levels and per cent share of samples in Jaipur city.

*C. Sulphur dioxide ($SO_2$)*

Sulphur di oxide in the ambient air causes irritation of the eyes, nose, throat and skin. Its irritant properties are caused due to the rapidity with which it forms sulfurous acid on contact with moist memebranes. Its prolonged exposure causes varied kinds of acute respiratory symptoms such as aggravated coughing inflammation of the respiratory tract etc.; having the above knowledge, it was considered important to study this air quality parameter and the results are presented in Table 3 and Fig. 6 and Fig. 7.

$SO_2$ levels in the ambient air of the study area ranged between 4.40-9.10 µg/m$^3$. It is observed fom the Table and Figure that half (51 per cent) the total number of monitored locations has $SO_2$ concentration level of 6.00-8.00 µg/m$^3$ while little more than two-fifth(43 per cent) locations have 4.00-6.00 µg/m$^3$ $SO_2$ concentration and the remainder locations has $SO_2$ levels more than 8.00 µg/m$^3$. The maximum $SO_2$ concentration is observed Near Riddhi Siddhi on Gopalpura Byepass and Railway Station, where the level of concentrations is 8.19µg/m$^3$, 9.10µg/m$^3$, respectively.

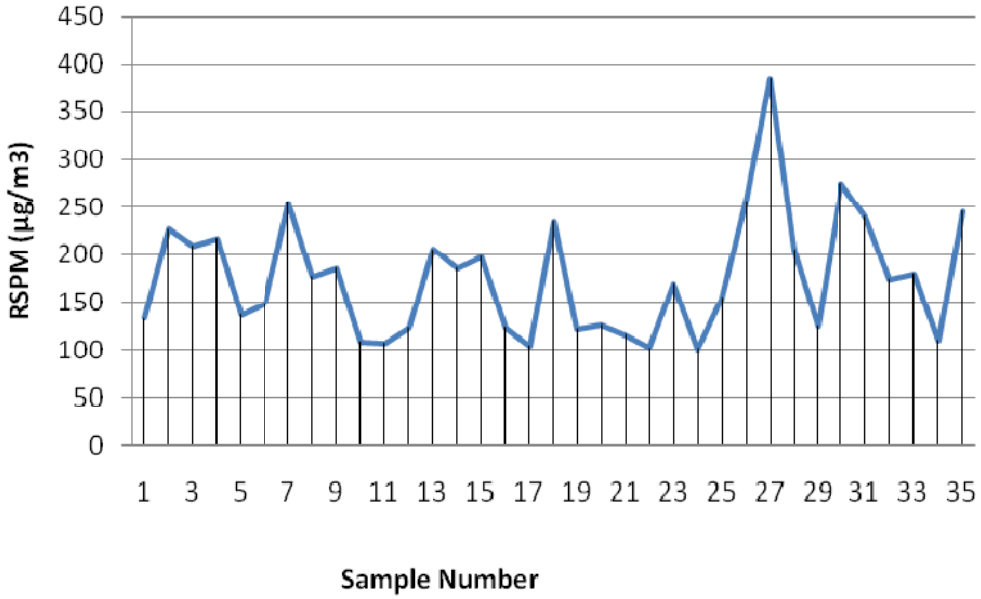


**Fig. 5.** Distribution of RSPM levels in Jaipur City.

**Table 2: Distribution of Sulphur dioxide ($SO_2$) Level in Jaipur City.**

| **Serial No.** | **RSPM µg/m$^3$** | **No. of Samples** | **Per cent Distribution** |
|---|---|---|---|
| 1 | 4.00-6,00 | 15 | 43 |
| 2 | 6.00-8.00 | 18 | 51 |
| 3 | 8.00-10.00 | 02 | 06 |
| **Total** | | **35** | **100** |

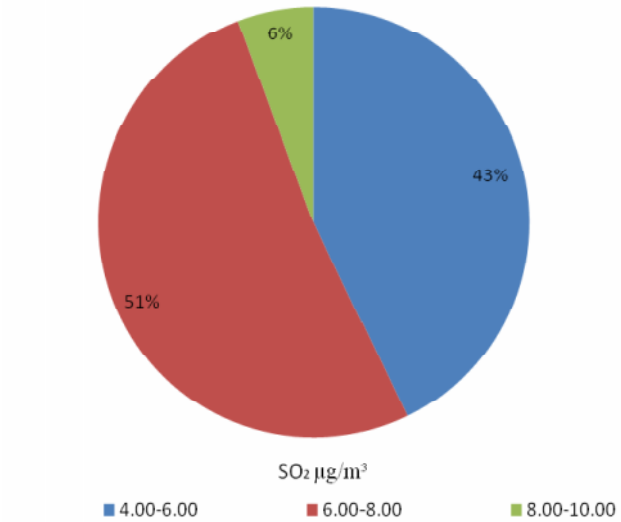


**Fig. 6.** $SO_2$ levels and per cent share of samples in Jaipur city.

*D. Nitrogen Oxides ($NO_X$)*

Nitrogen oxides are released to the air from the exhaust of motor vehicles and burning of fossil fuel. $NO_X$ reacts with ammonia, moisture and other copounds to form nitric acid vapor and related particles. It affects human body in numerous ways such as damage to lung tissues, respiratory diseases and aggravates heart disease. In the light of above facts, it was considered necessary to study this air quality parameter and the results are presented in Table 4 and Fig.8 and Fig. 9.

$NO_x$ levels in the ambient air of the study area ranged between 28.25-79.58 µg/m$^3$. It is observed from the Table and Figure that that half (51 per cent) the total number of monitored locations has $NO_x$ concentration level of 40.00 - 60.00 µg/m$^3$ while another two-fifth (40 per cent) locations have 20.00 - 40.00µg/m$^3$ $NO_x$ concentration and the remainder locations has $NO_x$ levels more than 60.00 µg/m$^3$. The maximum $NO_x$ concentration is observed Near Laxmi Mandir on and Gopalpura crossing, where the level of concentrations is 79.58 µg/m$^3$, 76.54µg/m$^3$, respectively.

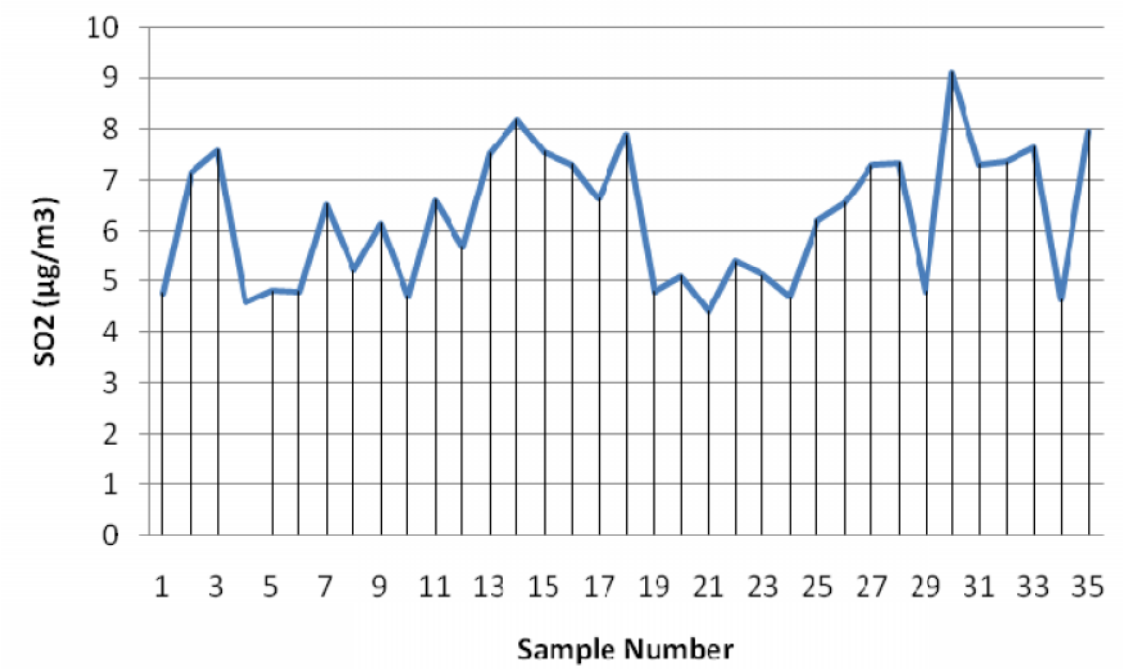


**Fig. 7.** Distribution of $SO_2$ levels in Jaipur City.

**Table 4: Distribution of Oxides of Nitrogen ($NO_x$) Level in Jaipur City.**

| **Serial No.** | **RSPM µg/m$^3$** | **No. of Samples** | **Per cent Distribution** |
|---|---|---|---|
| 1 | 20.00 - 40.00 | 14 | 40 |
| 2 | 40.00 - 60.00 | 18 | 51 |
| 3 | 60.00 - 80.00 | 03 | 09 |
| **Total** | | **35** | **100** |

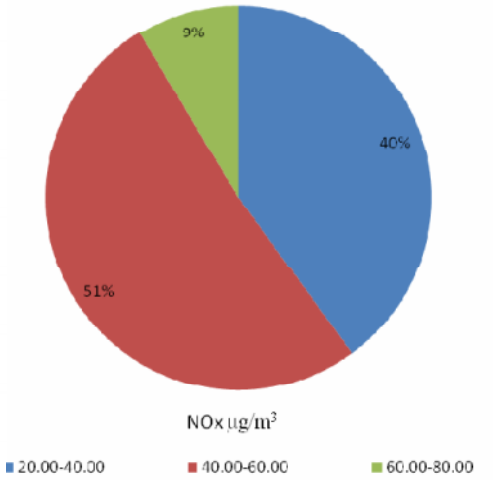


**Fig. 8.** $NO_x$ levels and per cent share of samples in Jaipur city.

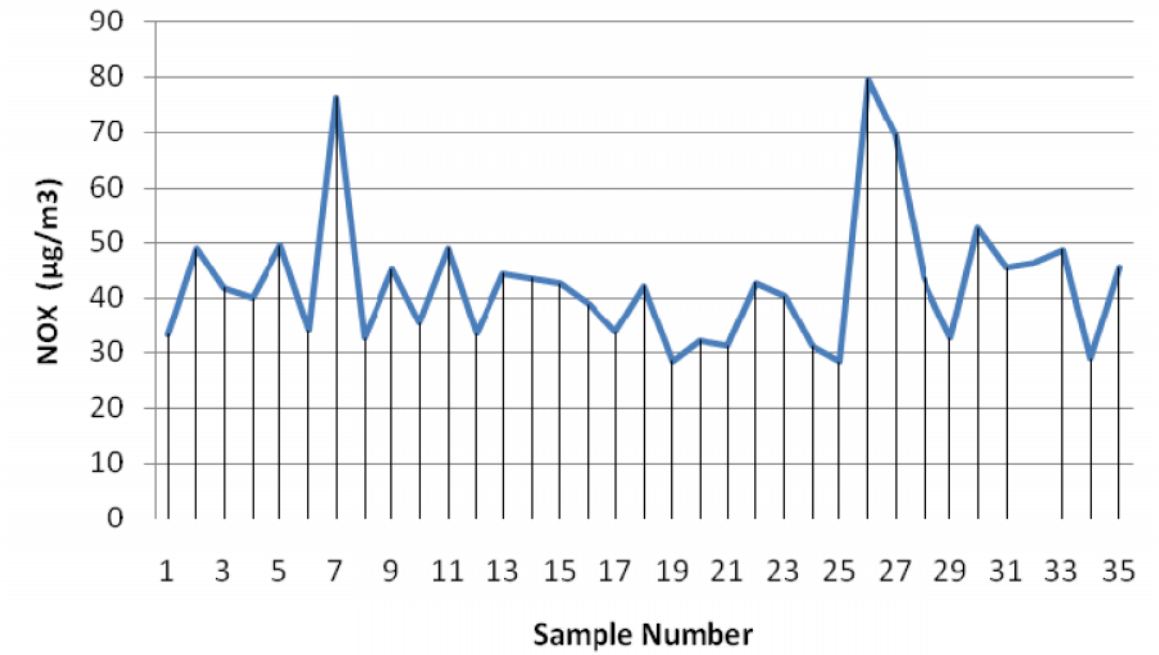


**Fig. 3.** Distribution of Oxides of Nitrogen (NOx) Level in Jaipur City.

Having analyzed the concentration of individual air pollutants, an attempt has further been made to compute air quality index of various locations in the study area and is presented in the subsequent section.

*E. Air Quality Index*

The cumulative effect of concentration of individual pollutants in ambient air is often expressed through a single value in the form of air quality index (AQI). The index has been computed by using the following equation (Anand, Ashish and Upendra Pandel, 2011):

AQI = $1/4\{(SPM_{actual}/SPM_{standard})+(RSPM_{actual}/RSPM_{standard})+(SO_{2\ actual}/SO_{2\ standard})+(SO_{2\ actual}/SO_{2\ standard})\}$ x 100

The AQI values so derived was divided into five categories (Rao and Rao 1989) i.e. 0 -25 = Clean Air, 26-50 = Light air pollution, 51-75 = Moderate air pollution, 76-100 = Heavy air pollution and the value above 100 signifies severe air pollution; and the results are presented in Table 5 and Fig. 10 and Fig. 11.

Computation results reveal that AQI values in the study area range from 58.38 to195.09. It is observed from the Table 5 and Figure 10 and Fig. 11 that all the locations have the air quality index values of more than 50 and the one-sixth (17 per cent) of the total number of locations have air quality index between 51-75 range, which indicates moderate air pollution, while three-tenth (31 per cent) locations have air quality index value between 76-100 range, which signifies the heavy air pollution in those locations. It is surprising to know that more than half (52 percent) of the total number of locations has index value above 100, which implies severe air pollution in those locations.

**Table 3: Range and Distribution of Air Quality in Jaipur City.**

| Serial No. | Range | Category | No.of location | Per cent Distribution |
|---|---|---|---|---|
| 1 | 0-25 | Clean air | 0 | 0 |
| 2 | 26-50 | Light air pollution | 0 | 0 |
| 3 | 51-75 | Moderate air pollution | 6 | 17 |
| 4 | 76-100 | Heavy air pollution | 11 | 31 |
| 5 | >100 | Severe air pollution | 18 | 52 |

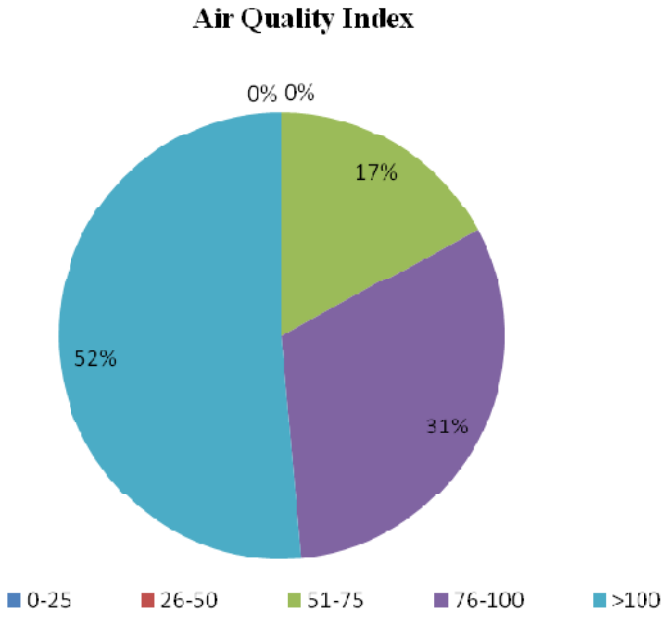


**Fig. 4.** Air Quality Index and per cent share of samples in Jaipur city.

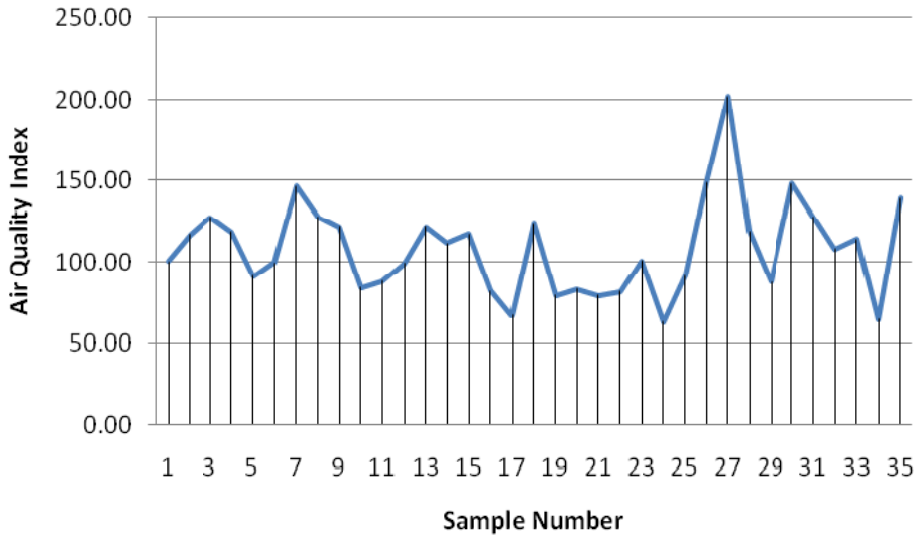


**Fig. 5:** Distribution of Air Quality in Jaipur City.

## IV. CONCLUSION

An attempt has been made in this investigation to ascertain air quality on major arterial roads of Jaipur city. Monitoring stations were set up at thirty five strategic locations on all arterial roads of the study area after gaining knowledge about their traffic characteristics and analyzed the air samples from various monitoring locations, the results are being compared with permissible standards as specified in Gazette of India Notification Extraordinary Part III, Section-4, Year 2009 and subsequently computed the air quality index. The results reveal that more than half the total numbers of locations have severe air pollution while another one-third (31 per cent) suffer from heavy air pollution. However, it is largely attributed to high SPM and RSPM levels. Nevertheless, study quantifies the pollution level arising due to growing number of vehicles, which is the predominant source of air pollution in the study area. It follows from the research that adequate pollution abatement measures coupled with vehicle retirement policy is essential to bring down pollution levels in the study area.

## APPENDIX-1

| COMPARATIVE STATEMENT OF AIR QUALITY RESULTS AT DIFFERENT LOCATIONS, JAIPUR CITY | | | | | | |
|---|---|---|---|---|---|---|
| S.No. | Place of Collection ↓ | RSPM | SPM | $SO_2$ | $NO_X$ | |
| | **Standard →** | **100 (µg/m3)** | **(Previously 200 µg/m3)** | **80 (µg/m3)** | **80 (µg/m3)** | **AQI** |
| 1 | OTS Crossing,J.L.N Marg | 133 | 440 | 4.77 | 33.26 | 100.13 |
| 2 | North-West side of Khanda Manak Chauk Bari Choupar | 227 | 336 | 7.14 | 48.78 | 116.23 |
| 3 | Police Booth Rambagh Circle | 210 | 477 | 7.58 | 41.84 | 127.57 |
| 4 | Mahila Hospital, Sanganeri Gate | 217 | 398 | 4.59 | 40.02 | 117.94 |
| 5 | Sanganeri Gate | 137 | 317 | 4.82 | 49.45 | 90.83 |
| 6 | Narayan singh circle | 149 | 401 | 4.81 | 34.01 | 99.51 |
| 7 | Gopal Pura crossing | 254 | 452 | 6.52 | 76.54 | 145.96 |
| 8 | New Sanganer Road Sodala | 177 | 572 | 5.21 | 32.49 | 127.53 |
| 9 | Chhoti Chaupur | 186 | 468 | 6.14 | 45.09 | 121.01 |
| 10 | Ram Nivas Garden | 109 | 354 | 4.72 | 35.51 | 84.07 |
| 11 | Maharao Shekha circle (Chomu Pulia) | 107 | 351 | 6.61 | 48.96 | 87.99 |
| 12 | 22 Godam (Jyotibaphoole circle) | 124 | 447 | 5.69 | 33.43 | 99.10 |
| 13 | After Bridge, Gopalpura Byepass, Jaipur (Raj.) | 206 | 426 | 7.52 | 44.40 | 121.03 |
| 14 | Near Riddhi Siddhi, Gopalpura Byepass, Jaipur (Raj.) | 186 | 389 | 8.19 | 43.58 | 111.39 |
| 15 | Near Gurjar ki Thadi, Gopalpura Byepass, Jaipur (Raj.) | 198 | 414 | 7.56 | 42.51 | 116.78 |
| 16 | Near B-2 Byepass, Near JVVNL Office, Jaipur (Raj.) | 124 | 292 | 7.30 | 38.94 | 81.87 |
| 17 | After Tonk Road Crossing, B-2 Byepass, Jaipur(Raj.) | 104 | 227 | 6.63 | 33.56 | 67.04 |
| 18 | Collectrate Circle, Jaipur | 235 | 390 | 7.90 | 42.10 | 123.13 |
| 19 | Shastri Nagar Circle, Near Kanwatiya Hospital, Jaipur. | 122 | 305 | 4.80 | 28.39 | 79.00 |
| 20 | Vaishali Nagar & Khatipura Intersection, Jaipur. | 127 | 318 | 5.10 | 32.10 | 83.13 |
| 21 | NBC Intersection, Jaipur. | 116 | 313 | 4.40 | 31.20 | 79.25 |
| 22 | Sanjay Circle, Jhotwara, Jaipur. | 102 | 330 | 5.40 | 42.69 | 81.78 |
| 23 | Subhash Chauk, Jaipur. | 170 | 352 | 5.12 | 40.18 | 100.66 |
| 24 | Nahari ka Naka, Jaipur. | 101 | 215 | 4.70 | 31.10 | 63.31 |
| 25 | Delhi Byepass, Jaipur. | 155 | 335 | 6.20 | 28.25 | 91.39 |
| 26 | Near Laxmi Mandir, Jaipur. | 256 | 458 | 6.54 | 79.58 | 148.16 |
| 27 | Transport Nagar Intersection, Jaipur. | 385 | 650 | 7.29 | 69.53 | 201.51 |
| 28 | Ajmerigate, Jaipur. | 205 | 410 | 7.34 | 43.78 | 118.48 |
| 29 | Statue Circle, Jaipur. | 125 | 356 | 4.80 | 32.50 | 87.41 |
| 30 | Railway Station, Jaipur. | 275 | 478 | 9.10 | 52.52 | 147.76 |
| 31 | Govt. Hostle, Jaipur. | 240 | 410 | 7.30 | 45.46 | 127.74 |
| 32 | After Sanganer Pulia,Jaipur. | 174 | 380 | 7.35 | 46.21 | 107.74 |
| 33 | Before Sanganer Pulia, Jaipur. | 180 | 408 | 7.64 | 48.74 | 113.62 |
| 34 | Intersection Phagi, Jaipur | 110 | 215 | 4.64 | 28.74 | 64.81 |
| 35 | Chandpole,Jaipur | 245 | 490 | 7.98 | 45.34 | 139.16 |

**ACKNOWLEDGEMENTS**

Authors are thankful to Central Pollution Control Board, New Delhi, India and Dr. D.N. Pandey, Member Secretary; Rajasthan State Pollution Control Board, Jaipur, Rajasthan, India.

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