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A GIS Based Approach for Assessment of Ambient Air Quality in Kota City

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Abstract—*This article investigates the local air pollution pattern in urban area of Kota city using geospatial techniques. Ambient air quality for sulfur dioxide (SO_2), nitrogen oxide (NO_X) and respirable suspended particulate matter (PM_{10}) was assessed in different wards of Kota city during 2005 to 2016. The outcome of the study has been presented in the form of Air Quality Index (AQI) to evaluate the spatial and temporal pattern of the pollutants. The seasonal variations for all three pollutants were compared and results imply that particulate pollutants are major contributor for air quality deterioration in Kota city. Seasonal variation results indicate that concentration was higher in winter season compared to summer. The spatio-temporal distribution of AQI clearly depicts the severe air pollution in the city and it was very high during winter (124.81) and summer (113.97) season of the year 2012. Results infer that air quality was highly deteriorated in ward 6 and 26, therefore proper policies should be implemented to control and manage the environmental deterioration.*

Keywords: *Air pollutants, Air Quality Index, GIS, Kota.*

1. INTRODUCTION

Industrial activities and rapid growth of urban populations has witnessed the deterioration in air quality of megacities of India. Several research studies [1],[2], [3], indicated the poor air quality in densely populated urban centers, due to high transportation activities [4], [5] and industrial development. The high concentration of air pollutants has worsened the human health [6], [7] and quality of life. The impact of gaseous and particulate pollutants on health varies with season hence; number of studies has reported seasonal variations in urban air quality [8], [9], [10], [11].

Presently, Kota city is also facing deterioration in environmental quality due to expanding urbanization, traffic congestion, poor control of industrial emission and increase in air pollution [12], [13], [14]. Therefore, local authorities and decision makers require the detailed and accurate information of urban air quality for sustainable development of the city. The conventional techniques are expensive and time consuming for the monitoring and assessment of ambient air quality, especially in developing countries. Geographic Information System (GIS) provides a flexible environment for entering digital data from various sources, and is a powerful tool [15], [16] in analyzing statistical relationships [17], [18] within and among the map layers. Therefore, in this research an attempt has been made to study the ward wise spatial distribution of air quality in Kota city for the period of 2005 to 2016 using GIS techniques. The main objective of this study is to evaluate the temporal and seasonal variation in concentration of air pollutants using three fixed monitoring stations of the Kota city.

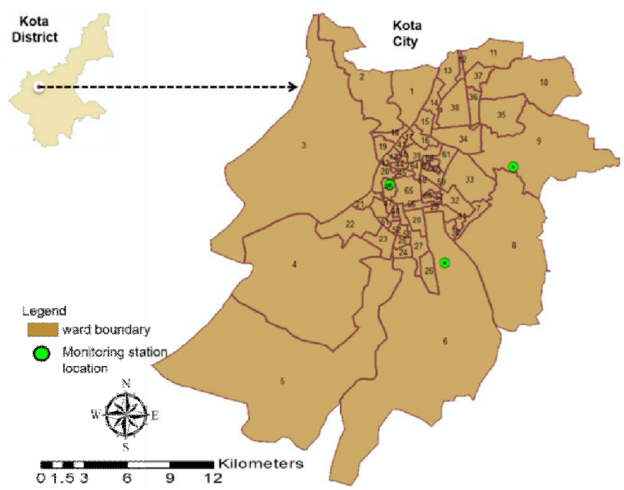

Fig. 1: Location map of the study area

2. DATA COLLECTION AND ANALYSIS

For the study area, the spatial data was first created within a geographical information system. The district boundary map of Kota and Kota ward boundary is created in GIS environment using ArcGIS 10.0 (ESRI software). The ambient air quality data was collected from Rajasthan State Pollution Control Board for 7 years (2010 to 2016) to give a comprehensive analysis of the air quality for Kota city under the national ambient air quality standards. The concentrations of air pollutants, sulfur dioxide (SO_2), nitrogen oxides (NO_X) and PM_{10} was collected from three fixed air quality monitoring stations (Table 1) of Kota city namely; Municipal Corporation Building, Regional Office, Anantpura and Samcore Glass Ltd. The location of these three air quality monitoring stations were plotted in Arc GIS software as shown in figure 1. On the basis of these three monitoring stations, the interpolated maps were generated for SO_2, NO_X and PM_{10} for summer (March to June) and winter season (November to February) during 2010 to 2016. Interpolation predicts the values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data [19].

Table 1: Ambient air quality monitoring sites

S. N.	Station Code	Station Name	Category
1	326	Municipal Corporation Building	Residential/Commercial
2	017	Regional Office, Anantpura	Residential/Commercial
3	325	Samcore Glass Ltd.	Industrial

The cumulative effect of concentration of individual pollutants in ambient air is investigated through Air Quality Index (AQI). AQI is a measure of the ratio of the pollutants concentration to the status of ambient air in different places and represents air quality status uniformly [20], [21]. AQI has been computed using following equation [22].

$$AQI = 1/3\ [{}_{actual}PM10\ /_{standard}PM10 + {}_{actual}SO2\ /_{standard}SO_2 + {}_{actual}NO_X\ /_{standard}NO_X\ ] \times 100 \qquad (1)$$

The AQI values so derived was divided into five categories 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.

3. RESULT AND DISCUSSION

3.1 Spatial and Temporal variations in ambient air quality

The ambient air quality pattern was evaluated for 65 wards of the Kota city using geospatial tools. The ambient air quality results indicate the higher **SO_2** Figure 2, 3 and table 2 represents the seasonal and temporal variations of SO_2 in different wards of Kota city. The results indicate that seasonal annual average concentration of SO_2 did not cross concentration of gaseous and particulate pollutants during winter and summer season (Dadhich et al. 2017a), therefore ambient air quality was evaluated for winter and summer season in different wards of Kota city.

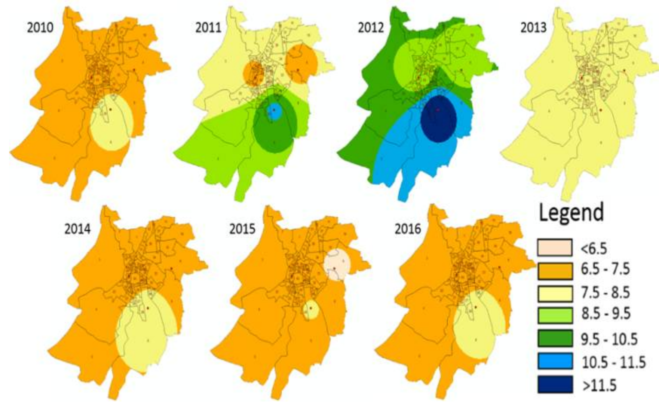

Fig. 2: Sulphur di oxide variations in winter season during 2010- 2016 (unit- µg/m^3)

Table 2: Concentration of SO_2 in Kota urban area

Winter	Min	Max	Mean	S.D.	Summer	Min	Max	Mean	S.D.
2010	6.71	7.89	7.15	0.22	2010	5.46	6.59	5.93	0.2
2011	7.12	10.75	8.46	0.68	2011	6.66	7.25	6.88	0.11
2012	8.92	12.53	10.21	0.68	2012	6.41	7.95	7.08	0.27
2013	7.5	8.37	7.92	0.15	2013	6.53	7.18	6.82	0.11
2014	6.54	8.08	7.23	0.27	2014	6.04	6.8	6.39	0.13
2015	6.39	7.59	6.88	0.21	2015	6	6.44	6.22	0.07
2016	6.59	7.94	7.21	0.22	2016	6.38	7.32	6.74	0.17

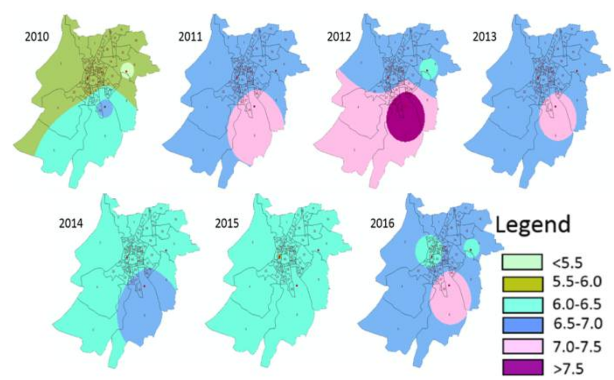

Fig. 3: Sulphur di oxide variations in summer season during 2010- 2016 (unit- µg/m^3)

the reference levels of 80µg/m^3 as prescribed by Central Pollution Control Board of India (CPCB). The spatial distribution of SO_2 (Figure 2 and 3) clearly indicates that in year 2012, SO_2 level was relatively high during both winter (10.21 µg/m^3) and summer (7.08 µg/m^3) season. The high level of SO_2 in ward 6 and 26 is due to the presence of several industries and their emission.

NOx From figure 4 and 5 it is elucidate that seasonal annual average concentration of NOx was also under the permissible limits as per CPCB and ranges between 32.49 µg/m^3 to 50.46 µg/m^{3}during winter season. Table 3 clearly indicates that high level of NOx was observed in winter season than summer season (up to 39.31 µg/m^3). The lower level of NOx in summer was due to the high wind speeds, resulting in dispersion of pollutants (Meena et al., 2012).

Table 3: Concentration of NOx in Kota urban area

Winter	Min	Max	Mean	S.D.	Summer	Min	Max	Mean	S.D.
2010	33.6	41.92	37.96	1.41	**2010**	21.59	24.54	22.82	0.52
2011	37.55	44.2	40.97	1.13	**2011**	27.8	32.2	29.7	0.74
2012	45.65	50.46	47.79	0.84	**2012**	24.35	26.57	25.25	0.39
2013	44.59	48.76	46.17	0.77	**2013**	31.1	34.1	32.29	0.53
2014	33.96	38.05	35.43	0.77	**2014**	33.11	36.82	34.95	0.61
2015	32.49	39.73	36.02	1.18	**2015**	31.55	35.3	33.46	0.61
2016	35.8	40.07	38.14	0.72	**2016**	37.27	39.31	38.35	0.34

PM_{10}Table 4 and figure 6, 7 represent the seasonal and temporal variations of respirable suspended particulate matter in different wards of Kota urban area. Results imply that seasonal annual average of PM_{10} was higher as per standard (100 µg/m^3) set by CPCB during the study period.

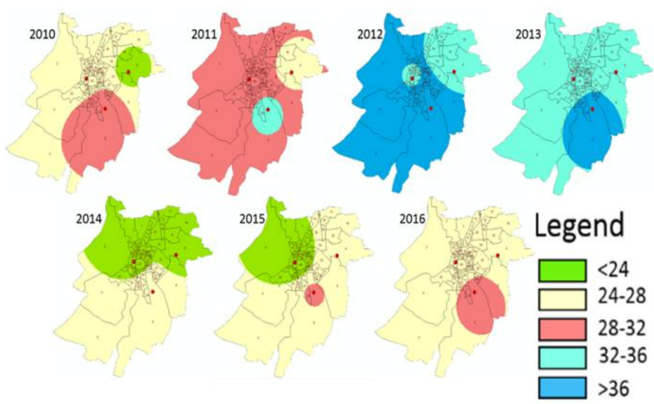

Fig. 4: Nitrogen oxide variations in winter season during 2010-2016 (unit- µg/m^3)

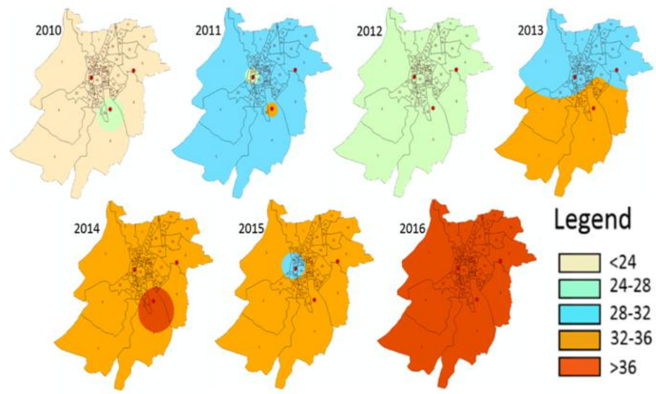

Fig. 5: Nitrogen oxide variations in summer season during 2010-2016 (unit- µg/m^3)

Table 4: Concentration of PM_{10} in Kota urban area

Winter	Min	Max	Mean	S.D.	Summer	Min	Max	Mean	S.D.
2010	149.4	177.2	160.8	4.93	**2010**	142.3	185.6	159.4	7.87
2011	167.3	229.7	192.9	10.81	**2011**	139.4	180.1	155.9	7.28
2012	177.5	211.8	191.2	6.17	**2012**	172.8	209.7	187.5	6.52
2013	142.3	218.9	174.4	13.12	**2013**	121.5	179.2	147.4	9.97
2014	148.8	206.9	171.6	10.32	**2014**	113.0	158.7	133.6	7.59
2015	174.3	212.8	188.3	7.24	**2015**	114.9	133.6	125.8	3.27
2016	150.6	207.0	174.7	9.56	**2016**	127.0	180.6	147.2	9.81

The high concentration of PM_{10} in all wards of the city was due to the transportation activities and industrial emission (Sandhu et al. 2004, Dadhich et al. 2017a). Seasonal and spatial variations indicate that the PM_{10} concentration was found to be much higher in industrial area (ward 6 and 26) during winter (229.73 µg/m^3) and summer (209.77 µg/m^3) in comparison to other wards of the city.

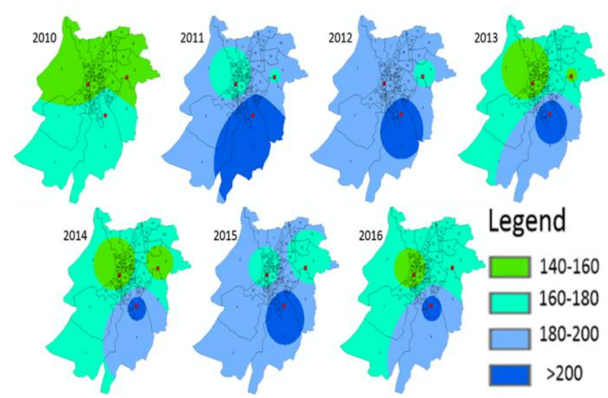

Fig. 6: Respirable particulate matter variations in winter season during 2010- 2016 (unit- µg/m^3)

Another reason for high concentration of PM_{10} in southern part of Kota city is the presence of barren land (Dadhich et al. 2017b), which leads to rise in PM_{10} levels.

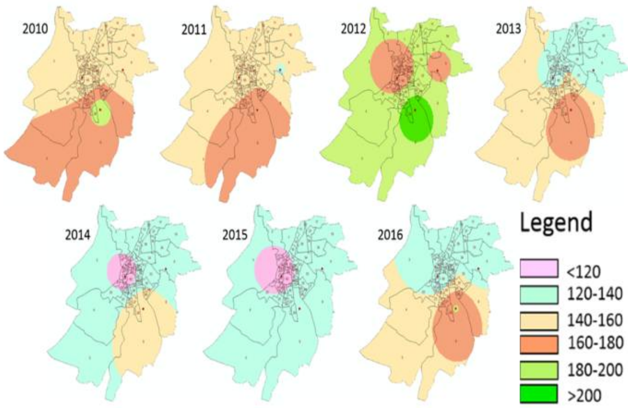

Fig. 7: Respirable particulate matter variations in summer season during 2010- 2016 (unit- µg/m^3)

3.2 Air Quality Index Assessment

The AQI was evaluated for winter and summer season in different wards of Kota city. AQI values (Table 5) indicates the status of ambient air during 2010 to 2016. The higher the AQI value, greater is the level of air pollution and greater the damage to health (Zlauddin and Siddiqui 2006, Joshi and Semwal 2011). The ward-wise spatial and temporal distribution of AQI is shown in figure 8 (winter season) and figure 9 (summer season) for the study period. It is observed that ambient air quality of Kota city varies from moderate to severe air pollution category during winter (minimum 69.39, maximum 124.81) and summer (minimum 60.52, maximum 113.97) season. All the wards of Kota urban area indicate heavy to severe air pollution from 2010 to 2015, however, low level of AQI was observed in year 2016 during winter and summer season except in industrial area.

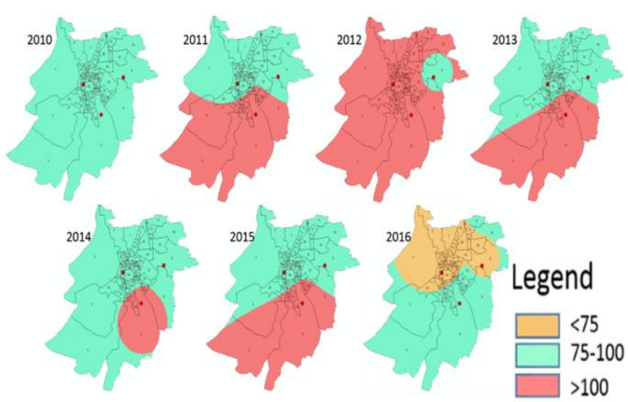

Fig. 8: Air Quality Index variations in winter season during 2010-2016

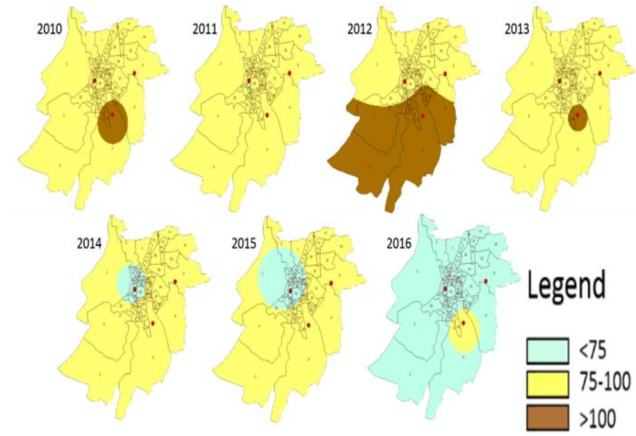

Fig. 9: Air Quality Index variations in summer season during 2010- 2016

Table 5: Ambient air quality index (AQI) values during the study period (2010-2016)

Winter	Min	Max	Mean	S.D.	Summer	Min	Max	Mean	S.D.
2010	77.9	98.3	87.2	3.5	2010	85.4	104.5	93.1	3.4
2011	89.7	121.9	102.4	5.9	2011	75.9	97.4	85.7	3.7
2012	96.4	124.8	108.9	4.9	2012	94.1	113.9	101.1	3.7
2013	85.1	121.6	99.6	6.5	2013	76.6	102.8	88.7	4.5
2014	79.4	113.3	91.8	6.3	2014	71.3	96.3	82.2	4.2
2015	89.7	116.6	99.4	5.1	2015	70.4	88.4	78.8	2.9
2016	69.3	89.1	77.6	3.3	2016	60.5	79.6	67.8	3.4

*Remarks: min-minimum, max-maximum, S.D.- standard deviation

4. CONCLUSIONS

The seasonal and temporal variations in ambient air quality of Kota city, clearly reveals that air quality was worst during the study period (2010 to 2016) in all the wards of the city. Results infer that gaseous pollutants viz. SO_2 and NOx were below the National Ambient Air quality Standard limit, however, particulate pollutant concentration was too high in all the wards of the city. The spatial distribution of AQI reveals that air quality of Kota urban area is affected by severe air pollution, especially the industrial area i.e. ward 6 and 26 is most influenced due to high industrial emission in area. The study also demonstrates that geospatial techniques are very effective in examining the spatial pattern and temporal changes of ambient air quality of the city. This study provides sound scientific basis for urban planners and decision makers to effectively manage air quality for health and environmental purposes.

5. ACKNOWLEDGEMENT

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