Analysis and Effects of Air Pollutants on Proposed Smart Cities of Rajasthan

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Abstract— The automobile sector plays a very important role in smart city concept. The increasing vehicle population and increased driving distances have led to serious air pollutions levels, particularly in Rajasthan. The overall emission of air pollutants like PM2.5, PM10, NOx, SOx, etc adversely affects the human health. So there is an absolute necessitity to calculate the concentration and AQI levels through the mathematical formulas through mobile app in Rajasthan RajVayu app launch by Govt. of Rajasthan has been used for this purpose and current status month wise and year wise of Jaipur and Jodhpur are compared. Through this comparison it is observed that the air pollutants level in the Jodhpur are higher than Jaipur city and once we calculate the AQI levels as well as their respective concentrations in the atmosphere we can take the remedial measures to reduce it so that the people residing in these cities will be protected with the hazardous effects of the air pollutants.

Key words: AQI , Air pollutants, Smart City, PM10, PM2.5, RajVayu App

I. INTRODUCTION

The government of India has listed 20 cities of India which are proposed to be building up as Smart City. Out of 20 cities, 2 cities of Rajasthan i.e Jaipur and Udaipur are among them. There are several factors which altogether work and are interrelated with each other in order to convert a city into smart city. Some of these factors are Mobility, Telecommunication, Special Economic Zones, Green Buildings, Solar power generation, Smart Buildings etc. Among them mobility plays a very important role in today's scenario because the major development of cities is dependent on city transportation system.[1] So, automobile sector is directly connected to the smart city concept and therefore the development of any city cannot be imagined without the positive contribution of an automobile sector.

Fig. 1: Different areas for smart city concept

The increasing size of urban areas, increasing vehicle population and increased driving distances have led to serious pollution levels of various cities of Rajasthan. The overall emission of air pollutants like NO_X, SO_X, PM2.5, PM10 etc. Can lead to smog, general public health problems and these harmful pollutants can be calculated by AQI known as Air Quality Index.[3]

II. CONCEPT OF AQI AND ITS CATEGORIES

AQI is a number which represents the level of air pollution area by numerically calculated the relative concentration of various pollutants and its health effects. AQI is a rating scale ranging from 0-500+ used for reporting the quality of air we breathe in and the associated health effects.
There are six AQI categories, which are tabulated as follows:

Sr.No.	Category Description	AQI Value	Health Advisory
1.	Good+ Satisfactory	0-100	No cautionary action required
2.	Moderate	101-200	Unusally sensitive people should consider reducing prolonged or heavy exertions and heavy outdoor work.
3.	Poor	210-300	People with heart or lung disease, older adults and children should reduce prolonged or heavy exertions.
4.	Very Poor	301-400	People with heart or lung disease, older adults and children should avoid prolonged or heavy exertions.
5.	Severe	401-above	Everyone should avoid all physical activities outdoors. People with heart or lung disease, older adults and children should remain indoors. Keep activities level low.

Table 1: AQI categories and its values

A. Air quality index calculations

First we have to find concentration of particular pollutant in µg/m^3, after knowing the concentration of particular pollutant in µg/m^3 (except for CO), we can find out AQI value from AQI to concentration calculator vice versa which is available online. Along with this information of concentration one can get the information regarding health effects statements and cautionary statements so that we can take preventive actions regarding the issues mg/m^3 dealt. [5]

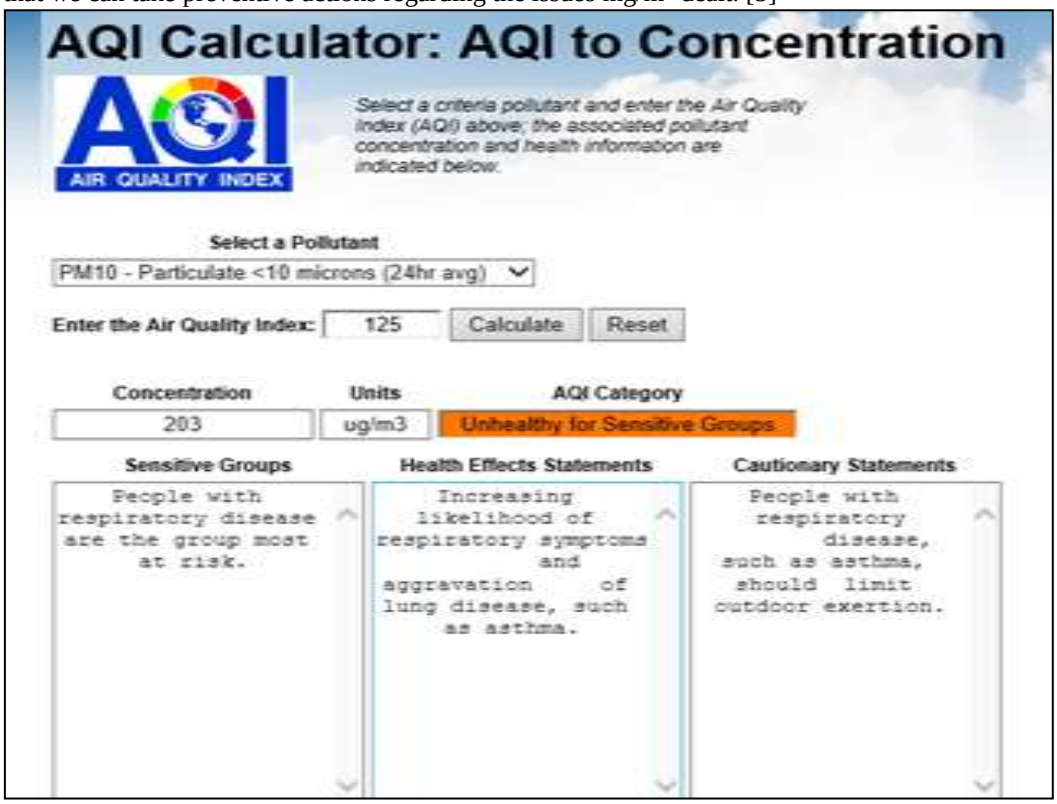

Fig. 2: AQI calculator

III. MATHEMATICAL CALCULATION OF AIR POLLUTANTS CONCENTRATION

The amount of pollution in the air, however sampled, is usually measured by its concentration in air. The concentration of a pollutant in air may be defined in terms of the proportion of the total volume that it accounts for. Concentrations of pollutant gases in the atmosphere are usually measured in parts per million by volume (ppmv), parts per billion by volume (ppbv) or parts per trillion (million million) by volume (pptv). Pollutant concentrations are also measured by the weight of pollutant within a standard volume of air, for example microgrammes per cubic metre (µgm^{-3}) or milligrammes per cubic metre (mgm^{-3}).

Active sampling methods use physical or chemical methods to collect polluted air, and analysis is carried out later in the laboratory. Typically, a known volume of air is pumped through a collector (such as a filter, or a chemical solution) for a known period of time. The collector is later removed for analysis. Samples can be collected daily, providing measurements for short time periods. Conversion shown below gives the relationship between concentration of pollutants from parts per million by volume (ppmv) to microgrammes per cubic metre (µgm^{-3}) or milligrammes per cubic metre (mgm^{-3}).

$$ppmv = mg/m^3 * (0.08205-T)/M \text{ and}$$

$$mg/m^3 = ppmv * M/(0.08205-T) \quad \text{.....(1)}$$

Where:
mg/m^3=milligrams of pollutant per cubic meter of air at sea level atmospheric pressure and T
ppmv=air pollutant concentration, in parts per million by volume
T= ambient temperature in K=273.15+ °C..... (2)
0.08205=universal gas constant in $atm.m^3/(kmol*k)$
M=molecular weight of the air pollutant

IV. MATHEMATICAL CALCULATION OF AQI

The AQI is a piecewise linear function of pollutant concentration. To convert from concentration to AQI this equation is used:

$$I=\{I_{high}-I_{low} / C_{high}-C_{low}\} * (C-C_{low})+I_{low}.....(3)$$

Where:
I=The Air quality index
C=The pollutant concentration
C_{high}=The concentration breakpoint that is≤C
C_{low}= The concentration breakpoint that is≥C
I_{high}=The index breakpoint corresponding to C_{high}
I_{low}= The index breakpoint corresponding to C_{low}

$PM_{2.5}(\mu g/m^3)$	$PM_{10}(\mu g/m^3)$	CO(ppm)	SO_2(ppm)	NO_2(ppm)	AQI	AQI
C_{low}-C_{high}(avg)	C_{low}-C_{high}(avg)	C_{low}-C_{high}(avg)	C_{low}-C_{high}(avg)	C_{low}-C_{high}(avg)	I_{low}-I_{high}	Category
0.0-12.0	0-54	0.0-4.4	0-35	0-53	0-50	Good
12.1-35.4	55-154	4.5-9.4	36-75	54-100	51-100	Moderate
35.5-55.4	155-254	9.5-12.4	76-185	101-360	101-150	Unhealthy for sensitive groups
55.5-150.4	255-354	12.5-15.4	186-304	361-649	151-200	Unhealthy
150.5-250.4	355-424	15.5-30.4	305-604	650-1249	201-300	Very unhealthy
250.5-350.4	425-504	30.5-40.4	605-804	1250-1649	301-400	hazardous
350.5-500.4	505-604	40.5-50.4	805-1004	1650-2049	401-500	hazardous

Table 2:Concentration and Index breakpoint range reference table

A. Illustration of how to calculate AQI index

Pollutant: PM_{10} Concentration of PM_{10}: 203($\mu g/m^3$) [calculated from instruments]
For the corresponding values of given concentration, concentration and Index breakpoint values are taken from table 2
C_{high}= 254($\mu g/m^3$) C_{low}= 155($\mu g/m^3$)
I_{high}= 150 (from AQI range) I_{low}= 101(from AQI range)
$I=\{I_{high}-I_{low} / C_{high}-C_{low}\} * (C-C_{low})+I_{low}$ from eq^n (3)
I= {150-101/254-155}*(203-155) +101
I= {49/99}*(48) +101
I= 24+101= 125
Hence, the value of AQI is 125 which is equals to the one which is calculated by AQI calculator online.

AQI Category (Range)	PM_{10} (24hr)	$PM_{2.5}$ (24hr)	NO_2 (24hr)	O_3 (8hr)	CO (8hr)	SO_2 (24hr)	NH_3 (24hr)	Pb (24hr)
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.5-1.0
Moderately polluted (101-200)	101-250	61-90	81-180	101-168	2.1-10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748	17-34	801-1600	1200-1800	3.1-3.5
Severe (401-500)	430+	250+	400+	748+	34+	1600+	1800+	3.5+

Source: RajVayu App of Govt.Of Rajasthan
Table 3: AQI category, pollutant and health breakpoints

The colours of table 3 have particular significance related to the intensity of various air pollutants. In terms of air pollution PM 2.5, is associated with more serious health impacts than PM 10. It consists of fine, particulate pollution which damages respiratory system more intensely than PM 10 which have coarse pollution particles.

B. Current scenario of pollution in selected cities as smart cities of rajasthan

Among the most polluted cities in the world, Rajasthan has five in the list hinting at the deteriorating air quality in the state. According to World Health Organization's (WHO) urban air quality database released on Thursday, Jodhpur ranks 30th most

polluted city in the world followed by Jaipur at 33rd position. Apart from two, Kota (58), Udaipur (59) and Alwar (61) are also among the polluted cities in the world. Air quality of 3,000 cities in 103 countries were surveyed by the WHO and is based on ground measurements of annual mean concentrations of particulate matter (PM 10 and PM 2.5). Out of 122 cities in India where air pollution data was measured, Jodhpur recorded 101 micrograms per cubic meter as its annual PM 2.5 mean and is 13th most polluted. Jaipur with 100 micrograms per cubic meter is 15th in the country. Both cities annual mean is about 10 times the WHO standard of 10 micrograms per cubic meters. Including Kota, Udaipur and Alwar, Rajasthan has five cities in the top 25 populated cities in the country. In terms of air pollution PM 2.5, is associated with more serious health impacts than PM 10. It consists of fine, particulate pollution which damages respiratory system more intensely than PM 10 which have coarse pollution particles. Jaipur: Among the most polluted cities in the world, Rajasthan has five in the list hinting at the deteriorating air quality in the state. Including Kota, Udaipur and Alwar, Rajasthan has five cities in the top 25 populated cities in the country.

C. Government initiatives for pollution control and measurement in rajasthan

On the eve of World Environment Day 2016, Chief Minister Smt. Vasundhara Raje lauched a mobile app RajVayu for sharing of information about air quality index of three cities of Jaipur, Jodhpur and Udaipur. Another app 'Drishti' for monitoring of pollution levels in industrial regions was also launched on this occasion. App RajVayu is based on the data collected by sophisticated air quality monitoring equipments and weather sensors. It would share details about the air quality, such as levels of pollutants likes Particulate Matter, SOx, NOx, CO, Ozone particles with the city residents and tourists.

On this occasion, the CM said that to ensure participation of common man and particularly youth in pollution control and environment conservation, such apps should be made more interactive and interesting by installing gaming features. RajVayu app has been designed by RSPCB with the help of Indian Institute of Tropical Meteorology of the Ministry of Earth Sciences and UNICEF Rajasthan. Drishti has been designed by the RSPCB with the support from RajComp.

D. CURRENT STATUS OF EMISSION POLLUTANTS IN RAJASTHAN'S MAJOR CITIES

As discussed earlier that for smart city concept the pollution is the biggest problem directly or indirectly it is making us restricted to achieve our goal ,so it necessary to understand the current scenario of the emission in cities and in support to this we have shown below the graphical comparisons of Jaipur nad Jodhpur city.

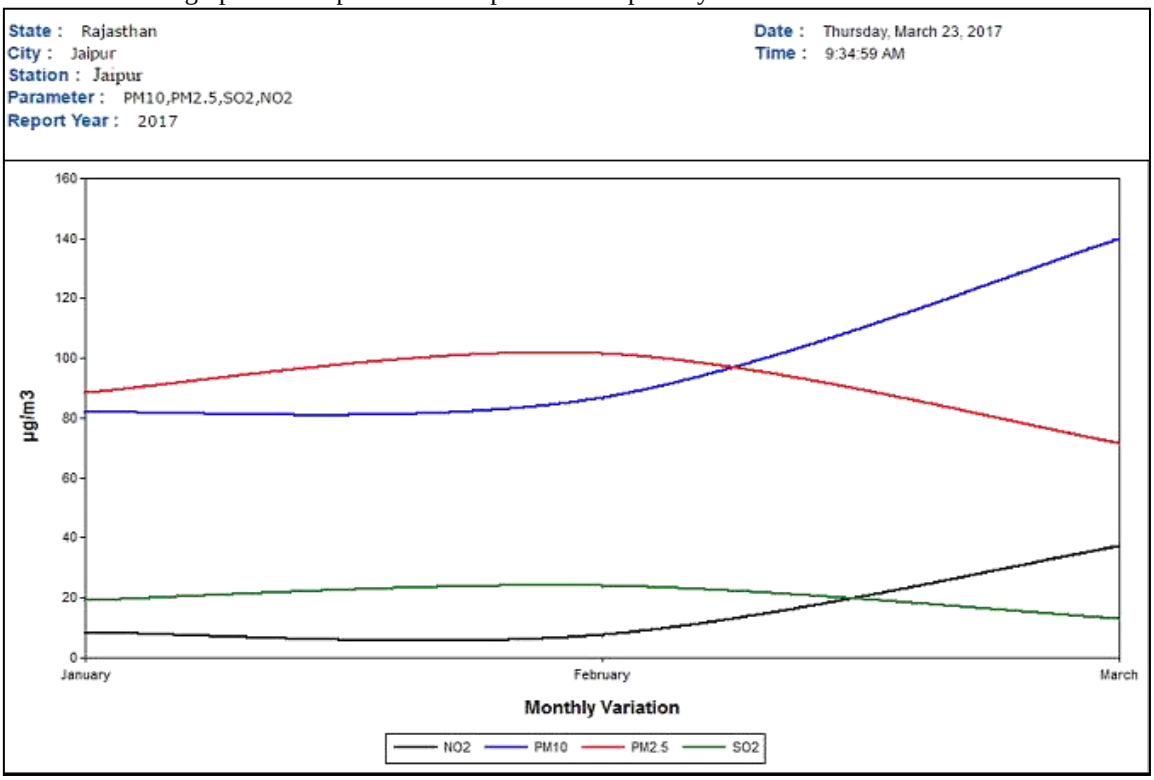

Fig. 3 Monthly variation of emission pollutants for Jaipur city (Source: CPCB,Delhi)

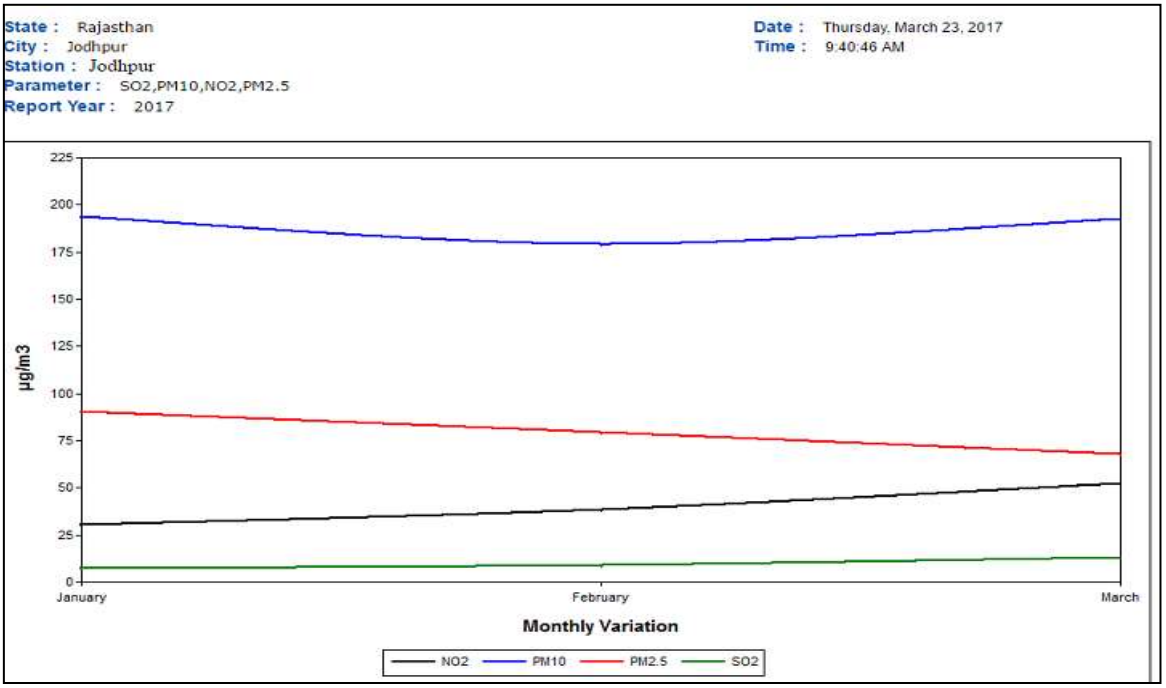

Fig. 3: Monthly variation of emission pollutants for Jodhpur city (Source: CPCB,Delhi)

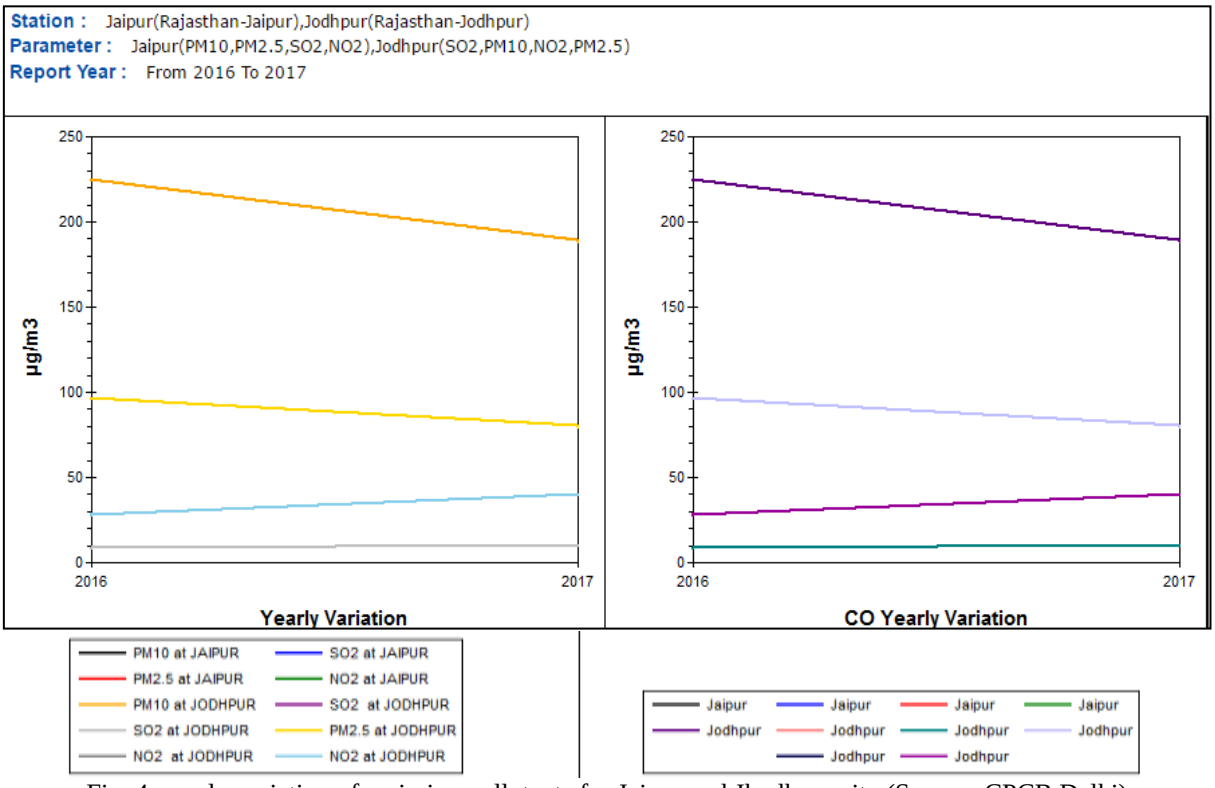

Fig. 4: yearly variation of emission pollutants for Jaipur and Jhodhpur city (Source: CPCB,Delhi)

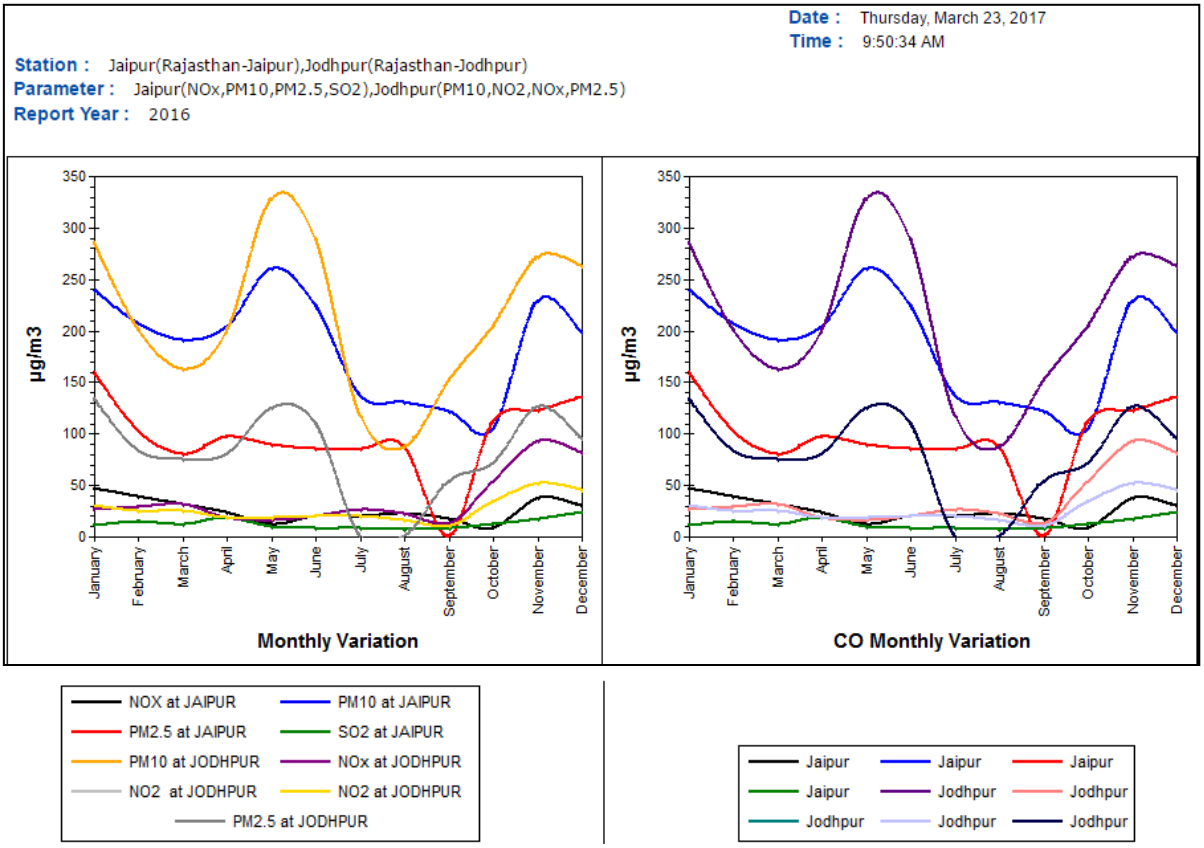

Fig. 5: (yearly month-wise) variation of emission pollutants for Jaipur and Jhodhpur city (Source: CPCB,Delhi)

V. COMPARISON CHARTS FOR EMISSION POLLUTANTS BY DIFFERENT SOURCES (IN PERCENTAGE)

As we can see in fig.6 and fig.7 the major pollutants PM10, CO, PM2.5 have major percentage and the sources are transportation and road dust, so mobility is directly connected to pollution of the city and it should be controlled to make our city as smart city.

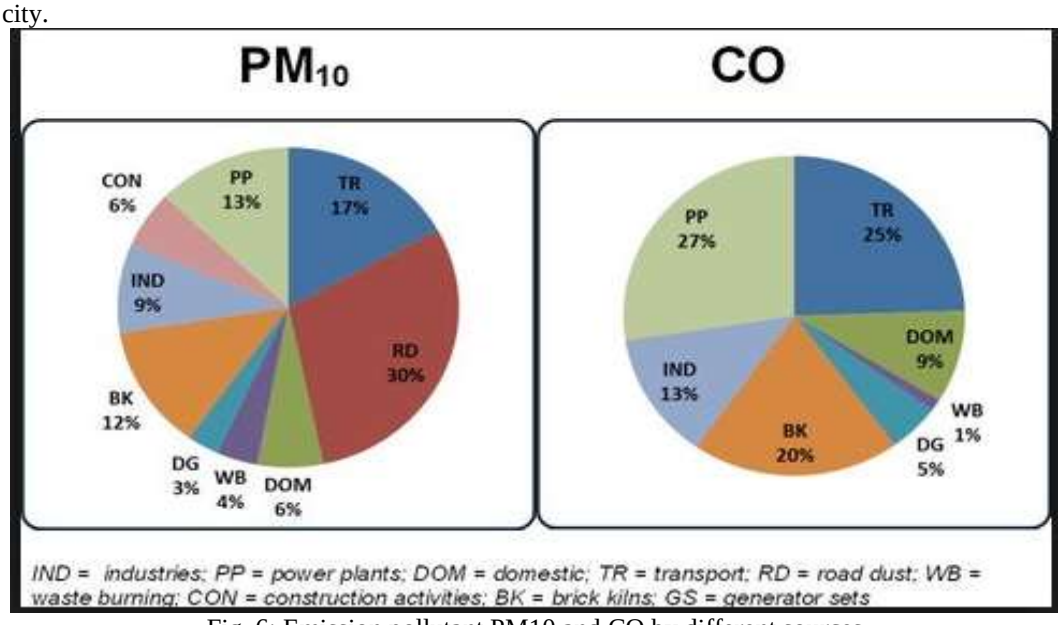

Fig. 6: Emission pollutant PM10 and CO by different sources

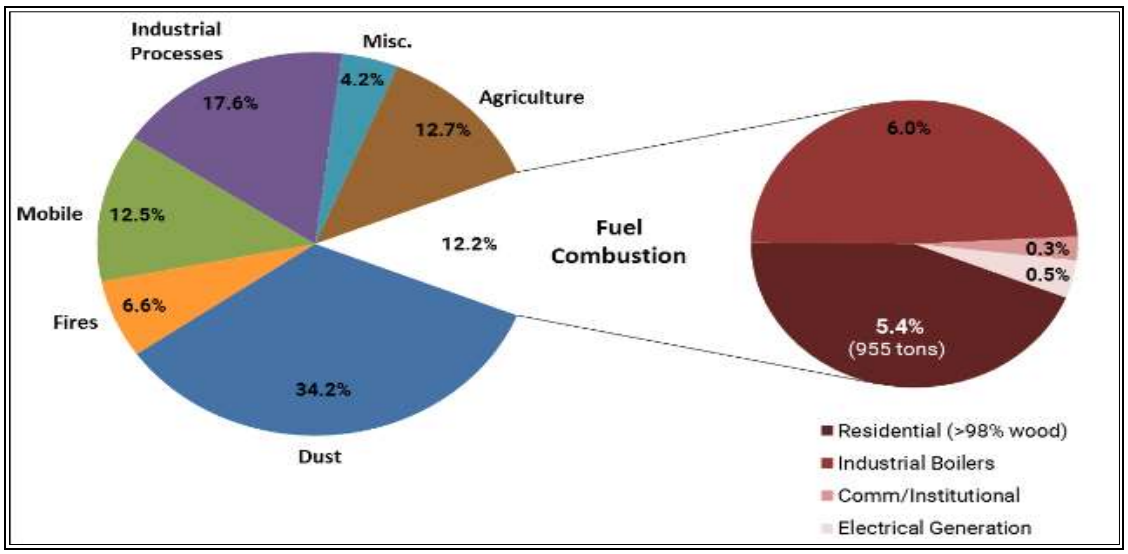

Fig. 7: Emission pollutant PM 2.5 by different sources

VI. CONCLUSION

Based on the above observations and graphical analysis the following conclusions can be drawn:

The major air pollutants which are harmful for the people of Rajasthan can also be easily viewed by common people through RajVayu App, but this app is limited only to direct representation of AQI number and its effects on health. The app is unable to show the particular concentration levels of harmful air pollutants that have the health hazardous effects which are directly related to common people of the city.

Because, once we know the concentrations of NO_X, SO_X, PM10, PM2.5 etc we can take the necessary action regarding health. As we know that PM2.5 is directly related to vehicle exhaust emissions, PM10 emissions originate from non-exhaust emissions one can easily take corrective and preventive actions regarding reduction of these pollutants which majorly comes from automobile sector.

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