



# Monthly And Seasonal Analysis Of Particulate Matter Over Major Cities Of Rajasthan

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## Abstract

The major cities of Rajasthan and that is western part of India has different identity and surrounded by arawali ranges and desert. The cities including Udaipur, Jaipur, Jodhpur, Ajmer, Pali, Bhiwadi, Alwar and Kota on world map due to tourist attraction. In past four-year 2019 to 2022 the particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>) indicate an upsetting ever-increasing trend due to rapid increasing industry. The average level of PM<sub>2.5</sub> in Jodhpur and Bhiwadi crosses the NAAQS set by India for 2019 to 2022 and the value of PM<sub>10</sub> also crosses national ambient air quality standard for Bhiwadi, Jodhpur (2019 to 2022), Jaipur, Kota, Pali, and Udaipur in the year of 2019, 2021, 2022. Special in Bhiwadi, PM<sub>2.5</sub>(110.83 $\mu\text{gm}^{-3}$ ) and PM<sub>10</sub>(230.66 $\mu\text{gm}^{-3}$ ) in 2021. The mass concentration of PM<sub>2.5</sub> and PM<sub>10</sub> is most dangerous for our respiratory system and health.

**Keywords:** Air Quality, NAAQS, Atmosphere

## Introduction

Atmosphere consists the layer of gases. When the change in mixture of gases by addition of particle atmosphere becomes pollute. Atmospheric particles are the one of the most factor of urban air pollution. Urban air make the serious health effect by the region of atmospheric particle (Harrison & Yin, 2000; Seaton et al., 1995). Particle pollution consist PM<sub>10</sub> is the particle with diameter of 10 micrometers. And PM<sub>2.5</sub> is fine particle with the diameter of 2.5 micrometer and smaller. It has major impact on human health (Hall, 1996). Particulate matter is the mixture of large and small particle of chemical composition. Particulate matters (PM) are emitted by smokestacks, fires, construction sites and unpaved roads. In 10 micrometers diameter size has some particles and it can get deep into our bloodstream and lungs. And 2.5 micrometer diameter size of fine particle PM<sub>2.5</sub> is the most danger to health (R. Kumar & Joseph, 2006). All the parameter of atmosphere affected trends and variability by these major factors (Elminir, 2005). The two major factors of pollution at any location are condition of meteorological and emission of pollution. In the major cities of Rajasthan industries, factories and large number of vehicles increases very fast in recent time due to fast industrialization and urbanization. Hence as result of these Udaipur and different part of Rajasthan undergoes the serious problem of air pollution (Chang et al., 2011). It is the case of concern that a big portion of population is exposed to unhealthy levels of pollution in Udaipur. The particulate pollutants make the impact on health with season, it means seasonality is a factor for determine the pollution in lower atmosphere (Balogun & Orimoogunje, 2015). For urban air quality many studies reported seasonal variations

(Chen et al., 2015; Karar & Gupta, 2006; Kulshrestha et al., 2009), so considerable effort required to devoted to this issue because of the local environment conditions are still poorly understood.

There was a reduction during the COVID-19 lockdown, by 16–50% in PM<sub>2.5</sub> and by 22–47% in PM<sub>10</sub> (Yadav et al., 2022). India was pummelled on seventeenth May 2021 by the strongest storm on record to arrive at its west coast, hampering specialists' reaction to the Covid-19 (Pandya et al., 2021). U Pandya suggest that during lockdown, pollution level was declined but before Diwali pollution was rice up. During Diwali time pollution level was also declined (U Pandya Joshi E, 2020).

Jaipur, Jodhpur, Kota, Alwar, Pali, Ajmer, Udaipur and Bhiwadi are the fastest developing cities of Rajasthan (India). These cities are located in the northwest part of India has a special significance on world map it attracts millions of national and international tourists due to natural beauty, forts and glory of history, especially during winter season which demands pure environment.

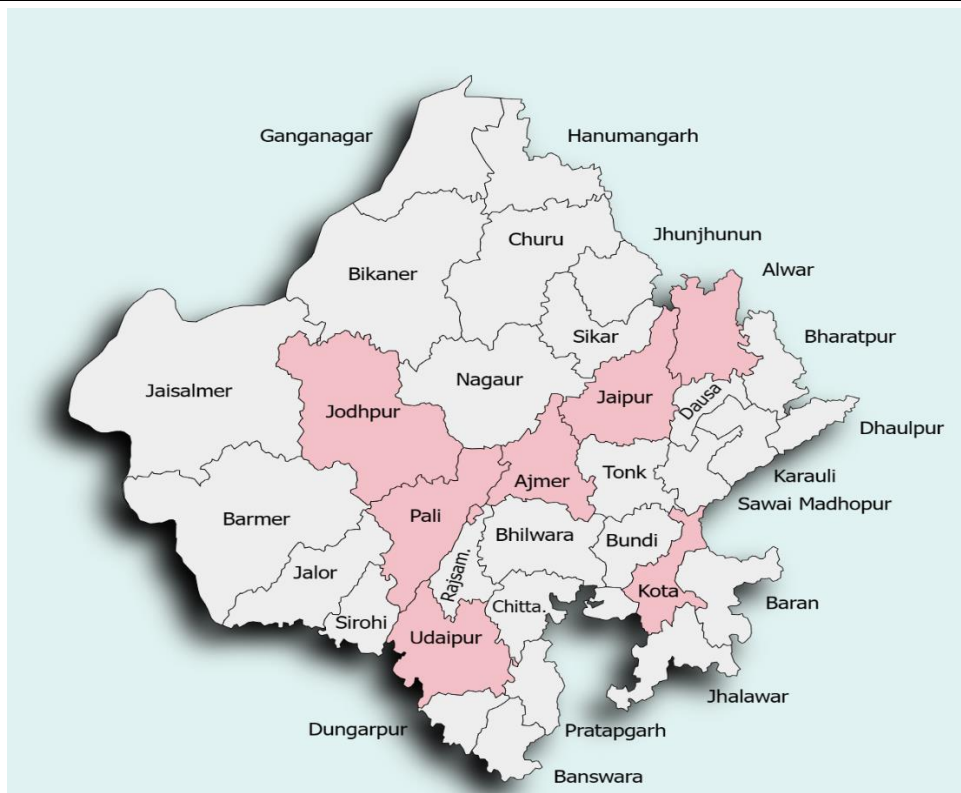
In the current paper made to study the spatial distribution of air quality in the different part of Rajasthan for the period of 2019 - 2022.

The main intention of this study to find seasonal and temporal variation in concentration of air pollutants using eight cities of Rajasthan and analyze the relationship between meteorological parameters and air quality,

## Materials and Methods

### Site description

India s largest state Rajasthan located in the north western part of India map (Fig.1). Rajasthan has area about 3.4 km<sup>2</sup> (maps of India 2011) with E-longitude 69° 3' to 78° and N-latitude 23° 31' to 30° 12'. Rajasthan has mainly an agricultural economy but now in the recent year other industries like cement, handicraft, marbles, It, chemical plants, textiles, steel and thermal power plants are flourish very fast and playing a important role in providing employment and generating income. Mainly the industries has Jaipur, Jodhpur, Ajmer, Kota, Udaipur, Alwar, Pali and Bhiwadi. In Rajasthan industrial activities, unpaved road, mining and automobiles are the responsible for air pollution (Chauhan, 2010; S. S. Kumar & Sharma, 2016).



**Fig.1 map of Rajasthan (India)(we plotted map as per district area)**

Rajasthan state can be divided into four major parts by Geomorphologically as Aravali hill range, Eastern plain areas, Western sandy plains and sand dunes, and low lying Vindhyan hill and adjacent areas. The Rajasthan suffers from monsoon, showing rainfall as high 819 mm in the eastern part and low as 170 mm in the western part of the state (Maanju & Saha, 2013). Rajasthan is the largest mineral-producing states, with 57 minerals are produced commercially availability out of 80 kinds of minerals in India. The tourist attractions of Rajasthan as historic monuments, wildlife sanctuaries, deserts, etc. offer an attractive investment opportunity to developers and investors. Also, the state is the leading producer of cement grade limestone in India. The state has about 26% share in proven limestone reserves in the country (IBEF : India Brand Equity Foundation 2020).

## Methodology

The impact of meteorological parameter on particulate matter of eight cities of Rajasthan (Jaipur, Jodhpur, Ajmer, Kota, Udaipur, Alwar, Pali and Bhiwadi) has been reviewed for monthly and seasonal for four year (2019 to 2022). The continuous ambient quality data for the selected eight cities of Rajasthan have been obtained from the Central Pollution Control Board, New Delhi (CPCB). The data included air pollutants: (i) PM<sub>2.5</sub> (particulate matter of size less than 2.5 $\mu$ m) (ii) PM<sub>10</sub> (particulate matter of size less than 10 $\mu$ m).

Particulate matter PM<sub>2.5</sub> and PM<sub>10</sub> data, in these cities located in the northwest part of India, were analyzed to investigate the pollution levels during the long-term monthly and seasonal. The data has been study of the seasonal variation, the year was divided into three seasons: summer (March to June), winter (November to February), and monsoon (July to October) as per the regional meteorological considerations. The concentrations of air pollutants PM<sub>2.5</sub> and PM<sub>10</sub> were analyzed for all the three seasons for the period of 2019 to 2022 in Rajasthan at eight major cities air quality monitoring stations of central pollution control board (CPCB).

## Results and discussion

Fig. 2 & 3 shows the mass concentration of particulate matter PM<sub>2.5</sub> and PM<sub>10</sub> with NAAQS for eight cities of Indian state of Rajasthan during different months in the year of 2019 to 2022. The level of PM<sub>2.5</sub> crosses NAAQS in January, February, March, April, May, Jun, October, November and December in Jodhpur and Bhiwadi but Kota about to crosses the level for the year 2019 to 2022. And cities Alwar, Ajmer and Jaipur under the level of NAAQS but Udaipur city in November, December and January cross the level of National Ambient Air Quality Standard ( $60\mu\text{g}/\text{m}^3$ ). In Jodhpur the maximum value of PM<sub>2.5</sub> in a month as  $113.03\mu\text{g}/\text{m}^3$ ,  $108.59\mu\text{g}/\text{m}^3$ ,  $108.50\mu\text{g}/\text{m}^3$  and  $96.79\mu\text{g}/\text{m}^3$  respectively May, November, November, May for 2019, 2020, 2021, 2023. The maximum value of PM<sub>2.5</sub> in Bhiwadi as  $154.19\mu\text{g}/\text{m}^3$ ,  $196.07\mu\text{g}/\text{m}^3$ ,  $195.31\mu\text{g}/\text{m}^3$ ,  $153.73\mu\text{g}/\text{m}^3$  in January, November, November, April respectively 2019, 2020, 2021, 2022. In Ajmer the maximum value of PM<sub>2.5</sub> crosses NAAQS in January (2019) and May (2022) respectively  $62.32\mu\text{g}/\text{m}^3$  and  $71.89\mu\text{g}/\text{m}^3$ . The capital of Rajasthan, Jaipur city in 2019 control PM<sub>2.5</sub> value and that is below NAAQA but in 2020, 2021 and 2022 level are  $85.35\mu\text{g}/\text{m}^3$ ,  $110.95\mu\text{g}/\text{m}^3$ ,  $82.41\mu\text{g}/\text{m}^3$  respectively November, November and May. In Kota the maximum value as  $74.53\mu\text{g}/\text{m}^3$ ,  $83.37\mu\text{g}/\text{m}^3$ ,  $120.93\mu\text{g}/\text{m}^3$ ,  $84.15\mu\text{g}/\text{m}^3$  in January, November, November, May in respective year 2019, 2022, 2021 and 2022. The maximum value of PM<sub>2.5</sub> in Pali for 2019, 2020, 2021 and 2022 respectively  $77.31\mu\text{g}/\text{m}^3$ ,  $63.96\mu\text{g}/\text{m}^3$ ,  $85.60\mu\text{g}/\text{m}^3$ ,  $72.11\mu\text{g}/\text{m}^3$  April, November, March and May. And the city of lakes Udaipur level of PM<sub>2.5</sub> as  $71.39\mu\text{g}/\text{m}^3$ ,  $71.03\mu\text{g}/\text{m}^3$ ,  $87.48\mu\text{g}/\text{m}^3$ ,  $81.80\mu\text{g}/\text{m}^3$  in January, December, January and December respectively in the year of 2019, 2020, 2021 and 2022.

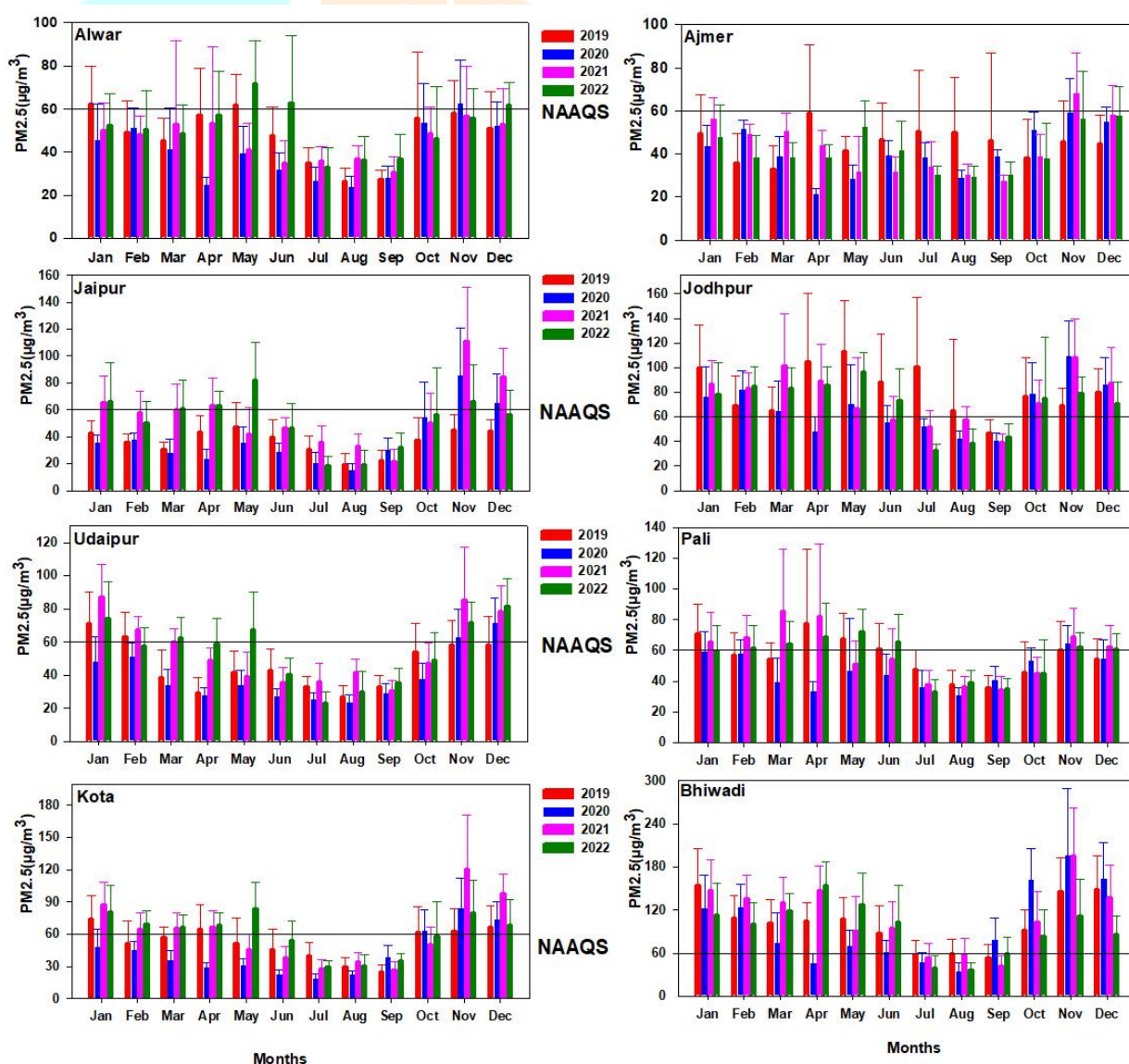
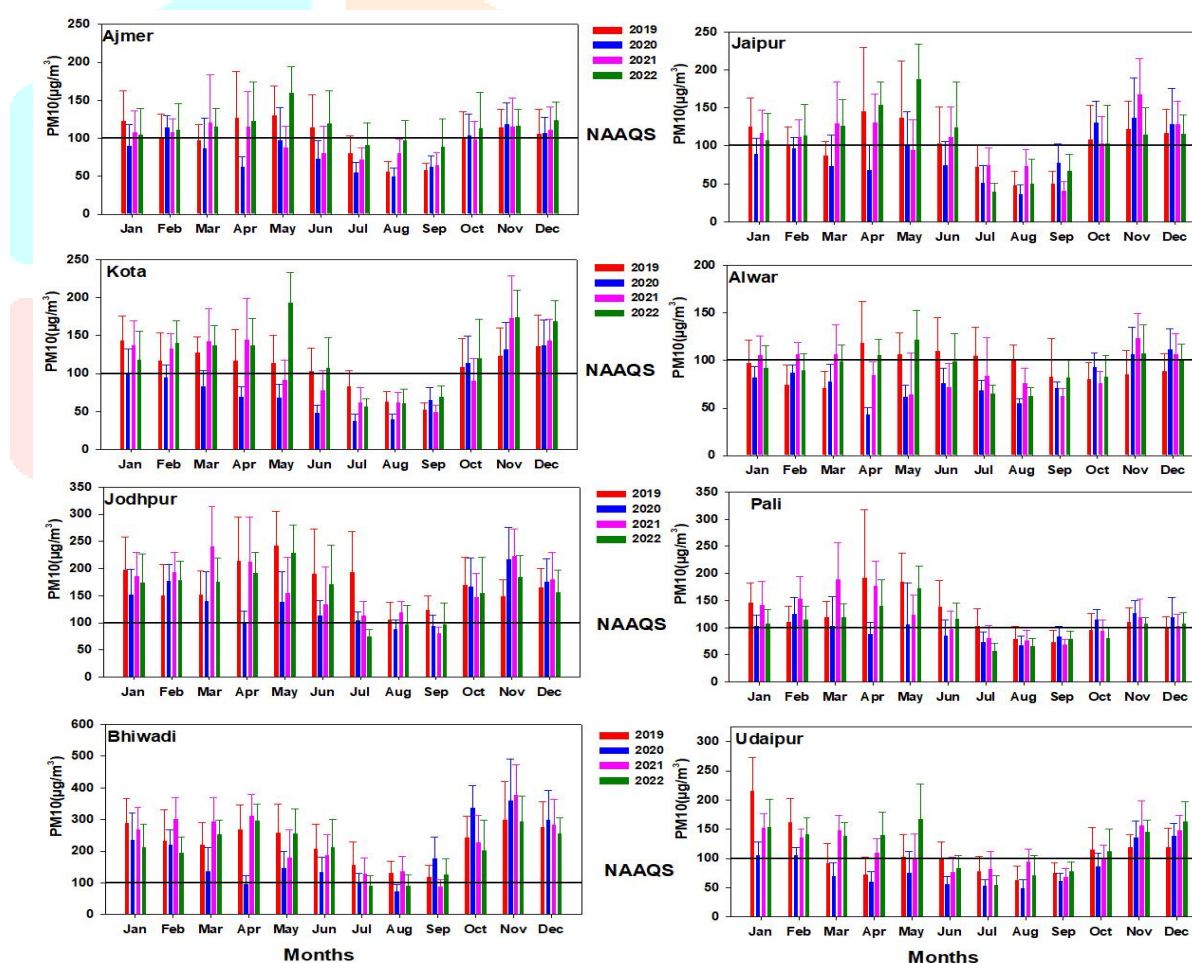


Fig.2 Monthly distribution of PM<sub>2.5</sub> during past four year for different cities of Rajasthan

Fig. 3 shows concentration of particulate matter PM10 and represents all the months (not include July, August, September) for year 2019 to 2022 the level crosses NAAQS. The national ambient air quality standard set for PM10 by India is  $100\mu\text{g}\text{m}^{-3}$  suggested by the WHO (World Health Organization) guidelines. The mass concentration of PM10 is found to be max during the months of May, November and December in almost all years. In Ajmer the level of PM10 found to be maximum in 2019, 2020, 2021 and 2022 as  $129.39\mu\text{g}\text{m}^{-3}$ ,  $118.16\mu\text{g}\text{m}^{-3}$ ,  $119.76\mu\text{g}\text{m}^{-3}$ ,  $159.10\mu\text{g}\text{m}^{-3}$  respectively May, November, March, May. The level of PM10 crosses NAAQS in the month of April, December, November, May as  $117.75\mu\text{g}\text{m}^{-3}$ ,  $111.85\mu\text{g}\text{m}^{-3}$ ,  $122.87\mu\text{g}\text{m}^{-3}$ ,  $121.94\mu\text{g}\text{m}^{-3}$  respectively 2019, 2020, 2021 and 2022 in Alwar and in Bhiwadi the value found to be max  $299.26\mu\text{g}\text{m}^{-3}$ ,  $359.63\mu\text{g}\text{m}^{-3}$ ,  $377.63\mu\text{g}\text{m}^{-3}$ ,  $296.64\mu\text{g}\text{m}^{-3}$  in November (2019), November (2020), November (2021) and April (2022). In Jaipur the level of PM10 found to be max as  $145.07\mu\text{g}\text{m}^{-3}$ ,  $136.57\mu\text{g}\text{m}^{-3}$ ,  $166.75\mu\text{g}\text{m}^{-3}$ ,  $186.99\mu\text{g}\text{m}^{-3}$  respectively in the month of April (2019), November (2020), November (2021) and May (2022). The level of PM10 crosses NAAQS and found max in the month of May (2019), November (2020), March (2021), May (2022) as  $240.96$ ,  $217.08$ ,  $240.30$ ,  $227.93\mu\text{g}\text{m}^{-3}$  in Jodhpur and in Kota found as  $143.41$ ,  $136.30$ ,  $172.83$ ,  $193.04\mu\text{g}\text{m}^{-3}$  respectively in January (2019), December (2020), November (2021), May (2022). In Pali the value found to be max in April (2019), November (2020), March (2021), May (2022) respectively as  $191.80\mu\text{g}\text{m}^{-3}$ ,  $126.73\mu\text{g}\text{m}^{-3}$ ,  $188.67\mu\text{g}\text{m}^{-3}$ ,  $171.71\mu\text{g}\text{m}^{-3}$  and in Udaipur the level of PM 10 found max as  $215.52\mu\text{g}\text{m}^{-3}$ ,  $137.61\mu\text{g}\text{m}^{-3}$ ,  $156.03\mu\text{g}\text{m}^{-3}$ ,  $167.34\mu\text{g}\text{m}^{-3}$  respectively in the month of January (2019), December (2020), November (2021), May (2022).



**Fig.3 Monthly distribution of PM10 during past four year for different cities of Rajasthan**

Fig. 4 shows the seasonal variation of particulate matter PM10 and PM2.5, in that order for the duration of different months in 2019 to 2022. Month divide as season with four month winter (November, December, January and February), summer (March, April, May and Jun) and monsoon (July, August, September and October). The AAQS (ambient air quality standard) for PM2.5, set by India is  $60\mu\text{g}\text{m}^{-3}$  suggested by WHO guidelines. In winter month average for 2019 to 2022 fig. Shows Ajmer and Alwar the mass concentration PM2.5 below the NAAQS level and satisfactory level although Bhiwadi represent maximum concentration

for all year and crosses threshold level who is very dangerous for our respiratory system and health 2019 ( $139.38\mu\text{gm}^{-3}$ ), 2020 ( $150.9738\mu\text{gm}^{-3}$ ), 2021 ( $153.638\mu\text{gm}^{-3}$ ) and 2022 ( $102.8838\mu\text{gm}^{-3}$ ). In Jodhpur city the PM 2.5 concentration crosses also threshold level and 2019 ( $79.71\mu\text{gm}^{-3}$ ), 2020 ( $87.91\mu\text{gm}^{-3}$ ), 2021 ( $91.58\mu\text{gm}^{-3}$ ) and 2022 ( $78.39\mu\text{gm}^{-3}$ ) and Kota city  $63.86\mu\text{gm}^{-3}$ ,  $62.17\mu\text{gm}^{-3}$ ,  $92.87\mu\text{gm}^{-3}$  and  $74.75\mu\text{gm}^{-3}$  respectively 2019, 2020, 2021 and 2022. Where Jaipur, Pali and Udaipur represent the concentration of PM2.5 level (2019 and 2020) under the satisfactory condition and NAAQS set by India. The cities are Jaipur, Pali and Udaipur also crosses NAAQS in the year of 2021 and 2022.

In summer season the mass concentration PM2.5 cities Ajmer, Jaipur, Kota shows under NAAQS for three years of 2019 to 2021 but in 2022 the concentration value  $60.06\mu\text{gm}^{-3}$ (Ajmer),  $63.51\mu\text{gm}^{-3}$ (Jaipur),  $68.45\mu\text{gm}^{-3}$ (Kota) and Alwar, Udaipur shows satisfactory level for 2019 to 2022. Where Jodhpur  $92.84\mu\text{gm}^{-3}$ ,  $59.2\mu\text{gm}^{-3}$ ,  $78.65\mu\text{gm}^{-3}$ ,  $84.66\mu\text{gm}^{-3}$  and Bhiwadi  $100.68\mu\text{gm}^{-3}$ ,  $62.12\mu\text{gm}^{-3}$ ,  $115.73\mu\text{gm}^{-3}$ ,  $125.59\mu\text{gm}^{-3}$  respectively 2019, 2020, 2021 and 2022 crosses NAAQS for PM2.5 ( $60\mu\text{gm}^{-3}$ ) set by India.

The average of monsoon month (July, august, September and octomber) for year of 2019 to 2022 of particulate matter PM2.5 for Ajmer, Alwar, Jaipur, Kota, Pali and Udaipur under the satisfactory level PM2.5 ( $60\mu\text{gm}^{-3}$ ) due to washout effect and in Jodhpur (2019) and Bhiwadi (2019, 2020 and 2021) crosses NAAQS set by India although rainy season.

The mass concentration PM10 in seasonal variation fig.4 shows in winter approx all cities (Ajmer, Alwar, Bhiwadi, Jaipur, Jodhpur, Kota, Pali and Udaipur) crosses threshold level NAAQS set by India PM10 ( $100\mu\text{gm}^{-3}$ ) for 2019 to 2022. In Alwar (2019, 2020 and 2022) the value of PM10 under satisfactory level. But in Bhiwadi the mass concentration PM10 almost double and third of NAAQS level  $273.81\mu\text{gm}^{-3}$ ,  $278.1\mu\text{gm}^{-3}$ ,  $307.32\mu\text{gm}^{-3}$ ,  $238.38\mu\text{gm}^{-3}$  respectively 2019, 2020, 2021 and 2022 and that is the much higher of NAAQS and most hazardous for our health.

Jodhpur and Udaipur city are the second and third most dangerous city in Rajasthan for our respiratory system and health after Bhiwadi in winter season. In summer season Bhiwadi crosses NAAQS and touches highest level  $237.71\mu\text{gm}^{-3}$ (2019),  $127.02\mu\text{gm}^{-3}$ (2020),  $242.57\mu\text{gm}^{-3}$ (2021) and  $254.16\mu\text{gm}^{-3}$ (2022). In monsoon season Almer, Alwar, Jaipur, Kota, Pali and Udaipur under the satisfactory level due to washout effect but in Jodhpur  $147.35\mu\text{gm}^{-3}$ ,  $112.41\mu\text{gm}^{-3}$ ,  $114.49\mu\text{gm}^{-3}$ ,  $105.55\mu\text{gm}^{-3}$  and  $162\mu\text{gm}^{-3}$ ,  $170.45\mu\text{gm}^{-3}$ ,  $144.12\mu\text{gm}^{-3}$ ,  $126.14\mu\text{gm}^{-3}$  respectively in 2019, 2020, 2021 and 2022 that are the first and second most dangerous for our health in monsoon season.

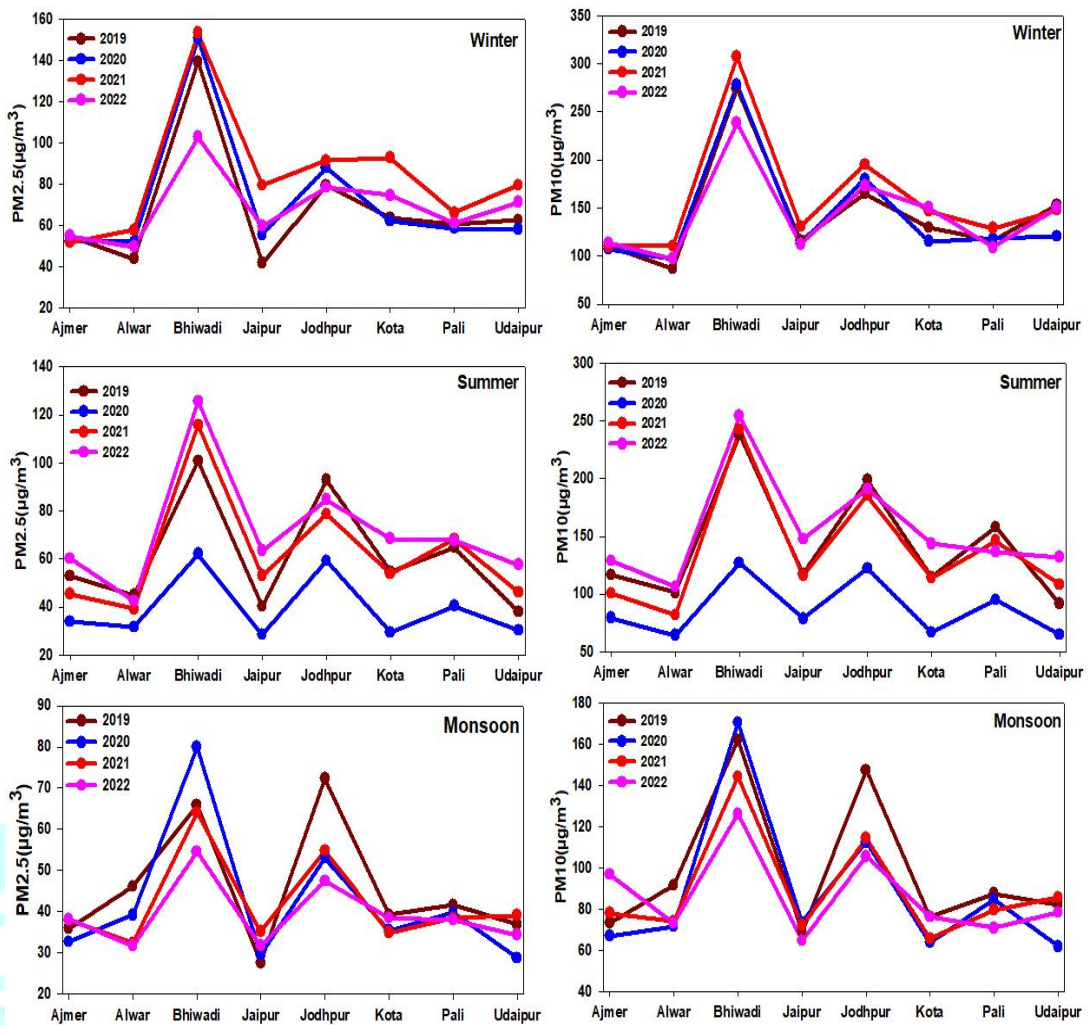


Fig.4 seasonal variation (winter, summer and monsoon) of Particulate Matter (PM2.5 and PM10)

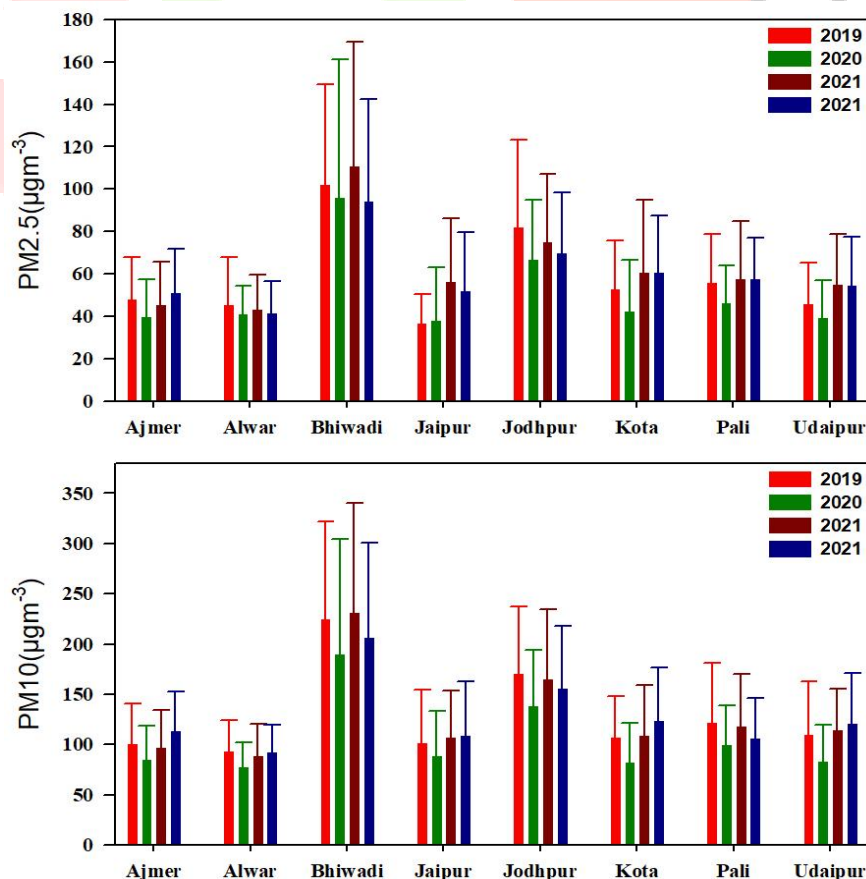


Fig.5 yearly average mass concentration of PM2.5 and PM10 for all eight cities

The average mass concentration for year 2019 to 2022 under the NAAQS PM<sub>2.5</sub> ( $60\mu\text{g}\text{m}^{-3}$ ) of Ajmer, Alwar, Jaipur, Pali and Udaipur but Jodhpur  $81.76\mu\text{g}\text{m}^{-3}$ ,  $66.68\mu\text{g}\text{m}^{-3}$ ,  $74.98\mu\text{g}\text{m}^{-3}$ ,  $69.66\mu\text{g}\text{m}^{-3}$  and Bhiwadi  $101.98\mu\text{g}\text{m}^{-3}$ ,  $95.9\mu\text{g}\text{m}^{-3}$ ,  $110.83\mu\text{g}\text{m}^{-3}$ ,  $94.13\mu\text{g}\text{m}^{-3}$  in the year of 2019, 2020, 2021 and 2022 crosses NAAQS set by India and that is most dangerous for our health. Fig.5 PM<sub>10</sub> concentration shows yearly average Bhiwadi  $224.46\mu\text{g}\text{m}^{-3}$ (2019),  $189\mu\text{g}\text{m}^{-3}$ (2020),  $230.66$ (2021),  $206$ (2022) and Jaipur  $100.87$ (2019),  $106.21\mu\text{g}\text{m}^{-3}$ (2021),  $108.04\mu\text{g}\text{m}^{-3}$ (2022) and Jodhpur  $170.49\mu\text{g}\text{m}^{-3}$ (2019),  $138.01\mu\text{g}\text{m}^{-3}$ (2020),  $164.58\mu\text{g}\text{m}^{-3}$ (2021),  $155.12\mu\text{g}\text{m}^{-3}$ (2022) and Kota  $106.88\mu\text{g}\text{m}^{-3}$ (2019),  $108.41\mu\text{g}\text{m}^{-3}$ (2021),  $123.41\mu\text{g}\text{m}^{-3}$ (2022) and Pali  $120.98\mu\text{g}\text{m}^{-3}$ (2019),  $117.87\mu\text{g}\text{m}^{-3}$ (2021),  $105.27\mu\text{g}\text{m}^{-3}$ (2022) and Udaipur  $109.05\mu\text{g}\text{m}^{-3}$ (2019),  $113.76\mu\text{g}\text{m}^{-3}$ (2021),  $120.26\mu\text{g}\text{m}^{-3}$ (2022).

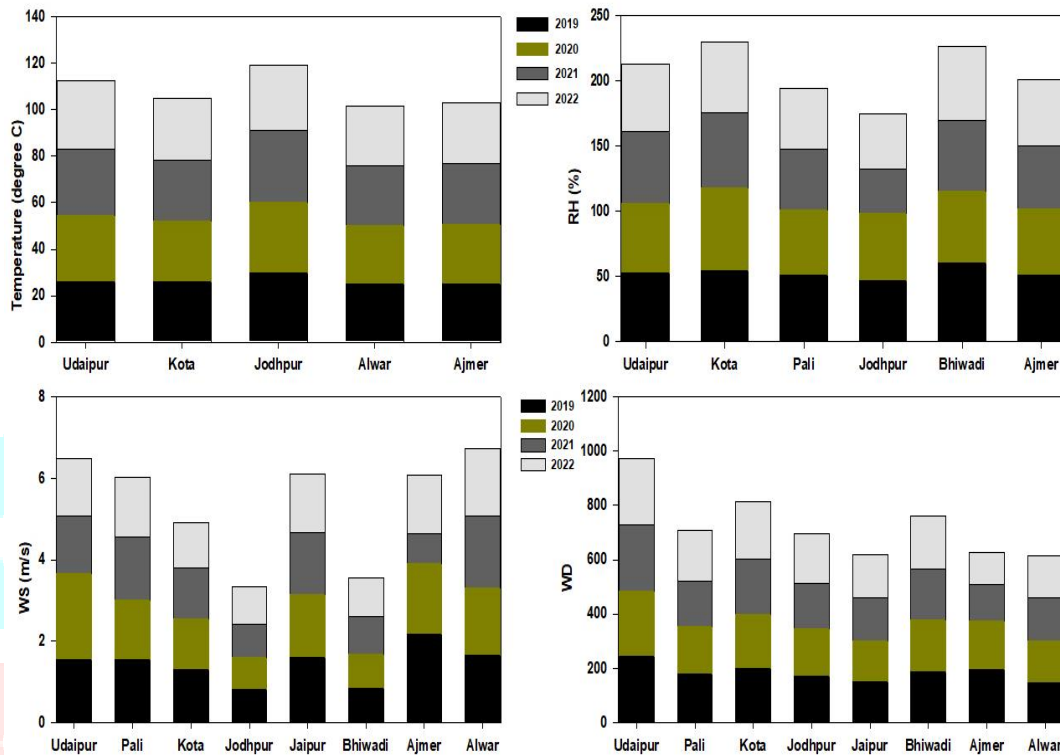


Fig.7 yearly average of (a) Temperature (b) Wind speed (c) Relative humidity and (d) Wind direction

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