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STUDY OF PARTICULATE MATTER (PM10 AND SPM) DISTRIBUTION IN AMBIENT AIR OF JODHPUR, RAJASTHAN

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ABSTRACT:

Growth in population, industry, number of vehicles and improper implementation of emission standards have contributed towards making the air quality worse. Air quality of Jodhpur was analyzed by recording Suspended Particulate Matter (SPM) and Particulate Matter-10 micrometer (PM10), for 24 hour, each month at two sites- Shastri nagar (residential area) and HI area Basni Phase II (industrial area) from June 2019 to March 2020, along with meteorological parameters like relative humidity, wind speed and rainfall. The residential sampling site recorded highest SPM 231.75µg/m^3 to lowest 25.42µg/m^3 in month of June 2019 and September 2019 respectively. Highest PM10 was recorded being 153.22µg/m^3 and lowest being 19.89µg/m^3 in month of January 2020 and September 2019 respectively. Industrial sampling site recorded highest SPM being 665.14µg/m^3 to lowest 150.07µg/m^3 in month of June 2019 and September 2019 respectively. At same site PM10 highest value 686.27µg/m^3 was recorded in the month of March 2020 while lowest value of 152.59µg/m^3 was recorded in the month September 2019. Correlation analysis revealed that PM10 is negatively correlated with relative humidity, wind speed and rainfall at both sampling station during study period. The value of exceedance factor was found to be 0.95 and 2.66 for residential and industrial site respectively. The above findings (PM10 average of study period) was higher than the Revised National Ambient Air Quality Standards (NAAQS) 2009 given by Central Pollution Control Board (CPCB) at industrial site but at residential sampling site it was found to be within the standards.

Keywords: Jodhpur, air pollution, particulate matter, SPM, PM10, exceedance factor, CPCB.

INTRODUCTION:

Air pollution is a mixture of pollutants of both human-made and natural origins in the air (Air Pollution and Your Health, National Institute of Environmental Health Sciences). Ambient or outdoor air pollution is a distinct category for air pollution considered outdoors (Outdoor air pollution, NSW Government).

WHO mentions 4 million deaths every year (Li *et al.*, 2019) due to ambient air pollution. It is known that certain health conditions are exaggerated and caused by air pollution and an estimated 4.2 million deaths per year occur due to it (Air pollution, World Health Organisation).

Reports state that Jodhpur, the second largest district of Rajasthan has been tagged as the 12th most polluted city of the world, in year 2018 by AirVisual and Greenpeace (Koshy 2019). Such reports are a cause of concern, because AQI of the region has increased by 1.38 times in 2018, when compared with 2017's AQI (The Times News Network 2019).

Particulate Matter (PM) is a suspension of solid and liquid particles in atmosphere, which can be produced by combustion of fossil fuels, wood, livestock and vegetation or can be produced by chemical reactions in the ambience (Sierra- Vargas and Teran 2012). As PM are characterized by their size PM10 consists of PM of aerodynamic diameter equal to and less than 10 micrometer (Smith, Pm10: How Do Coarse Particles (Particulate Matter) Affect Air Quality?) while, SPM (Suspended Particulate Matter) consists of heterogeneous sized particles.

Meteorology affects fate and dispersion of various air pollutants, thereby, affecting the concentration of pollutants in the ambient air (Meteorological factors, Queensland Government). The extent to which these factors affect pollutants, is dependent on magnitude and cumulative effect exhibited by other factors. Çelik and Kadi (2007) observed in urban Karabuk, Turkey that topography interfered with pollutant removal efficiency of meteorological conditions (wind speed, relative humidity and air temperature) as the city is surrounded by mountains and hills and the pollution could not be carried away. Generally, higher concentration of PM10 is observed during low wind speed, but was found subjective to the proximity of monitoring station to the source of pollutant emission (Cichowicz *et al* 2020) and higher wind speeds (Liu *et al* 2020, El-Nouby Adam 2013).

Bathmanabhan and Madanayak (2010) elucidated prevalence of higher concentration of pollutants in the city of Chennai during calm conditions such as winter season and post monsoon period where stable atmospheric conditions (low wind speed, mixing height and inversion condition) don't allow displacement of pollutants to large distances.

Relative humidity greatly affects PM10 but has poor correlation with it (El-Nouby Adam 2013) because relative humidity is usually associated with other meteorological factors that favour increase in pollution levels (Zhao *et al* 2019)

Rainfall exhibits wet scavenging effect on particulate matter in the atmosphere (Zhao *et al* 2019; Liu *et al* 2020; El-Nouby Adam, 2013; Fung and Wu 2014). A detailed study conducted by Liu *et al* (2020) mentions that higher initial concentration of PM10 leads to more pronounced removal effect and is in agreement with findings of Zhao *et al* (2019) where they mentioned wet scavenging to be more effective on PM10 than PM2.5.

Due to rapid urbanization and yearly addition to existing population of Jodhpur (1,033,756 in 2011 census) and its vehicles, the pollution level are high and is the reason why this study was undertaken in two different environment.

MATERIAL AND METHODS:

The samples were collected for Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM or PM10) from two sampling sites, namely Shastri Nagar (residential area 26°26' 82" and 72° 99' 90" E) and HI area Basni Phase II (industrial area 26° 24' 19"N and 73° 01' 04"E) from June 2019 to March 2020. Shastri Nagar is a posh residential locality of Jodhpur about 3.5 km from the railway station.

Industrial area site HI area Basni Phase II has industries dealing in handicrafts, pipes, bearings, guar gum, packing material, textiles, artistic furniture's etc and has a high traffic load, mainly of Heavy Motor Vehicles (HMV) throughout the day. Industries have come up with a fast speed, as the demand of the city increased with increase in population. About 24374 industrial units are registered in Jodhpur district as per 2011-12 data, given by

Micro, Small and Medium Enterprises, Government of India.

Jodhpur is the second largest city of Rajasthan, 231 m (758 ft) above mean sea level, lying between 26.28°N and 73.02°E. It is popularly known as SUN CITY, as the sunshine hours are long throughout the year. Jodhpur is fast expanding, stretching 40 kilometers across with a population of 1,033,756 (in 2011 census) and is estimated to be about 1.32 million in 2021. Number of vehicles in Jodhpur has also increased alarmingly (more than 11 lakh vehicles are registered, as per Government of Rajasthan, transport portal website) and all this has created increase in pollution which was nonexistent a decade ago.

Samples were collected using Respirable Dust Sampler Model No. APM460BL (Envirotech Instruments ltd.) monthly at 24 hour cycle, keeping the sampling inlet 1-3 meter above the ground level, free from any obstructions to the flow of air and operating at the average flow rate of 1.0-1.5m^3/min. The APM-460BL Respirable Dust Sampler is provided with a cyclone- The cyclone has been designed to provide separation of PM10 particles. As the air with Suspended Particulate enters the cyclone, coarse non-respirable dust is separated from the air stream by centrifugal forces. The Suspended Particulate Matter falls through the cyclone's conical hopper and gets collected in the cyclonic-cup. The fine dust comprising the respirable fraction of TSPM passes through the cyclone and gets collected on GFF of 20×25 cm. The amount of non respirable Suspended Particulate Matter (SPM) and respirable particulate per unit volume of air passed, was calculated on the basis of the difference between initial and final weights of the cyclone cup and that of the filter paper, after keeping in desiccators for 24 hour (Gravimetric Method).

FORMULA USED FOR CALCULATION

Total air volume = Sampling time (in minutes) * Average flow rate (in m^3/min)

Particulate matter-10 micrometer (PM10) concentration (µgm/m^3) = Weight of dust collected on filter paper * 10^6 / Total volume of air sampled

Suspended particulate matter (SPM) concentration (µgm/m^3) = Weight of dust collected in cyclonic-cup * 10^6 / Total volume of air sampled

Meteorological parameters like Relative humidity, Wind Speed and Rainfall was recorded by Wind Monitoring Systems (Envirotech Instruments ltd) Model No. WM271.

The air quality of study locations was categorized into four categories based on Exceedance Factor (EF) (Kumar *et al* 2014, AAQ Report, 2007) which was calculated by:

EF = Observed annual mean concentration of criteria pollutant / Annual standard for the respective pollutant and area class

1. Critical pollution (C) – when EF is more than 1.5
2. High pollution (H) – when EF is between 1.0 to 1.5
3. Moderate pollution (M) – when EF is between 0.5 to 1.0
4. Low pollution (L) – when EF is less than 0.5

RESULT AND DISCUSSION:

Samples collected for Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM or PM10) from two sampling sites- Shastri Nagar (residential area 26°26' 82" and 72° 99' 90" E) and HI area Basni Phase II (industrial area 26° 24' 19"N and 73° 01' 04"E) for duration June 2019 to March 2020 on monthly basis, running samplers continuously for 24 hour. Results obtained are discussed below.

The residential sampling site recorded highest SPM 231.75μg/m^3 to lowest 25.42μg/m^3 in month of June 2019 and September 2019 respectively. Highest PM10 was recorded being 153.22μg/m^3 and lowest being 19.89μg/m^3 in month of January 2020 and September 2019 respectively. Industrial area sampling site recorded highest SPM being 665.14μg/m^3 to lowest 150.07μg/m^3 in month of June 2019 and September 2019 respectively. At same site PM10 highest value 686.27μg/m^3 was recorded in the month of March 2020 while lowest value of 152.59μg/m^3 was recorded in the month September 2019.

The climate of Jodhpur is hot and semi arid-heat during summer makes it hottest region in India. The aridity of west Rajasthan is due to vast anticyclone circulation cell in the middle of troposphere, extending from Arabia to Western Rajasthan. The source of particulates in Jodhpur are the industries related to dyes, textiles, timber and furniture, handicrafts, metals, chemicals, rolling mills, guar gum, pulses etc. According to statistics, there are more than 11 lakh vehicles registered in Jodhpur and the wind storms, to some extent, are responsible for the increase of particulates in the air. High concentration of PM at the residential area may be due to combustion of fuel in houses and public places, incineration of municipal waste and biomass combustion by slum in the area (Mathur and Mathur 2017).

The Particulate Matter may have natural dust, industrial dust or automobile exhausts. Dust deposited on road side is also made air born by movement of vehicles. PM10 is primarily produced by industrial and agricultural production and processes, construction, roadside dust and natural processes such as the re suspension of local soil and dust storms (Xueling *et al* 2020). Higher levels of SPM and RSPM in residential areas indicate that major cause of air pollution in Jodhpur city may be increasing number of vehicles (Sharma *et al* 2005-2006**).**

Rai (2016) did comparative study of ambient air quality, using Air Quality Index in the residential areas of Jodhpur city and found that primary pollutant at residential area of Jalori Gate is PM2.5 and at Kudi Housing Board, sector-3 is PM10. Reason cited behind these pollutants was basically related to vehicular pollution and light sand storm, as Jodhpur zone is an arid zone.

In present investigation, the average values of SPM and PM10 at Shastri Nagar (residential area) was near the standards while at HI area Basni Phase II (industrial area) sampling site it was much higher than the standards.

A modest rise in PM10 or PM2.5 level induces oxidative stress and was shown to be associated with small changes in cardiac function (Furuyama et al 2006**).** Major human health concerns from PM10 exposure include, effects on respiratory systems, damage to lung tissue, cancer and premature death (Torigoe *et al* 2000).

However, the magnitude of toxicity of PM10 and PM2.5 airborne particles is directly proportional to their physical properties (nature, shape and size, count, smoothness or roughness of the surface area), chemical composition and source of its origin (Pandey *et al* 2013). The predominant particle components of Particulate Matter (PM) are sulfate, nitrate, ammonium, sea salt, mineral dust, organic compounds and black or elemental carbon (Pöschl 2005). Relative Humidity can also act on air pollutants to create secondary aerosols, such as sulphate and nitrate ions which contribute positively to PM10 concentrations (Sharma and Sharma 2016).

Industries play very important role in air quality. PM10 and PM2.5 are found in high concentration at heavy industrial and heavy traffic areas. This indicates that industrialization and automobile emission are associated closely with health hazards (Goverdhan *et al* 2015). The increase in Particulate Matter have been shown to cause small, reversible decrements in lung function of normal asymptomatic children and in both adults and children who have some form of pre-existing respiratory condition, particularly asthma. These changes were often accompanied, especially in adults, by increase in symptoms such as chronic bronchitis or cough (National Ambient Air Quality Objectives For Particulate matter 1998) (Singhdeo and Suna 2008).

The health impact of particulates has been reported in many studies in terms of daily Relative Death Rate (RDR) due to each increase in the PM10 level of 10μg/m^3 (Pandey *et al* 2013). Dockery and Pope reported from U.S. meta-analysis studies on particulate air pollution and showed that each increase in the PM10 level of 10 μg/m^3 increased daily RDR from all the causes by 1%.

In the present study relative death rate (RDR), following Dockery and Pope (1994) study, was calculated after clubbing data from both sampling stations, was found to be 8.89%. Based on observed PM10 values it may be predicted that more than 1 lakh people (assuming population of Jodhpur in 2021 being 13 lakh) of Jodhpur are likely to be affected due to particulate pollution.

Meteorological parameters play quite important role in distribution of pollutants in the ambient air (Bhaskar and Mehta 2010). In fact, there is a strong seasonality in meteorological variables that modulate air quality levels (Espinosa *et al* 2004; Karar *et al* 2005). The possibilities of a pollutant entering the air, its persistent existence in air and its possibility of forming secondary pollutant is all dependent not only on source and rate of emission but also on air temperature, relative humidity, wind speed, turbulence level, wind direction, rainfall etc.

Average relative humidity observed during study period was 54.6%, average wind speed was 6.7 km/hr and average rainfall recorded was 9.0 mm at Shastri Nagar (residential area). At HI area Basni Phase II (industrial area) sampling site, average relative humidity was observed to be 62.9%, average wind speed was 4.1 km/hr and average rainfall recorded was 6.9 mm during study period.

Precipitation and wind speed cause reduction in particulate level in the atmospheric environment. Precipitation has relatively higher degree of correlation, with reduction in the particulate level than that of the other parameters mainly, because of rainfall, the damp soil restricts the possibility of soil derived particles being released (Misra *et al* 2008). Relative humidity also boosts the formation of secondary pollutant (Giri *et al* 2008). The inverse relationship between rainfall and Particulate Matter concentration reveal that at lower rainfall, a higher PM2.5 and PM10 concentration is observed (Onuorah *et al* 2019). Sharma and Sharma (2016) in their study found that PM10 showed a significant negative correlation with rainfall. The rain also acts as natural scrubber during monsoon and brings down the particulate level in the atmosphere (Jayamurugan *et al* 2013). This minima of pollutant concentration during the monsoon season is probably caused by the prevailing meteorological factors during the months from July to September such as washout by monsoon rains and suppressed wind erosion due to highest precipitation, highest cloud cover, highest wet day frequency and lowest diurnal temperature range as compared to whole year. All these meteorological conditions help in reducing pollutant concentrations (Deswal and Chandna 2010).

Increase of rainfall and humidity has negative correlation with average PM10 concentration in Kathmandu valley (Giri *et al* 2008). The weak negative correlation between PM2.5 and PM10 with rainfall shows that increase rainfall give rise to reduction in PM concentration due to its scavenging potential through wet deposition. (Onuorah *et al* 2019). It shows that increase in relative humidity slightly reduces PM2.5 concentration. This slight decrease is attributed to the fact that particles accumulate mass, owing to moisture which leads to dry deposition. (Onuorah *et al* 2019). Kliengchuay *et al* 2018 in their study found a significant negative correlation between relative humidity and PM10 (p-value < 0.001).

High wind speed transport large amount of particles to far distance thereby reducing PM concentration (Onuorah *et al*, 2019). PM10 particles settle more quickly on ground due to their higher deposition velocity. PM1 and PM2.5 particles remain airborne for longer time and in turn transported to longer distances (Tiwari *et al* 2012).

Correlation analysis of the data for both the sampling sites revealed that there exists a positive correlation between PM10 and SPM. Comparing the Particulate Matter level with meteorological data, it was found that PM10 had negative correlation with relative humidity, wind speed and rainfall.

The value of exceedance factor was found to be 0.95 and 2.66 for residential and industrial site respectively, which points to moderate pollution level at Shastri Nagar (residential area) and critical pollution at industrial site.

CONCLUSION AND RECOMMENDATION:

The present study points towards moderate pollution level at Shastri Nagar (residential area) and critical pollution level at industrial site sampling site, which are affected by metrological parameters like Relative Humidity, Wind speed and Rainfall. It is high time and the need of hour, to think about improving the quality of air by increasing use of public transport, better quality of road, traffic management and strengthening of green belt with suitable plant species. Today we are fighting COVID pandemic and there is a hue and cry for medical oxygen. Air has enough oxygen needed by living beings, but we have finished the natural factories, that is plants, which can produce all the needed oxygen. Hence, it is necessary to take timely steps otherwise existence of many of the species on earth, including humans on the planet earth, may fall in danger.

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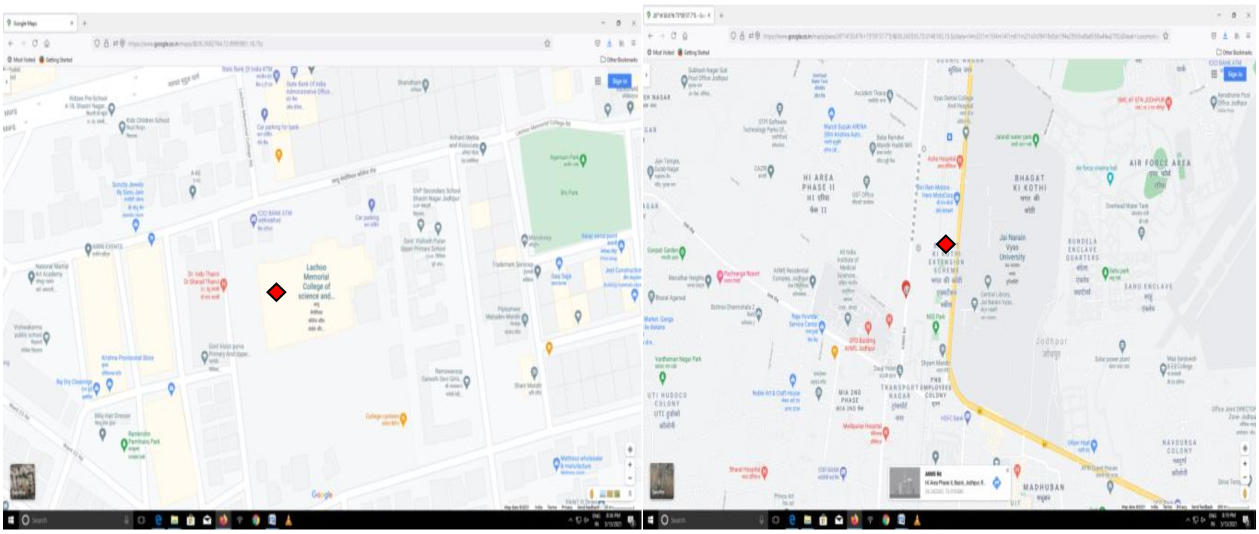

Fig 1. Sampling sites- Residential area (Shastri Nagar) and Industrial area (HI area Basni Phase II)

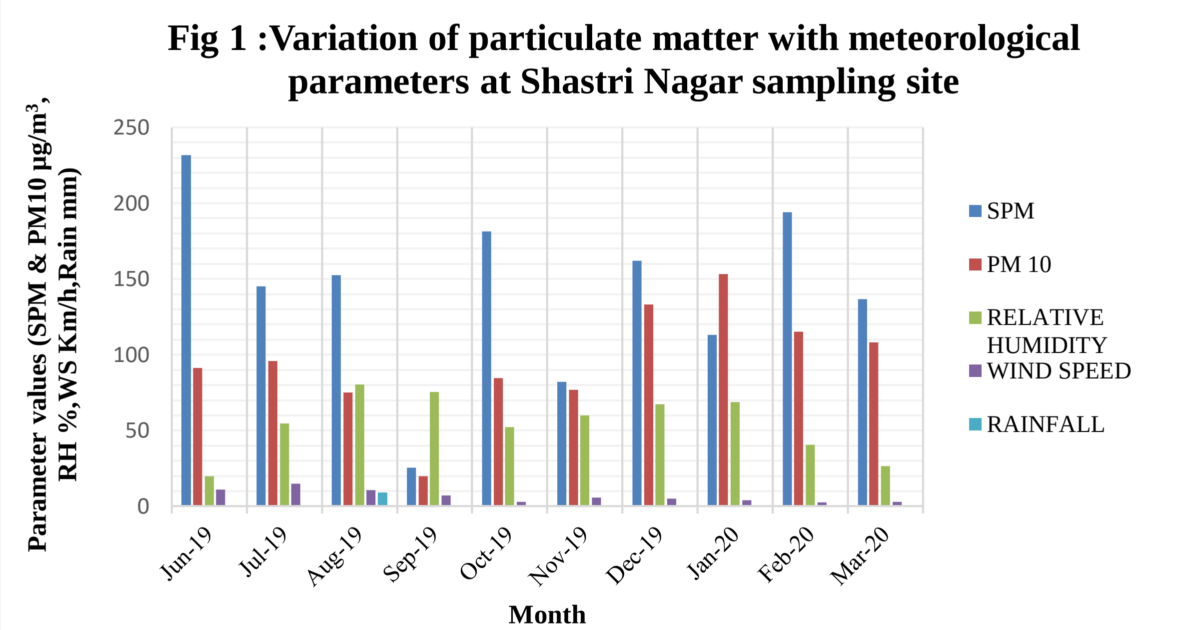
Fig 1 :Variation of particulate matter with meteorological parameters at Shastri Nagar sampling site
Parameter values (SPM & PM10 µg/m3, RH %,WS Km/h,Rain mm)
250
200
150
100
50
0
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Month
SPM
PM 10
RELATIVE HUMIDITY
WIND SPEED
RAINFALL

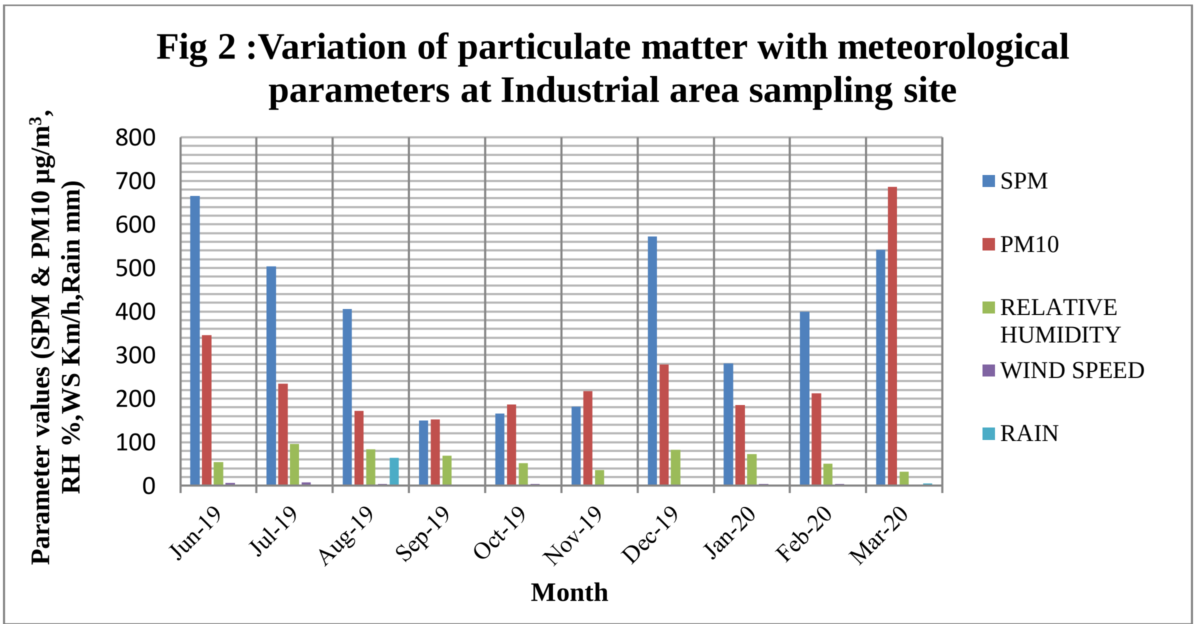
Fig 2 :Variation of particulate matter with meteorological parameters at Industrial area sampling site
Parameter values (SPM & PM10 µg/m3, RH %,WS Km/h,Rain mm)
800
700
600
500
400
300
200
100
0
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Month
SPM
PM10
RELATIVE HUMIDITY
WIND SPEED
RAIN