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Original Research Article

Studies on Seasonal Variation of Particulate Matter (PM_{10}) and Correlation with Meteorological Parameters (Temperature and Relative Humidity) at Jabalpur (MP), India

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Abstract

In this study, the relationship between inhalable particulate (PM_{10}), coarse particles ($PM_{2.5-10}$) and meteorological parameters such as temperature and relative humidity is studied. The data is statistically analyzed for urban region of Jabalpur during all three seasons (winter, summer and monsoon). Seasonal variation and ambient air quality was monitored with a sampling frequency of twenty-four hours at one monitoring sites covering a period of one year from January 2014 to December 2014. The 24-h average PM_{10} samples are collected using Beta Attenuator Methods and meteorological parameters such as temperature and relative humidity are also recorded simultaneously during the sampling period. The PM_{10} was found to be highest in winter season and decreases in monsoon season. It may be due to reason of meteorological parameter. A concentration of PM_{10} shows in table (4) the monthly variations. Statistical analyses have shown a negative correlation between PM_{10} and temperature (r= - 0.3695). The moderate negative correlation observed between particulate matter (PM_{10}) and relative humidity (r= -0.5321) which means there is a tendency for high X variable scores to go with low Y variable scores (and vice versa).

Keywords

Air quality

Meteorological parameter

Particulate matter (PM_{10})

Introduction

Present day atmosphere is quite different from natural atmosphere because of pollution. In this time, pollution is a major problem of all the big and small cities. Pollution creates so many problems as well as many diseases like skin and eye problem, cancer, asthma etc. With seasonally and diurnally variations there are many changes in climate and particulate pollutant affects to air quality. In the atmosphere, particles emitted directly into the air are known as particulate matter (PM). Particulate matter (PM) is the term for particles and liquid droplets suspended in the air. Particles come in a wide variety of sizes and have been historically assessed based on size, typically measured by the diameter of the particle in micrometers. Airborne PM presents a far greater complexity than most other common air pollutants. Not only it is a mixture of different chemical substances, but individual particles also spanning a wide range of sizes. Both chemical composition and size can provide valuable insights into the sources of airborne particles, and these parameters also determine the atmospheric behavior and fate of particles as well as influencing human health effects. The present study was aimed to study the SPM pollution and its correlation with meteorological parameters.

Giri et al. (2008) studied the influence of meteorological conditions on PM_{10} concentrations in Kathmandu Valley, Nepal. They found particulate matter PM_{10} and correlates with daily observed meteorological parameter wind speed, humidity, temperature, pressure and rain fall. Pearson's coefficient of correlation was applied to study the association between PM_{10} and meteorological variables. Another study by Bhaskar and Mehta (2010) investigated "atmospheric particulate pollutants and their relationship with meteorology in Ahmedabad". An Air Quality Index (AQI) was calculated for all stations for all months. An AQI value was high in summer season and low in monsoon season. PM_{10}, Ambient Temperature and Relative Humidity during the XXIX Summer Olympic Games in Beijing: Were the Athletes at Risk? (Branis and Vetvicka, 2010). In this research particulate air quality demonstrated that increased physical activity and the related increase in minute. To assess the effect of air pollution on the elite athletes health, ambient temperature, relative humidity and particulate matter with aerodynamic diameter below 10µm (PM_{10}) were measured during the XXIX Olympic Games in Beijing between August 3 and 24, 2009 in the Beijing Olympic Village. Continuous (15-min) temperature and relative humidity values were monitored by a data logging thermo-hygrometer and PM_{10} measurements were performed by a fast-responding DustTrak nephelometer. The relative humidity was lower during the pre-Games period than during the Games. According to their results, they can conclude that the participants at the XXIX Summer Olympic Games in Beijing were not at risk from poor air quality in terms of health or performance. Mamtimin et al. (2011) observed the air pollution and meteorological processes in the growing dry land city of Urumqi (Xinjiang, China). The seven years 2000–2006 of monthly PM_{10}, SO_2, and NO_2 concentrations are reported for Urumqi, the capital of Xinjiang in NW China. The shapes of seasonal variation of all pollutants were remarkably similar; however, winter/summer ratios of concentrations were quite different for PM_{10} (2–3) and NO_2 (≈4) compared to SO_2 (up to 30). Owoade et al. (2012) studied Correlation between particulate matter concentrations and meteorological parameters at a site in Ile-Ife, Nigeria. His measurement of atmospheric particulate matter was carried out with a view to establish the potential influence of meteorological parameters such as wind speed, wind direction, air temperature, rainfall, relative humidity and global radiation on the mass concentration. They used Pearson correlation analysis was performed on mass concentration and daily average meteorological data obtained from Nigeria Micrometeorological Experiment (NIMEX), Obafemi Awolowo University, Ile-Ife. The results showed seasonal variation was observed high concentrations in dry season and low in rainy season.

Whiteman et al. (2014) identified relationship between particulate air pollution and meteorological variables in Utah's Salt Lake Valley. Critical meteorological factors affecting daily particulate concentrations during winter for Utah's urbanized Salt Lake Valley are examined on the basis of forty years of data. In a typical winter, the National Ambient Air Quality Standard for particulate matter with aerodynamic diameter less than 2.5 microns ($PM_{2.5}$) is exceeded during 6 multi-day events comprising 18 winter days. Multi-day episodes of high stability produce these events, as synoptic-scale high-pressure ridges transit across Utah. The valley heat deficit, a bulk measure of atmospheric stability, exhibits large winter-to-winter variations that are highly related to similar variations in $PM_{2.5}$. $PM_{2.5}$ concentrations rise gradually over a period of days after a heat deficit threshold is exceeded as the air within the valley becomes decoupled from generally stronger winds aloft.

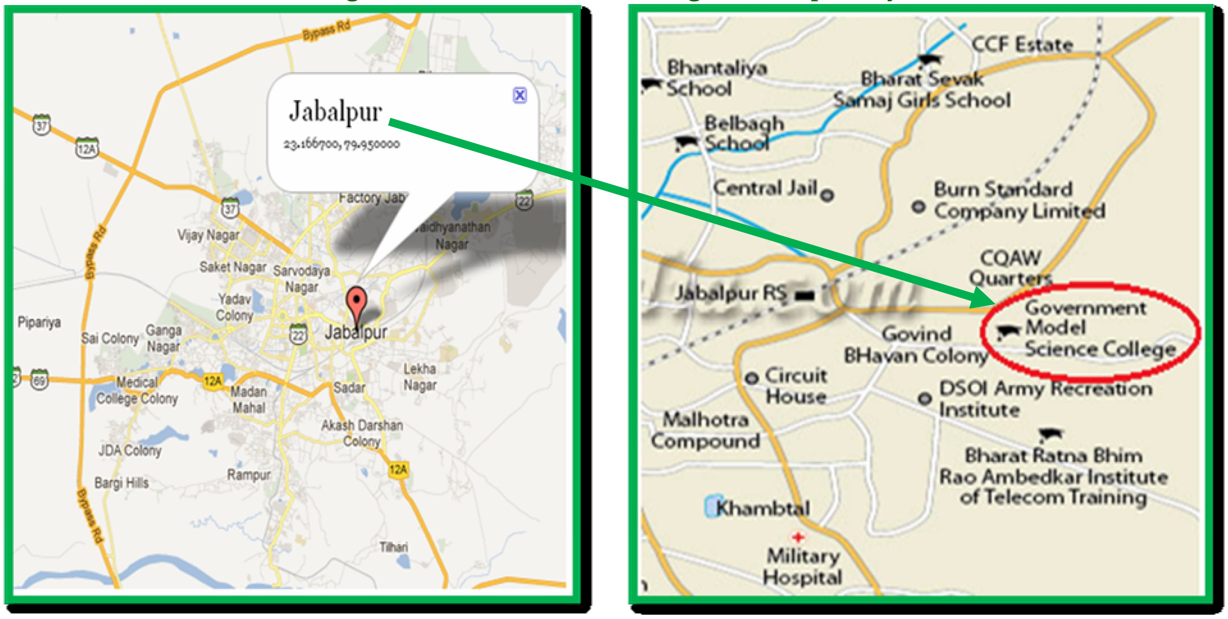
Signification of this study

This monitoring network study is generating huge amount of data, which need to be properly collected, collated, evaluated, interpreted and compiled in the form of reports. The data will provide information on the success of the abatement measures, air quality trend, and impact of policies etc. Good public information system is needed for air pollution in severely polluted countries.

Description of sampling site

The focus of the study is on the Jabalpur area and, specifically, one sampling stations are chosen for the present study: Govt. Model Science College. The Jabalpur city is situated in the heart of the country in central Madhya Pradesh. The density of Jabalpur is 5,900/km^2 and altitude from the sea level is 496 metres. The area of Jabalpur city is 154.21 sq. km. The most important part of this city lies between longitude and altitude is 23°9′38″N 79°56′19″E (Fig. 1).

Fig. 1: Location of Science College at Jabalpur city.



Materials and methods

Ambient air quality station

Ambient Air Quality Monitoring Systems (AQMS) monitored the level of pollutants – NOx, CO, CH_4, Particulate Matter (PM_{10} and $PM_{2.5}$), Ozone, etc. in the ambient atmosphere. From a single analyzer to complete systems provides a wide range of solutions to meet much of the Ambient Air Quality Monitoring demands.

Fig. 2: AAQMS (Ambient Air Quality Monitoring Station) with Beta Attenuation Monitor.

Ecotech established an instrument for environmental monitoring that is WinAQMS (Air Quality Monitoring Station). WinAQMS has been designed as a client/server program. This means that WinAQMS has two parts: the client and the server. The server handles all the communication between the logger and the analysers, recording of data and starting/stopping of calibrations. The client is concerned with giving the users access to settings and data. On its own the server has no user interface and there is no way you can interact with it using the mouse or keyboard. The client is the visual interface of WinAQMS and communicates with the server by requesting information or receiving information that it has asked for at a prior time. This arrangement means that the WinAQMS server must always be turned on before the WinAQMS client program can connect to it.

Features

- U.S. EPA Equivalent Method for PM_{10}, $PM_{2.5}$, and PM10-2.5 monitoring
- Very low operating costs
- Automatic Span Calibration checks
- Highly accurate, reliable, and mechanically simple flow system
- Hourly filter advances minimize effects on volatile compounds

- Advanced Smart Heater technology precisely controls sample relative humidity
- Integrated data logger allows the connection of up to six meteorological sensors
- Data retrieval through RS-232 serial ports using direct PC connections, modems, printers, or digital data collection systems.

Particulate Matter Monitoring by BAM [Beta Attenuation Monitor (Figs. 2, 3 and 4)]

The met one instrument model BAM-1020 automatically measures and record airborne particulate concentration level using the principal of beta ray attenuation. Thousands of BAM-1020 units are currently deployed worldwide, making the unit one of the most successful air monitoring platforms in the world. This method provides a simple determination of concentration in units of milligrams or micrograms of particulate per cubic meter of air. A small ^{14}C (carbon 14) element emits a constant source of high-energy electrons known as beta particles.

Fig. 3: The Model BAM 1020, Beta-Attenuation Mass Monitor.

These beta particles are detected and counted by a sensitive scintillation detector. An external pump pulls a measured amount of dust-laden air through a filter tape. After tape is loaded with ambient dust, it is automatically placed between the source and detector thereby causing an attenuation of the beta particle signal. The degree of attenuation of the beta particle signal is used to determine the mass concentration of particulate matter on the filter tape, and hence the volumetric concentration of particulate matter in ambient air.

Theory of operation

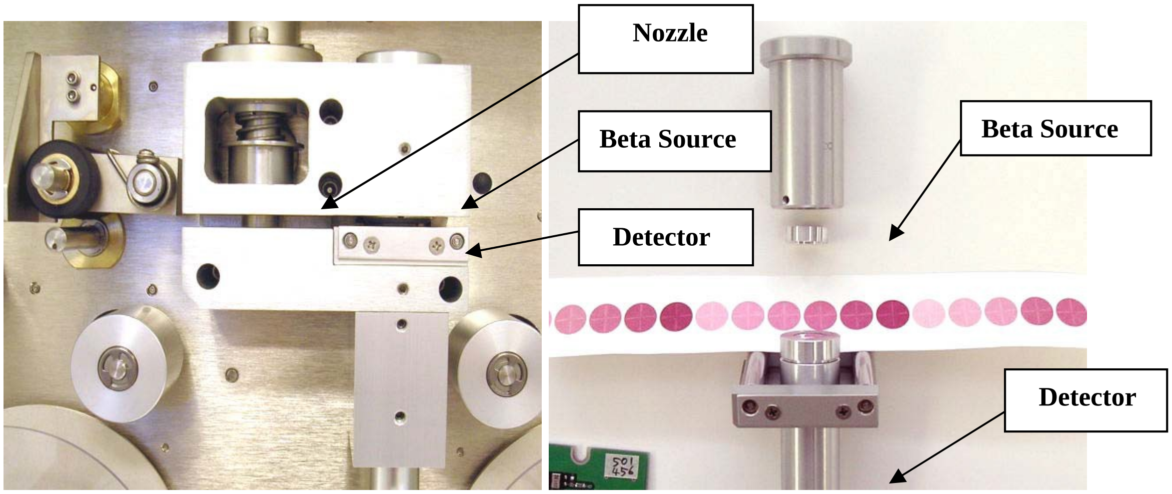
When the high –energy electrons emanating from the radioactive decay of ^{14}C (carbon-14) interact with nearby matter they lose their and, in some cases, are absorbed by the matter. These high-energy electrons emitted through radioactive decay are known as beta rays and the process is known as beta-ray attenuation. When matter is placed between the radioactive ^{14}C source and a device designed to detect beta rays, the beta rays are absorbed and/or their energy diminished. The result in reduction in the number of beta particles detected. The magnitude of the reduction in detection beta particles is a function of the mass of the absorbing matter between the ^{14}C beta source and the detector.

Beta attenuation monitoring (BAM) is a widely used air monitoring technique employing the absorption of beta radiation by solid particles extracted from air flow. This technique allows for the detection of PM10 and PM2.5, which are monitored as standards by most air pollution regulatory agencies.

The main principle is based on a kind of Bouguer (Lambert–Beer) law: the amount by which the flow of beta radiation (electrons) is attenuated by a solid matter is exponentially dependent on its mass and not on any other feature (such as density, chemical composition or some optical or electrical properties) of this matter. So, the air is drawn from outside of the detector through an "infinite" (cycling) ribbon made from some filtering material so that the particles are collected on it.

There are two sources of beta radiation placed one before and one after the region where air flow passes through the ribbon leaving particles on it; and there are also two detectors on the opposite side of the ribbon, facing the detectors. The sources' intensity and detectors' sensitivity being the same, the intensity of beta rays detected by one of detectors is compared to that of the other. Thus one can deduce how much mass has the ribbon acquired upon being exposed to air flow; knowing the drain velocity, actual particle mass concentration in air could be assessed.

Fig. 4: BAM-1020 Sample and measurement stations.



AWS (Automatic Weather Station)

This instrument provides metrological data e.g. wind speed, pressure, humidity, temperature, wind direction and rain fall with the help of intercept-software. It gives every 10 minutes data.

Fig. 5: AWS (Automatic Weather Station).

Results and discussion

Ambient concentration of Particulate matter (PM_{10}) compared with meteorological parameter like-Temperature and Relative Humidity was studied during 2014 in winter, summer and monsoon season at Jabalpur city.

From Table 1 it was observed that average value of PM_{10} in winter season is 102µg/m^3 and meteorological parameter value of Temperature is 18ºC or Relative Humidity is 65% (Figs. 6, 7). From Table 2 in summer season it was found that the value of PM_{10} is 89µg/m^3 and temperature is 29ºC or Relative Humidity is 43% (Figs. 8, 9).

At last form the Table 3 which is monsoon season the value of PM_{10} is 56µg/m^3 and temperature is 27ºC and Relative Humidity is 73% (Figs. 10, 11).

Variation of all the season is calculated in table-5 and it found that in winter season, the value of PM_{10} is maximum as compared to summer and monsoon season. Maximum concentration of PM_{10} is found may be due to the reason of decreasing temperature (Fig. 14). In summer and monsoon season, it was found that PM_{10} is decreasing and temperature is increasing or relative humidity as it is as a season no effect found by this parameter (Fig. 15).

Yearly average value of particulate matter (PM_{10}) and meteorological parameter like temperature or relative humidity in 2014 is presented in Table 4. After this calculation the value of PM_{10} is 82µg/m^3 and temperature value is 25ºC and relative humidity is 60%. Fig. 12 shows the variation between PM_{10} and Temperature and Fig.13 shows the variation between PM_{10} and Relative Humidity.

Table 1. PM_{10} and meteorological parameter (Temperature and Relative Humidity) winter season average value in 2014.

MONTHS	Parameters Unit	PM_{10} (µg/m³)	Temperature (°C)	Relative Humidity (%)
	November	116	21	55
	December	113	16	61
	January	107	17	75
	February	71	18	68
	Avg.	102	18	65
	Min.	71	16	55
	Max.	116	21	75

Fig. 6: Variation of PM_{10} and Tem. in winter season.

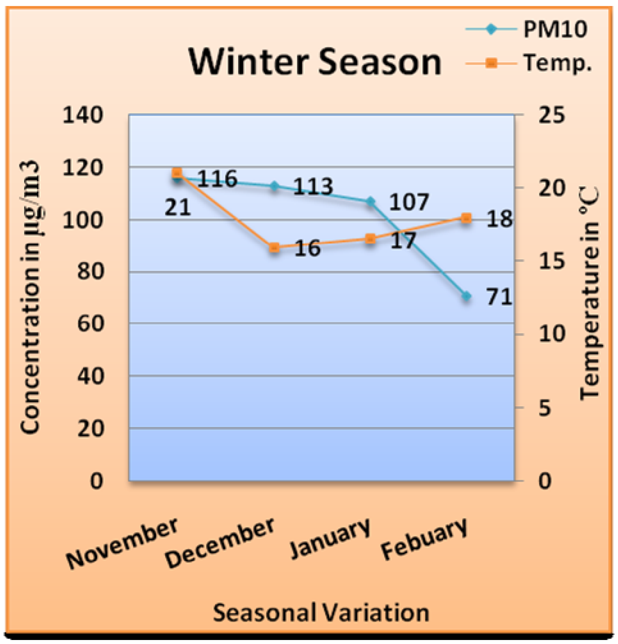


Fig. 7: Variation of PM_{10} and R.H. in winter season.

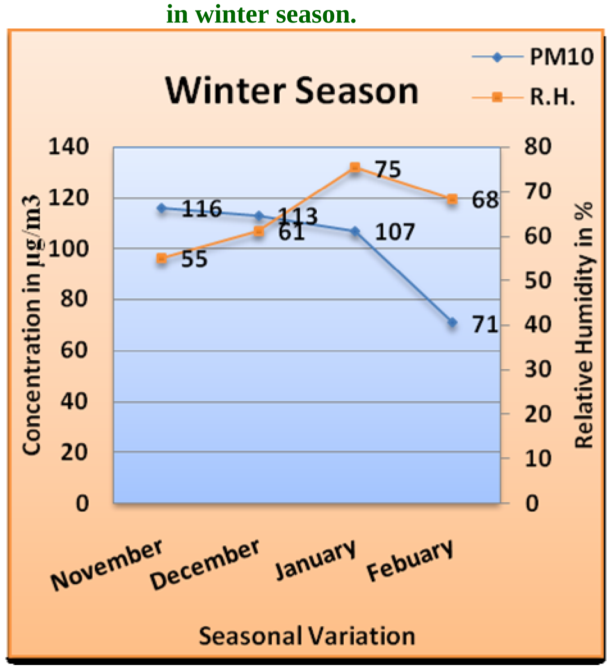


Table 2. PM_{10} and meteorological parameter (Temperature and Relative Humidity) summer season average value in2014.

MONTHS	Parameters Unit	PM_{10}(µg/m³)	Temperature(°C)	Relative Humidity(%)
	March	71	22	56
	April	103	29	37
	May	100	32	33
	June	82	33	46
	Avg.	89	29	43
	Min.	71	22	33
	Max.	103	33	56

Fig. 8: Variation of PM_{10} and Tem. in summer season.

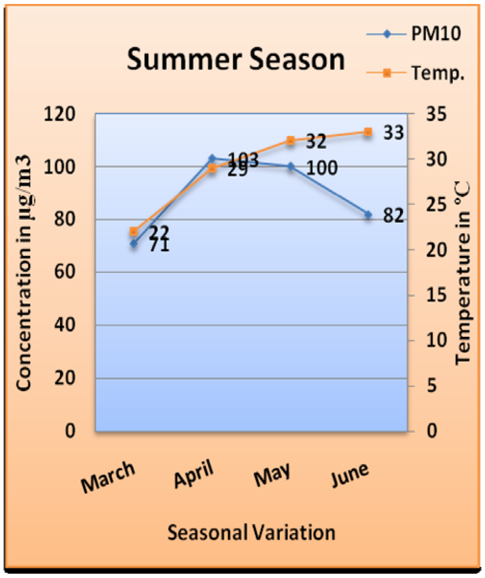


Fig. 9: Variation of PM_{10} and R.H. in summer season.

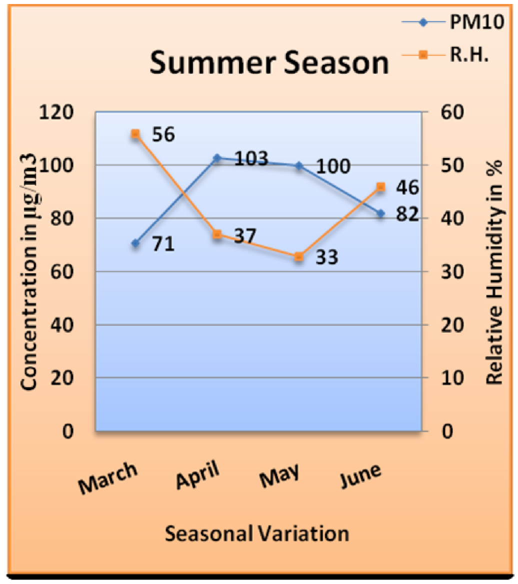


Table 3. PM_{10} and meteorological parameter (Temperature and Relative Humidity) monsoon season average value in 2014.

	Parameters Unit	PM_{10} (µg/m³)	Temperature (°C)	Relative Humidity (%)
MONTHS	July	41	29	73
	August	44	28	76
	September	52	27	75
	October	86	25	67
	Avg.	56	27	73
	Min.	41	25	67
	Max.	86	29	76

Fig. 10: Variation of PM_{10} and Tem. in monsoon season.

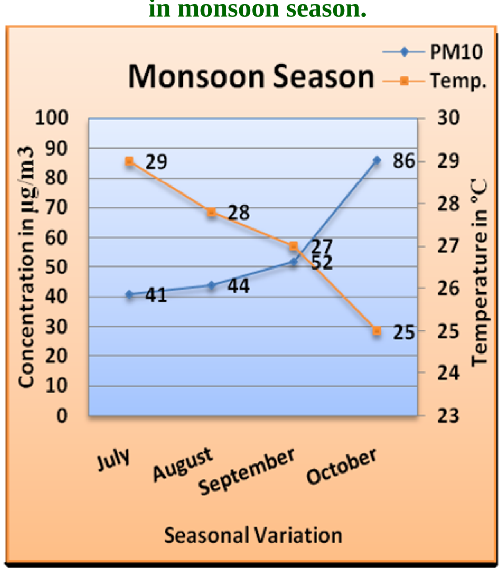


Fig. 11: Variation of PM_{10} and R.H. in monsoon season.

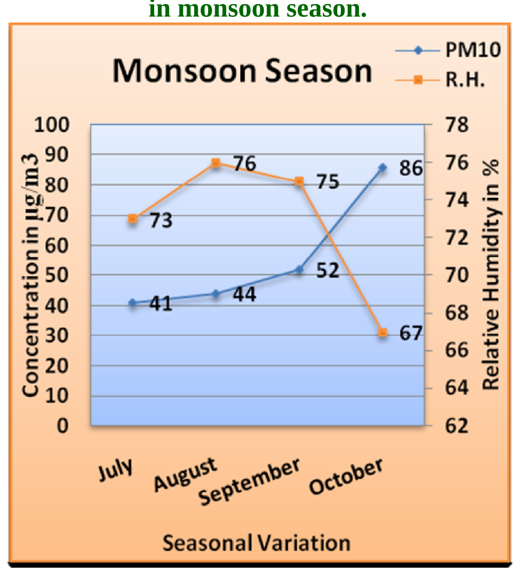


Table 4. PM_{10} and meteorological parameter (Temperature and Relative Humidity) all the season yearly average value in 2014.

	Parameters Unit	PM_{10} (µg/m³)	Temperature (°C)	Relative Humidity (%)
MONTHS	January	71	17	75
	February	71	18	68
	March	103	22	56
	April	100	29	37
	May	82	32	33
	June	41	33	46
	July	44	29	73
	August	52	28	76
	September	86	27	75
	October	116	25	67
	November	113	21	55
	December	82	16	61
	Avg.	41	25	60
	Min.	116	16	33
	Max.		33	76

Table 5. PM_{10} and meteorological parameter (Temperature and Relative Humidity) seasonal average value 2014.

Parameter	PM_{10}	Temperature	Relative Humidity
Winter	102	18	65
Summer	89	29	43
Monsoon	56	27	73
Avg.	82	25	60

Fig. 12: Yearly variation of PM_{10} and Temperature.

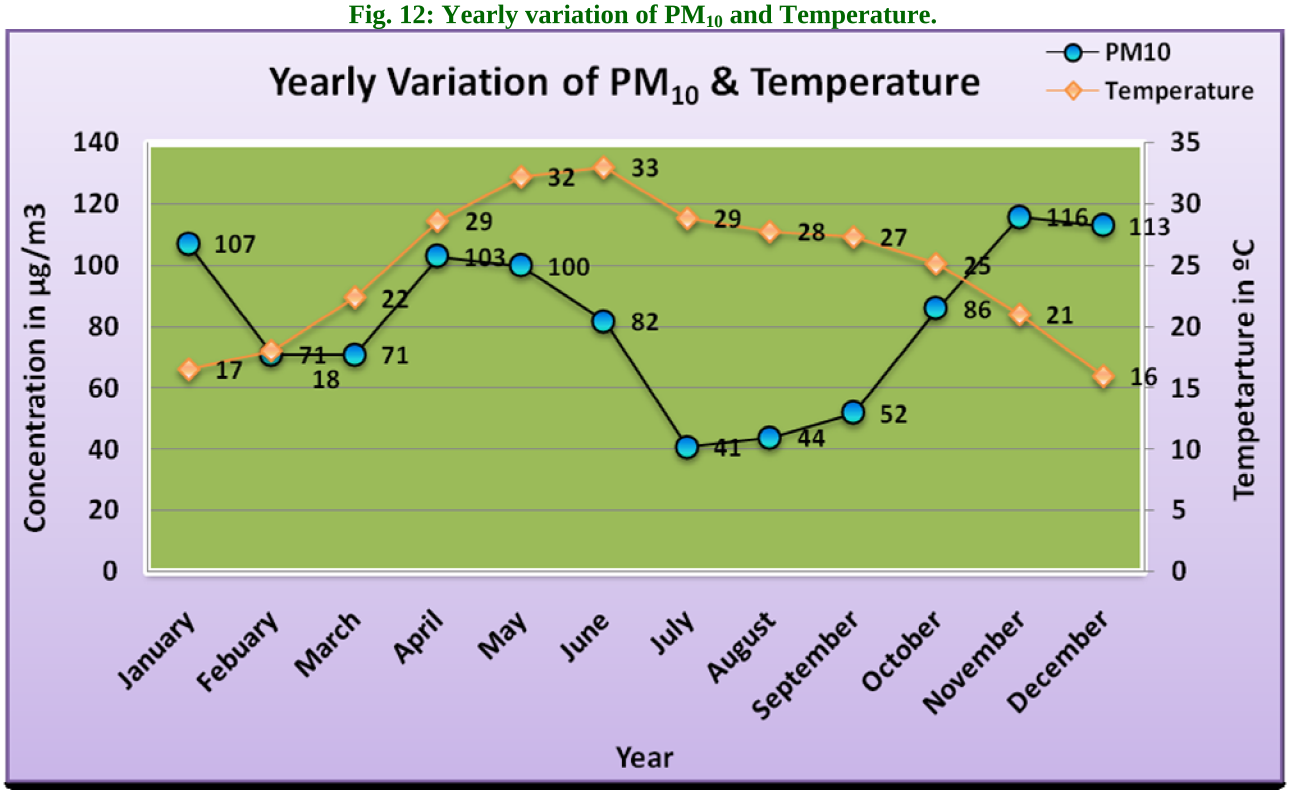


Fig. 13: Yearly variation of PM_{10} and Relative Humidity.

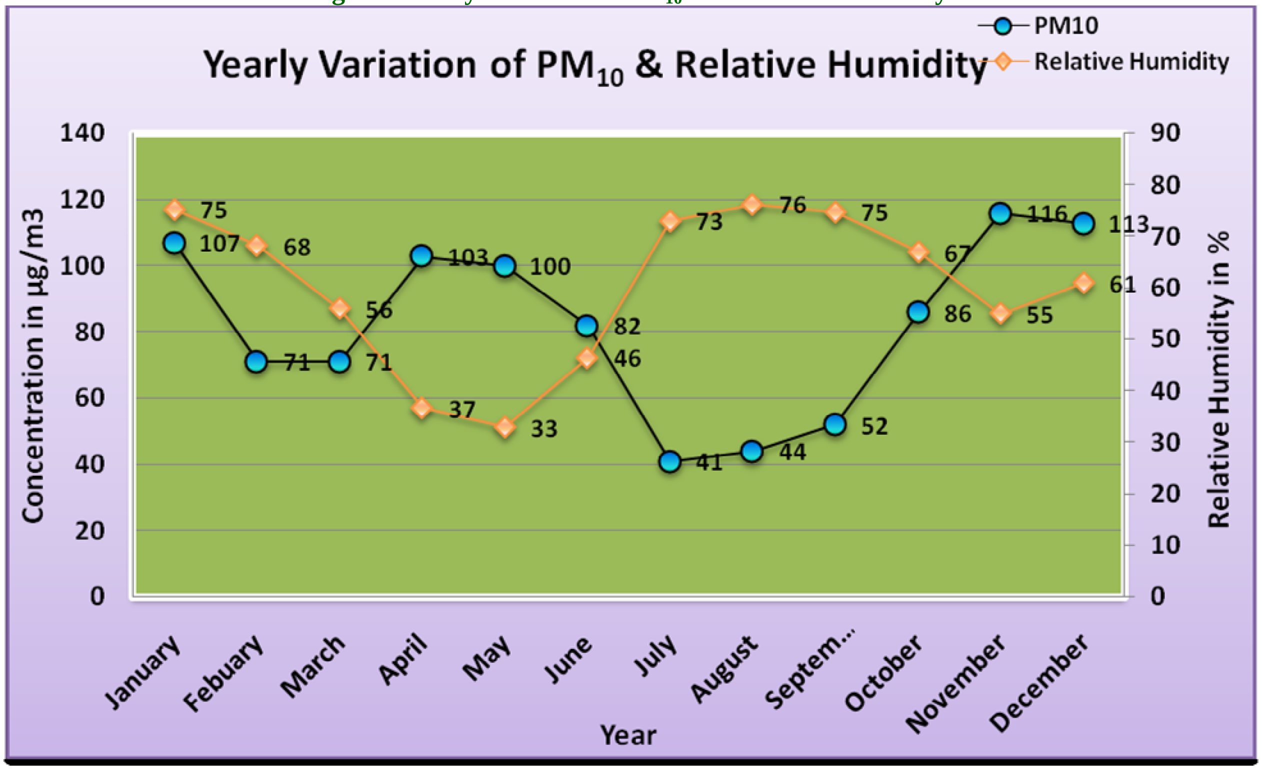


Fig. 14: Seasonal variation of PM_{10} and Temp.

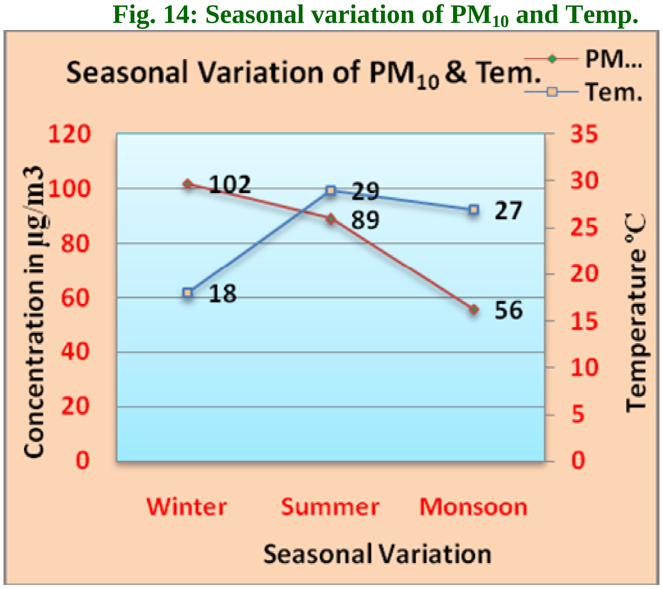
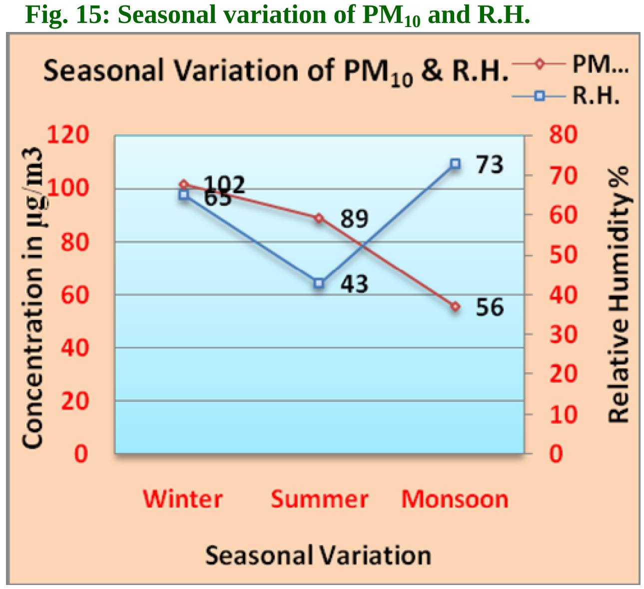


Fig. 15: Seasonal variation of PM_{10} and R.H.



Studies conducted in other places also showed the similar kind of results. Giri et al. (2008) reported that the atmospheric pressure, wind velocity and humidity was found to be significant factors compared to others influencing PM10. According to their study increase of rainfall and humidity has negative correlation with average PM10 concentration in Kathmandu valley. Bhaskar and Mehta (2010) observed suspended particulate matter concentration and air quality, and particulate pollutant concentration was compared with meteorological variables such as rainfall, humidity, temperature, and wind speed; SPM and PM_{10} showed negative correlations with rainfall. Mamtimin et al. (2011) observed very high consumption rates of fossil fuels for energy generation and domestic heating are mainly responsible for high annual pollution levels, as well as the very high winter/summer ratios. Annual and seasonal variations of pollutant's concentrations are discussed in the context of occurrences of inversions, boundary layer, stability classes, and Air Stagnation Index (ASI). The Pearson correlation coefficient between PM10 with temperature and relative humidity during 2014 is shown in Table 6.

Table 6: Pearson Correlation Coefficient between PM10 with Temperature and Relative Humidity during 2014.

PM_{10} with Temperature	PM_{10} with Relative Humidity
r = -0.3695	*r = -0.5321*
This is a negative correlation; the relationship between two variables is only weak.	This is a moderate negative correlation, which means there is a tendency for high X variable scores to go with low Y variable scores (and vice versa).
The value of r^2, the coefficient of determination, is *0.1365*.	The value of r^2, the coefficient of determination, is *0.2831*.

Conclusion

In this study correlations of particulate matter (PM 10) with various meteorological parameters have been studied. Result shows negative corellation with all the parameters studied.

Acknowledgement

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