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Ambient Air Quality Monitoring with Reference to Particulate Matter (PM_{10}) in Kolhapur City

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ABSTRACT

Air is an important medium for all living beings and is essential for the well-being of all. Monitoring of air is important to know the quality of air. The air quality monitoring was carried out in Kolhapur City under the National Air Monitoring Program. The present study involves the assessment of PM_{10} as described in the National Ambient Air Quality Standards (NAAQS). The source apportionment study related to particulate matter was carried out in Kolhapur City. The study also determined the average PM_{10} concentration in the city as it will be useful for preparing an action plan to reduce PM_{10} concentration. PM_{10} concentration was calculated as per the standard method adopted by CPCB. Sampling was carried out for 8 hours in three shifts twice a week at each sampling site for three consecutive years. Mahadwar Road (MR) and Dabholkar Corner (DC) were selected per the surrounding residential area, population density, and traffic conjunction. The third site Shivaji University (SUK), was selected as a control site. The results indicated that the PM_{10} level has risen above the prescribed standards of NAAQS. The reason for the rise in PM_{10} may be due to fossil fuel burning, construction activity, vehicles, and unpaved roads. The Analysis of Variance (ANOVA) technique is used to check the equality of the mean concentration of PM_{10} at these three locations and found a significant difference between mean concentrations of PM_{10}, suggesting increased particulate matter.

INTRODUCTION

Determining the amount of particulate matter in the Earth's atmosphere was the initial focus of studies on atmospheric chemistry. Finding the sources, characteristics, and consequences of different chemical species in the clean and polluted air grew more important as air pollution became an increasing concern in many large cities. Urban air pollution is a significant issue in many countries throughout the world. According to the growing urbanization rates in Indian urban areas, poor air quality is essential to declining quality of life and negative consequences on people's wellness. Since crucial pollutants such as particulate matter (PM_{10} and $PM_{2.5}$), NOx, SO_2, and O_3 are commonly found to exceed the National Ambient Air Quality Standard (NAAQS) limits and therefore, air quality monitoring has become increasingly important in recent decades (Guttikunda et al. 2014). The primary pollutant causing the decline in ambient air quality is particulate matter (PM) released from anthropogenic and natural sources.

The particulate matter is categorized as coarse ($PM_{2.5-10}$) and fine ($PM_{2.5}$) particles based on aerodynamic diameter. It was discovered that vehicular activity and associated emissions, including biomass burning, diesel generators, vehicles, and commercial coal burning, are the main PM sources. Vehicle exhaust and non-exhaust emissions were divided into two categories. Exhaust emissions come from a vehicle's tailpipe, whereas non-exhaust emissions come from the wear and tear of the vehicle, i.e. by abrasions of the brake, tire, clutch, and road dust re-suspension. These particles have been shown to harm human health and are released close to human activity (Buckeridge et al. 2002, Rissler et al. 2012).

In Indian cities, worsening urban air quality is a significant cause of health concerns. It was discovered that the amount of various dangerous contaminants and their concentration in the ambient environment exceeded health-based criteria. PM has been regarded as one of these pollutants' main public health issues. In the recent past, the vehicular population in urban areas has taken up a hasty increase. It contributes a major part to declining ambient air quality in urban areas. Additionally, small-scale enterprises working inside urban communities were found to play a significant role in worsening the ambient air quality (Pant & Harrison 2013).

The current study area is Kolhapur City, a tourist place and industrial hub. Its increased urbanization and industrialization pose a threat to deteriorating the ambient air quality, especially from vehicular emissions. In Kolhapur alone, approximately 3 lakh commercial and private vehicles release 1 ton and more PM10 into the atmosphere daily. Thus, there is a compelling need to frame an air quality management plan to formulate effective strategies to control ambient air pollutants. National ambient air quality standards (NAAQS) have been established for the parameters particle matter ($PM_{2.5}$) of less than 2.5 microns and particulate of less than 10 microns (PM_{10}) (CPCB 2009, 2011).

MATERIALS AND METHODS

Kolhapur city is known as Dakshin Kashi and Karveer Nagari, located on mountain ranges of the Western Ghats part of the Maharashtra state. The city has a network of 974.01 km of roads of different widths and types. It has a national highway of around 3.79 km, a state highway of around 29.41 km, other main district roads of around 1.87 km, and other roads of around 938.94 km.

There are 10,95,948 two-wheelers and 2,64,700 private and commercial vehicles registered in the city. The city Goddess Ambabai temple and 20 km away Shree Jotiba Temple is located, and all through the year, numerous festivals are celebrated in Kolhapur city. Therefore, the city is a popular tourist place all over the country. In the city, two industrial areas are Shivaji Udamnagar and Y. P. Powar Nagar. In those areas, foundries, showrooms, machine shops, and silver ornamental industries are situated. Many other developmental activities are increasing at a noticeable rate. Public transport facilities are also available in the city. In some villages, Kolhapur Municipal Transportation provides transportation for the city and around the city. CBS, Rankala Bus Stand, and Sambhaji Nagar Bus Stand are the state government's transport bus services hubs that provide inter-state and inter-district transport services for the public and freight. At the same time, roads and building construction activity, brick kilns, and increased road traffic, including private, commercial, and government vehicles, are responsible for the emission of particulate matter. A study was conducted to track the changes in ambient air quality from January to December of the years 2017, 2018, and 2019 to evaluate the ambient air quality in Kolhapur City. The mean and standard deviation were used in the descriptive statistical analysis of PM_{10} concentration, and a radar diagram and simple bar chart were used for the graphical presentation. to compare the mean PM_{10} concentration at the chosen locations using the Analysis of Variance (ANOVA) method.

Sampling Sites

The purpose of choosing the three sampling locations was to represent commercial, residential, and background site influences. Three places for sampling were chosen Dabholkar Corner (DC), Mahadwar Road (MR), and the Department of Environmental Science at Shivaji University (SUK). Dabholkar Corner is situated near the central bus stand, railway station, and private bus stand. In this area, many hotels, many shops, and lodges are situated. This area has dense traffic. Mahadwar Road is the main marketplace, and the goddess Ambabai temple is situated here. All pilgrims and local people visit the temple. The main clothing and vegetable market is here. Last few years in this area, lodges number has increased. Densely populated area situated around the Mahadwar Road site. Traffic congestion in these two; areas plays the main role in increasing air pollution. Shivaji University's location is at a minimum pollution level due to restricted activities in the university premises but in front of the university old Pune-Bangalore highway is situated. This road is one of the city's most important and busy roads. The locations of the sampling sites are shown in Fig. 1.

Measurement Techniques

Particulate matter testing was carried out throughout 2017, 2018, and 2019. A sample of 24 hours is taken twice weekly at each sampling site. In Table 1, the details of sampling locations are given. Envirotech's calibrated APM 460DX and APM 460NL Respirable Dust samplers (RDS) were used for sampling at flow rates of 1.0 to 1.2 $m^3.min^{-1}$ as recommended by the CPCB on a pre-weighed 8 x 10-inch glass fiber filter paper. PM_{10} was quantified using the gravimetric method (IS 5182 Part IV) and the HVS filtering method. The weight of the filter paper affects both the concentrations and quantity of dust collected. The sampling apparatus was set up three to ten meters above the ground. The collected samples were brought to Shivaji University's Environmental Science lab for further examination.

RESULTS AND DISCUSSION

The PM_{10} concentration was monitored at Shivaji University, Dabholkar Corner, and Mahadwar Road during 2017, 2018, and 2019. There were around 105 sampling days for each year. The PM_{10} data varied from site to site, season to season,

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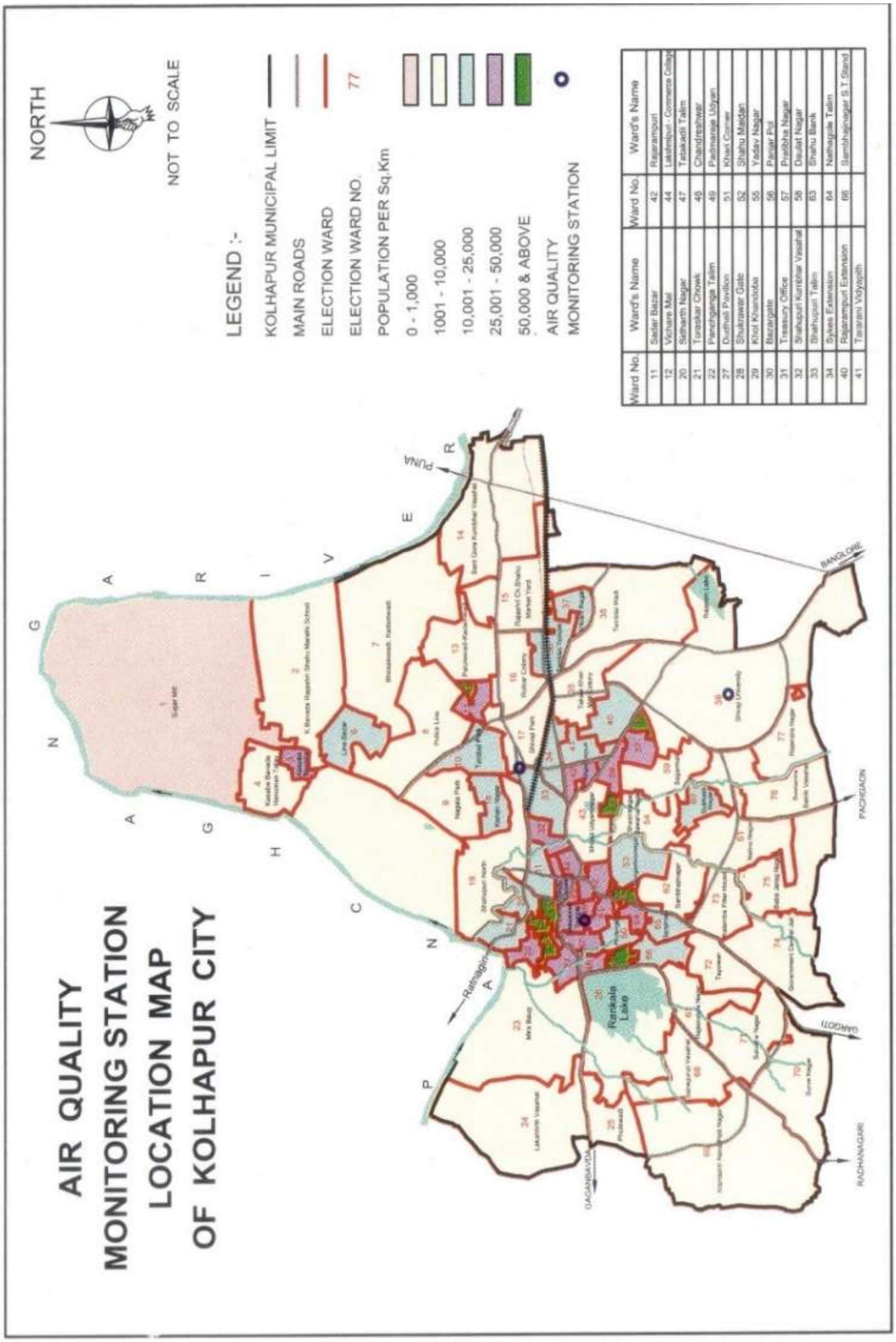

Fig. 1: Sampling Sites in Kolhapur City.

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Table 1: Ambient Air Quality Monitoring Sampling Site of Kolhapur City.

Sr. No.	Sampling site	Location	Status	Monitoring day and time
1.	Dabholkar Corner, Kolhapur	Longitude – 1615.35‘42°” N Latitude – 7430.25‘14°” E Elevation – 1850 ft	Ratnagiri highway, CBS, Railway station, main road to enter city, visitor’s no is more, Commercial area	2017, Monday 6 AM to Tuesday 6 AM 2018 -19, Wednesday 6 AM to Thursday 6 AM
2.	Mahadwar Road, Kolhapur	Longitude - 1640.15‘41°” N Latitude – 7418.40‘13°” E Elevation – 1847 ft	Heavy traffic density, Vegetable and Cloth market, Goddess Ambabai temple, crowded area	2017, Wednesday 6 AM to Thursday 6 AM 2018-19 Tuesday 6 AM to Wednesday 6 AM
3.	Dept of Environmental Science, Shivaji University, Kolhapur	Longitude - 1636.00‘40°” N Latitude – 7410.28‘15°” E Elevation – 1956 ft	Educational Institute, less traffic, in front of University Old national highway is passes	2017, Tuesday 6 AM to Wednesday 6 AM 2018-19 Monday 6 AM to Tuesday 6 AM

i.e., from 30 to 150 and above. The frequency distribution of PM_{10} concentration at these three locations, along with the standard, is shown in Fig. 3.

Fig. 3 shows that the maximum frequency of PM_{10} concentration at the DC site where PM_{10} exceeds the standard, i.e. $\mu g.m^{-3}$, was 72 times in 2017, 79 times in 2018, and 85 times in 2019. MR site where PM_{10} exceeded the standard was 40, 34, and 49 times respectively. SUK site PM_{10} concentration is not observed above the standard in all studied years.

The results of the study for locations SUK, DC, and MR are shown as a monthly mean concentration of PM_{10} during 2017, 2018, and 2019 in Table 2. From the three locations studied, Dabholkar Corner’s mean concentration of PM_{10} exceeded the NAAQS limit, i.e., 100 $\mu g.m^{-3}$ throughout the year except in monsoon season i. e. June, July, and August during 2017, 2018, and 2019. This location is near the central bus stand, railway station, and commercial area; hence, traffic intensity is maximum compared to other locations. The local sources found in metropolitan areas and the long-distance movement of the air pollutants play a significant role in assessing PM concentrations and sources. Developed nations have a greater variety of PM sources (Abulude 2016). This is followed by Mahadwar road PM_{10} concentration which exceeded the NAAQS limit in January, February, March except 2018, April, May 2019, and December 2017, 2018, and 2019. Sometimes high air pollution load is observed at MR, a commercial area and one of the famous religious places in India. Hence, the large vehicular activity of the locals as well as tourists is observed in this place (Manglekar et al. 2015).

On the contrary, at the Shivaji University campus, PM_{10} concentration was observed below the prescribed NAAQ standards in all seasons during 2017, 2018, and 2019, as it is located at the boundary of the city. The site has less traffic density observed due to the educational institute and a large area covered by green plants. Trees absorb air pollution, reducing the concentration of contaminants in the air (Prajapat & Tripathi 2008). Due to their ‘porous’ nature, plants help remove and deposit airborne pollutants while influencing regional air pollutant dispersion patterns (Escobedo & Nowak, 2009, Fantozzi et al. 2015). Urban roadside plants’ foliar surfaces serve as sinks for the deposition of PM, and as a result, they exhibit particular morphological, physiological, and biochemical responses. The deposition of PM particles on a leaf surface results in structural and functional alterations (Lalita & Kumar 2015).

The data analysis demonstrates unequivocally that PM_{10} is becoming a crucial pollutant that requires special attention. Additionally, these particles are crucial in contributing to environmental issues, including climate change and reduced visibility (Gunasekaran et al. 2012). As PM_{10} disperses over a wide area, it interacts chemically with respiratory system molecules, damaging the processes and causing unfavorable chemical changes. These might make people’s lungs less capable (Ghose et al. 2005). It results in a negative relationship between precipitation and PM_{10} concentration which can be explained by the well-known wet removal mechanism (Flossmann et al. 1985). The presence of PM_{10} in the atmosphere has been linked to health problems, an increase in mortality, morbidity, and asthma (Dockrey et al. 1993). While drifting pollutants increase concentration per unit area in the summer, settling is the primary factor for reduced pollution levels during the rainy season (Patil et al. 2019). Because air pollutants, particularly PM_{10}, are washed off during precipitation, ambient pollutant concentration was at its lowest, with winter and summer recording the most significant levels (Manglekar et al. 2013).

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Table 2: Month-wise average concentration ($\mu g.m^{-3}$) of Atmospheric PM_{10} in Kolhapur City during 2017, 2018, and 2019.

Sr. No.	Month	Year	Shivaji University	Dabholkar Corner	Mahadwar Road	NAAQS (2009)
1.	January	2017	62.50 ±12.97	**144.44** ±30.81	**120.92** ±22.28	100
		2018	80.86 ±12.07	**146.45** ±28.02	**126.70** ±24.71	100
		2019	71.37 ±13.27	**142.44** ±28.94	**122.22** ±19.18	100
2.	February	2017	59.11 ±11.69	**140.36** ±31.27	**104.25** ±22.58	100
		2018	70.31 ±11.81	**122.14** ±21.08	**106.68** ±16.60	100
		2019	70.05 ±10.22	**135.07** ±20.94	**118.92** ±16.11	100
3.	March	2017	68.21 ±14.51	**149.23** ±36.59	**102.08** ±21.20	100
		2018	70.10 ±12.29	**116.74** ±19.97	97.76 ±11.64	100
		2019	67.63 ±11.35	**142.45** ±22.46	**110.42** ±16.05	100
4.	April	2017	78.56 ±12.25	**150.78** ±30.67	**109.80** ±16.21	100
		2018	73.57 ±17.64	**121.44** ±17.48	**103.21** ±12.33	100
		2019	70.23 ±12.75	**138.12** ±20.90	**118.13** ±18.02	100
5.	May	2017	62.50 ±13.59	**120.06** ±29.26	90.28 ±17.17	100
		2018	63.50 ±10.07	**112.15** ±21.78	88.27 ±17.47	100
		2019	65.20 ±13.21	**133.49** ±27.52	**106.48** ±17.06	100
6.	June	2017	51.93 ±17.83	**104.05** ±17.91	75.91 ±16.66	100
		2018	53.17 ±10.38	86.00 ±12.13	69.60 ±9.65	100
		2019	53.14 ±14.55	**103.17** ±11.40	83.81 ±11.82	100
7.	July	2017	42.82 ±15.52	72.31 ±17.61	59.38 ±15.92	100
		2018	47.07 ±7.40	97.52 ±15.86	74.11 ±10.85	100
		2019	47.80 ±9.14	90.67 ±10.83	69.15 ±9.62	100
8.	August	2017	39.66 ±13.32	80.56 ±19.79	62.58 ±16.35	100
		2018	47.38 ±7.48	**101.35** ±11.43	85.59 ±11.12	100
		2019	50.52 ±10.90	**100.42** ±12.55	78.53 ±12.37	100

Table Cont....

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Sr. No.	Month	Year	Shivaji University	Dabholkar Corner	Mahadwar Road	NAAQS (2009)
9.	September	2017	43.19 ±12.80	**102.62** ±23.09	73.96 ±17.90	100
		2018	70.23 ±11.13	**105.64** ±16.84	86.42 ±14.26	100
		2019	60.01 ±7.74	**120.79** ±16.54	83.33 ±11.36	100
10.	October	2017	57.18 ±14.86	**105.75** ±29.98	82.90 ±28.23	100
		2018	52.16 ±9.29	**107.72** ±10.43	86.34 ±8.38	100
		2019	56.75 ±11.35	**124.73** ±21.66	87.85 ±11.14	100
11.	November	2017	57.41 ±10.85	**109.64** ±17.95	95.99 ±15.42	100
		2018	48.69 ±8.38	**112.04** ±15.57	92.45 ±17.81	100
		2019	53.70 ±10.29	**111.81** ±18.68	95.14 ±13.96	100
12.	December	2017	62.33 ±15.17	**133.64** ±31.59	**111.19** ±27.46	100
		2018	66.32 ±10.24	**135.11** ±24.88	**114.12** ±16.47	100
		2019	56.03 ±11.52	**139.04** ±25.97	**112.73** ±19.06	100

Note: Bold values show the concentration of PM_{10} is above the NAAQS. Figures indicate Mean ± SD

Pollutants are transferred from the atmosphere to the surface of the ground through a process called deposition. Precipitation, scavenging, and sedimentation are its three constituent phenomena. The surface on which the particles are deposited is among the climatic factors and the characteristics of the particles that matter most (Damian 2019). Sharp edges, friction velocity, micro-scale roughness, and surface temperature significantly impact the deposition process, as demonstrated by Jonsson et al. 2008. Buildings and vegetation play a significant impact in metropolitan settings. According to earlier research, high winds frequently cause changes in vegetation density (Janhall 2015). It has been said that the primary factors governing the transport of air pollutants are wind speed and direction. These are all connected in some way to temperature. Put another way, the more wind there is, the more turbulence there is, and the more quickly and completely contaminants in the air disperse (Guttikunda & Gurjar 2012).

Fig. 2 shows the mean concentration of PM_{10} below the NAAQS observed in SUK for 2017, 2018, and 2019. According to research on street canyons in central London (Jeanjean et al. 2017) and Leicester (Jeanjean et al. 2016), trees' aerodynamic effects outweighed their deposition effects. This is confirmed by the above results.

Mahadwar Road PM_{10} concentration of January, February, and March, except for 2018, April, and May 2019, is above the NAAQ standards. Lack of road space and unplanned traffic hinder typical vehicular movements, which raises fuel consumption and exhaust emissions (Wijetileke & Krunatune 1995). In December every year, the PM_{10} concentration is observed above the NAAQ standards, and Dabholkar corner represents the concentration of PM_{10} always higher than the other locations except rainy season. Pollutant particulate matter in the sub-micron range, or 10^{-6} m diameter, is buoyant and stays suspended. A better knowledge of the relationship between particulates and morbidity points to the significance of sub-micron particles (PM_{10}), the primary source being motor vehicles (Anon 1995). A study on the assessment of ambient air quality concerning PM_{10}, SO_2, and NO_2 in the Bishnumati corridor, Kathmandu metropolis, found that heavy traffic and few roads without asphalt: perceivable mal-odor and the persistent stench emanating from the careless disposal and subsequent purification process, dense population, and increased commercial activities are other vital contributing sources to the end-result pollution of the corridor (Simkhada et al. 2005). People in Singapore, Japan, and Hong Kong are dealing with severe PM issues due to increased motorized

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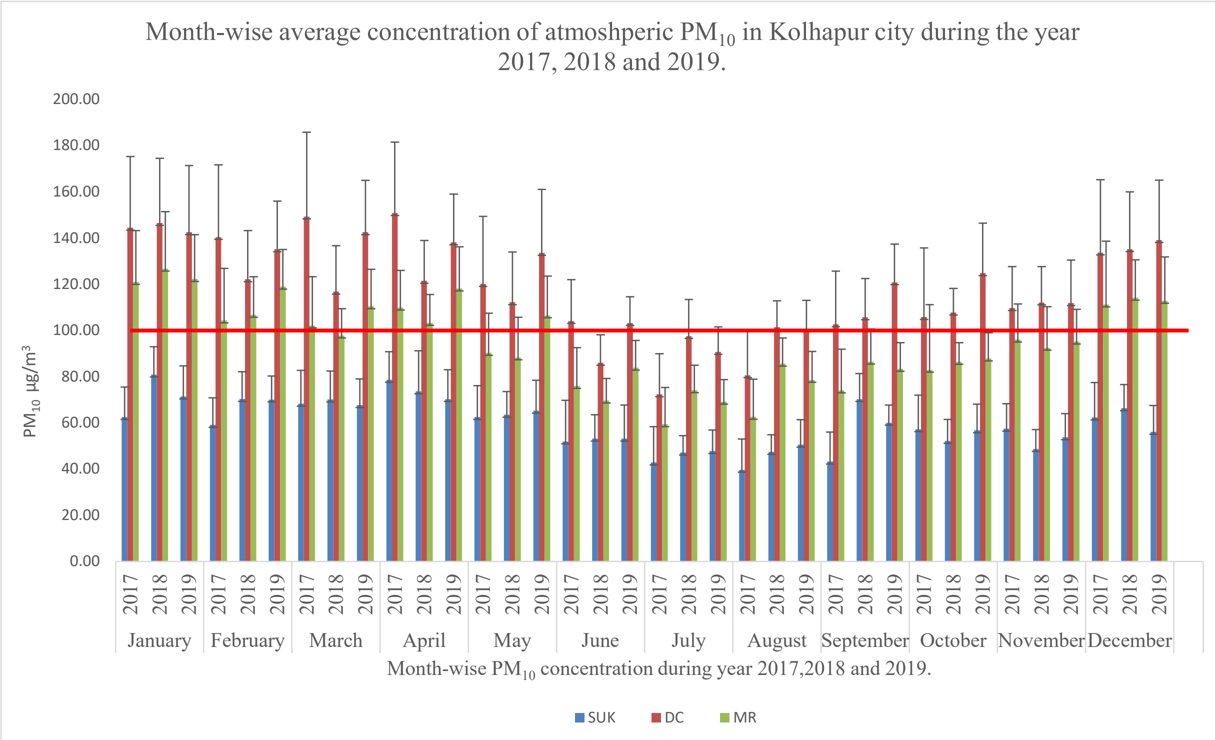

Fig. 2: Month-wise average concentration of atmospheric PM_{10} in Kolhapur city during the years 2017, 2018, and 2019.

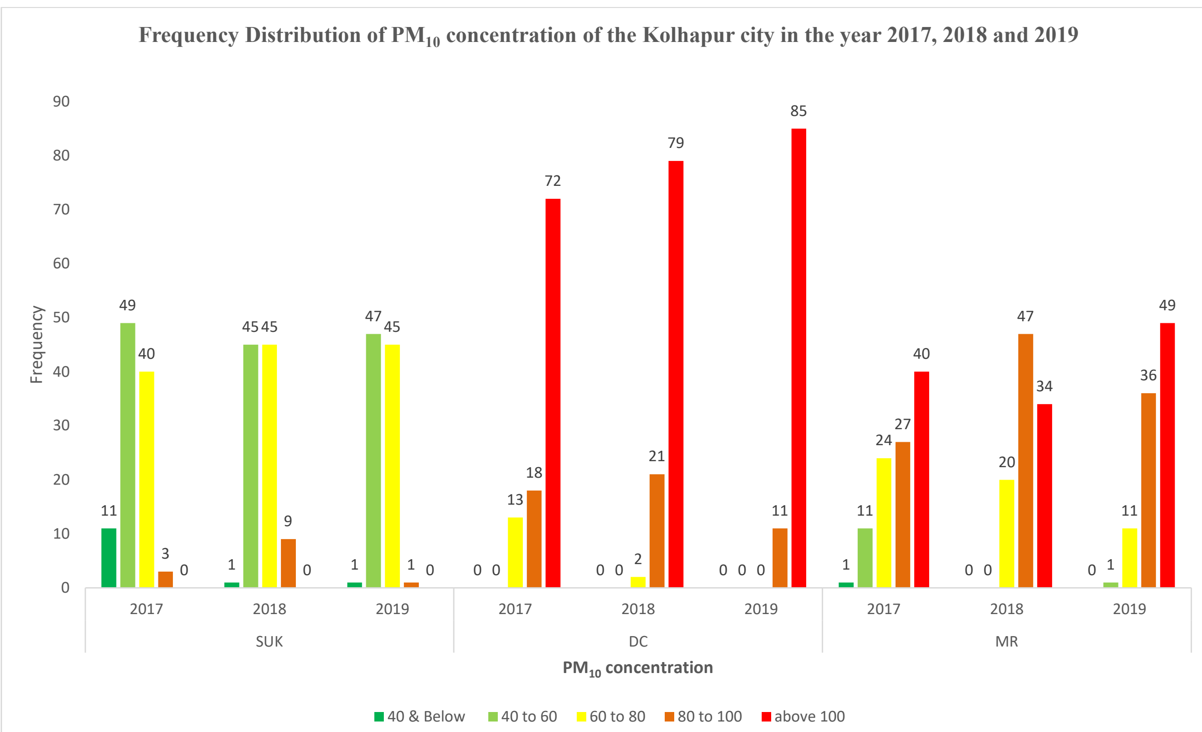

Fig. 3: Frequency distribution of PM_{10} concentration of Kolhapur city in the years 2017, 2018, and 2019.

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Table 3: One-way ANOVA test results for PM_{10} based on different locations.

Source	Sum of Squares	Degree of Freedom	Mean Square	F - Values	p- Value	F – critical value	Decision
The year 2017							
Between locations	22173.92	2	11086.96	27.2799	1.02×10^{-7}	3.2849	Reject H_0: There is a significant difference between mean concentrations of PM_{10}
Within locations	13411.67	33	406.4141				
Total	35585.58	35					
The year 2018							
Between locations	16397.33	2	8198.663	36.5283	4.31×10^{-9}	3.28491	Reject H_0 : There is a significant difference between mean concentrations of PM_{10}
Within locations	7406.756	33	224.4472				
Total	23804.08	35					
The year 2019							
Between locations	24446.62	2	12223.31	50.7384	8.57×10^{-11}	3.2849	Reject H_0 : There is a significant difference between mean concentrations of PM_{10}
Within locations	7949.984	33	240.9086				
Total	32396.6	35					

transportation (Edesess 2011). The study's multiple parameters have multiple sources for variation. They have to do with the variability of emissions from both point and non-point sources and potential changes in geographical factors such as mixed layer depth, wind speed, and relative humidity levels.

Analysis by One-Way ANOVA Test

The monthly mean concentration of PM_{10} for the years 2017, 2018, and 2019 at three locations, namely Dabholkar Corner (DC), Mahadwar Road (MR), and Shivaji University (SUK) of Kolhapur City, was recorded. Interest is to test the equality of the mean concentration of PM_{10} at three locations for a particular year. The claim was made with the help of one-way analysis of variance (ANOVA) technique. The null hypothesis (H_0) and alternative hypothesis (H_1) as H_0 were set. There is no significant difference between mean concentrations of PM_{10} at three locations H_1: There is a significant difference between mean concentrations of PM_{10} at three locations.

Now test H_0 against H_1 at a 5% level of significance (LOS). Table 3 reports the ANOVA results and shows that the p-values are significant for all three years. Thus, it can be concluded that there is a significant difference between mean concentrations of PM_{10} at three locations for each year.

CONCLUSION

Due to urbanization, an increase in the number of vehicles, industrialization, the use of fuel with poor environmental performance, and weak environmental legislation, ambient air quality has been steadily declining in India and other developing nations. The city of Kolhapur needs to control traffic pollution due to a higher level of PM_{10} concentration at Dabholkar Corner than in the other two places. Shivaji University consistently has the lowest PM_{10} concentration, ascribed to low traffic volume and rich canopy areas. The current study results show that greater transportation planning is required, with an awareness of the necessity for minimal automobile use and well-planned traffic routes. The Ambient Air Quality Network lays forth the fundamental guidelines for assessing the air quality of Kolhapur. Due to considerable traffic, particularly in the morning and evening, Dabholkar Corner has consistently displayed the highest PM_{10} concentration. Shivaji University has low PM_{10} concentrations, while Mahadawar Road has medium PM_{10} concentrations. The concentration of PM_{10} was found to be mostly associated with transportation and higher in the winter than in the summer or during the monsoon. ANOVA results indicate a significant difference between mean concentrations of PM_{10} at these three locations. It is suggested that a sizable green plantation be established around the region. Alongside the highways, planting trees that are effective at retaining dust is recommended, and water should be sprayed continually where particulate matter is produced.

Some megacities in developed countries have recently shown signs of improvement in terms of PM. This is because the Urban Air Quality Management Plan (UAQMP) has been implemented (Gulia et al. 2015). According to a report from the European Environmental Agency (EEA), from 1990 to 2009, pollutants decreased by 16 percent (PM_{10}) and 21 percent, respectively ($PM_{2.5}$). It has also been noted that despite strenuous efforts, 18 to 49% of the populace in these nations is still in danger of exposure to PM_{10} levels above the regulatory limits (EEA 2014). In US megacities, high PM concentration values from 1999 had decreased by

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around 38% by 2010, yet in some places, the safety standards are being broken (USEPA 2012). But from 1997 to 2009, the average trend of $PM_{2.5}$ was more or less stable (Gulia et al. 2015).

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