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Comparative Particulate Matter (Pm_{10} & $Pm_{2.5}$) Analysis in Construction Sites and Residential Areas of Delhi

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ABSTRACT
Particulate matter is one of the dangerous and major components of air pollution. Construction site is one of the sources to produce particulate matter. As in Delhi, Construction is at peak, like there is construction of flyovers, metro stations, road, residential buildings etc. The objectives of this research are to monitor PM_{10} and $PM_{2.5}$ at various construction sites of Delhi, monitoring of PM_{10} and $PM_{2.5}$ at various residential areas of Delhi and the comparative analysis of monitored PM_{10} and $PM_{2.5}$ at residential areas and constructional sites. Handy sampler (pollution meter) was used to take the data/samples at the selected locations. The analysis of data has been done by using the Excel sheet. It was seen that the concentration of PM_{10} was more than $PM_{2.5}$ and concentration of particulate matter was more at construction sites than residential areas. On comparison between construction sites and residential areas, the construction sites have higher concentration of particulate matter. The construction areas are unsatisfied and unsafe, as it crosses the permissible limits of WHO and CPCB for particle pollution. As the previous researches have shown that the particulate matter has very serious health issues to the human so the safety should be provided to the workers at construction sites.

KEYWORDS: Analysis, Concentration, Construction site, Monitoring, Particulate Matter,

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I. INTRODUCTION

Particle pollutions are major parts of air pollutants. In a simple definition, they are a mixture of particles found in the air. Particle pollution which is more known as particulate matter is linked with most of pulmonary and cardiac-associated morbidity and mortality. Particulate Matter varies in size ranging mostly from 2.5 to 10 µm ($PM_{2.5}$ to PM_{10}). PM arises from different sources like burning of wood, heavy traffic, factories, construction and demolition activities etc. Construction site is one of the sources to produce particulate matter. Delhi is considered the most polluted capital in the world and ranks first. PM levels are very high in Delhi especially during the hindu religion festival 'Diwali', reason being the burning of crackers. Construction activities also add the PM concentration levels in Delhi pollution. The comparison of particulate matter between construction sites and residential areas has been done.

There are many pollutants which pollute the air and particulate matter is considered as one of the major pollutant which has contribution in polluting the atmosphere. Particulate matter (PM) is composed of inert carbonaceous cores with multiple layers of various adsorbed molecules, including metals, organic pollutants, acid salts and biological elements, such as endo-toxins, allergens and pollen fragments [Gualtieri et. al. 2009]. The greatest number of particle fall into the ultrafine size range, consisting of PM with a diameter of 0.1 µm or less (PM0.1). These ultrafine particles (UFPs) dominate the surface area of particulate pollution, but do not contribute largely to the PM mass (USEPA,2004). According to literature cited, it was observed that the most contributors to PM include vehicles, construction and demolition activities, industrial activity, household fuel, power sector, fugitive dust and unprocessed biomass fuel like wood, dung and crop residues (Alahmr et al. (2012), Dallman et al. (2014), Crilley et al. (2004), Onabowale and Owoade (2015), Fawole et al. (2016), Owoade et al. (2015) and Orogade et al. (2016). Dust storms, smoke from forests and grass fires, volcanic activities and spring dust have been noted to raise the PM levels above WHO guidelines. Araujo et.al. 2014 said that the issue of environmental protection is an important issue throughout the world. There are large direct and indirect effects of Building construction and operation on the environment. Pollution sources resulting from construction processes include harmful gases, noise, dust, solid and liquid wastes.

Air pollutants ambient such as PM2.5, PM 10, N02, S02 and CO cause the asthma and respiratory patient number increase (Guo et al., 2018). (Lamichhane et al., 2018) found that the exposure of emission to pregnant women in third trimester will give more impact and severe to the baby and mother.
The main objectives of the paper are to monitor PM_{10} and $PM_{2.5}$ at various construction sites of Delhi, monitoring of PM_{10} and $PM_{2.5}$ at various residential areas of Delhi and comparative analysis of monitored PM_{10} and $PM_{2.5}$ at Residential areas and Constructional areas

II. METHODOLOGY

Methodology gives the framework of processes by which the whole work has been completed. The main part of the methodology is the selection of the study area due to which the study becomes limited and is only carried out for the selected area. The other main parts of the methodology are monitoring instrumentation, monitoring procedure and data analysis procedure.

2.1 Selection Of The Study Area

Delhi, officially the National Capital Territory of Delhi (NCT), is a city and a union territory of India. Delhi is located at 28.61°N 77.23°E and lies in Northern India. It borders the Indian states of Haryana on the north, west and south and Uttar Pradesh (UP) to the east. The National Capital Territory of Delhi covers an area of 1,484 km^2 (573 sq mi), of which 783 km^2 (302 sq mi) is designated rural, and 700 km^2 (270 sq mi) urban therefore making it the largest city in terms of area in the country. It has a length of 51.9 km (32 mi) and a width of 48.48 km (30 mi).

2.1.1 Location Of The Selected Construction Areas

1) Construction site 1

Address: 272, TTI road, Gulmohar Enclave, Jamia Nagar, Okhla, New Delhi, 110025.

Activities at Construction Site 1	**Latitude**	**Longitude**
<u>Laying of Sewer pipes:</u> Excavation, Drilling, Laying of sewer pipes, Cement Work, movement of Vehicles, Labor Work	28.562653	77.289665

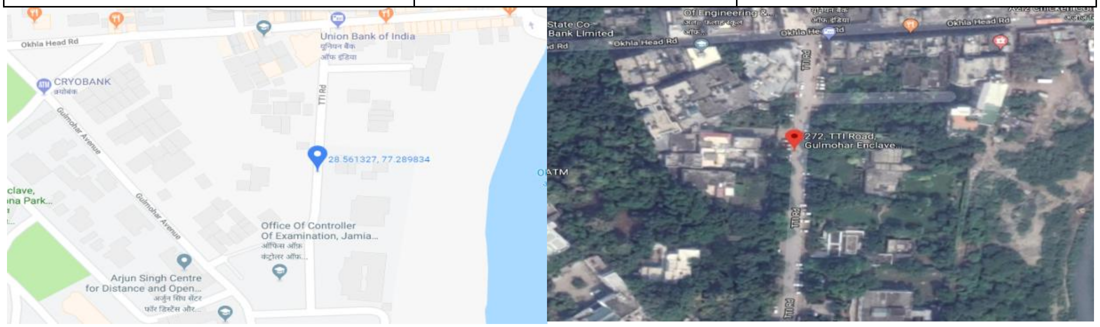


Figure 2.1 Map and Satellite image of Construction site 1

2) Construction site 2

Address: 2086,Street 32, Tughlakabad extension, Tughlakabad, New Delhi, Delhi, 110019

Activities at Construction Site 2	**Latitude**	**Longitude**
<u>Demolition and Reconstruction of Residential Building:</u> Excavation, Drilling, Demolition, Cement Work, movement of Vehicles, Trenching, Masonry Work, Labor Work	28.5201325	77.2572183

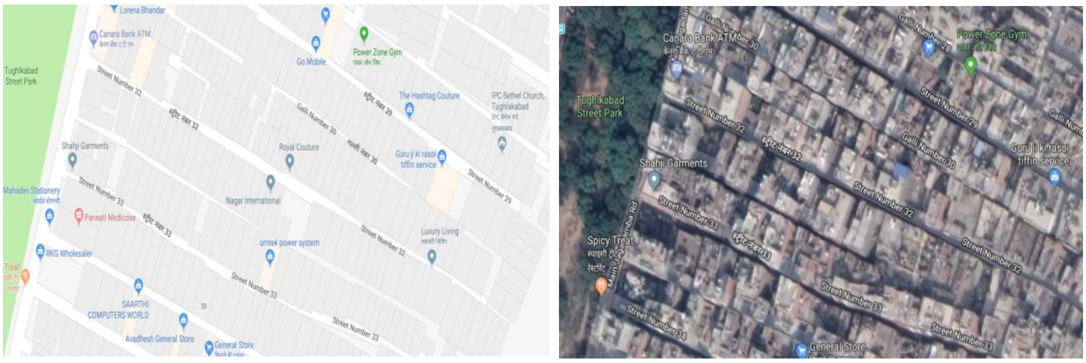


Figure 2.2 Map and Satellite image of Construction site 2

3) Construction site 3
Address: Parallel to RTR Flyover, Palam Marg, Vasant Vihar, New Delhi, 110057

Activities at Construction Site 3	Latitude	Longitude
<u>Construction of Flyover:</u> Excavation, Drilling, Laying of Aggregates, Cement Work, movement of Vehicles, Labor Work, RCC work, Construction of Road.	28.5713293	77.1621724

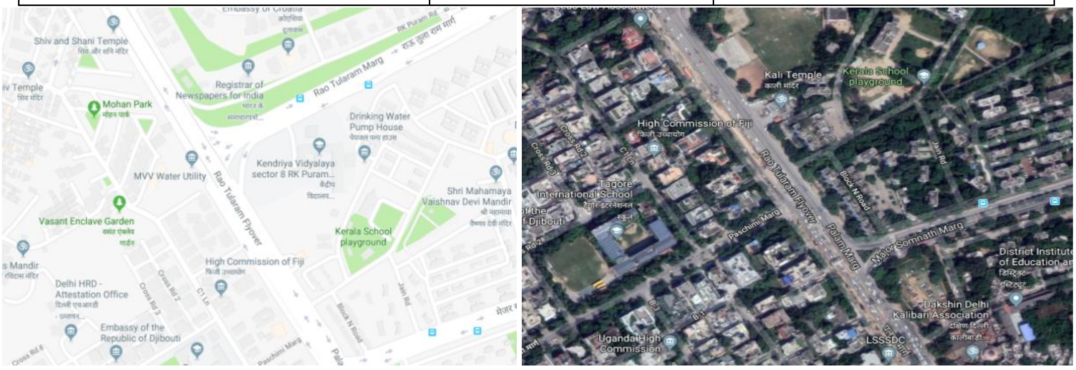


Figure 2.3 Map and Satellite image of Construction site 3

4) Construction site 4
Address: NSIC, Bakhti Vedant Swami Marg, Okhla Phase III, Okhla Industrial Area, New Delhi, 110020.

Activities at Construction Site 4	Latitude	Longitude
<u>Construction of Residential Building:</u> Drilling, Marble Cutting, Cement Work, movement of Vehicles, Labor Work, RCC work, Marble finishing, Plastering	28.5529857	77.2651597

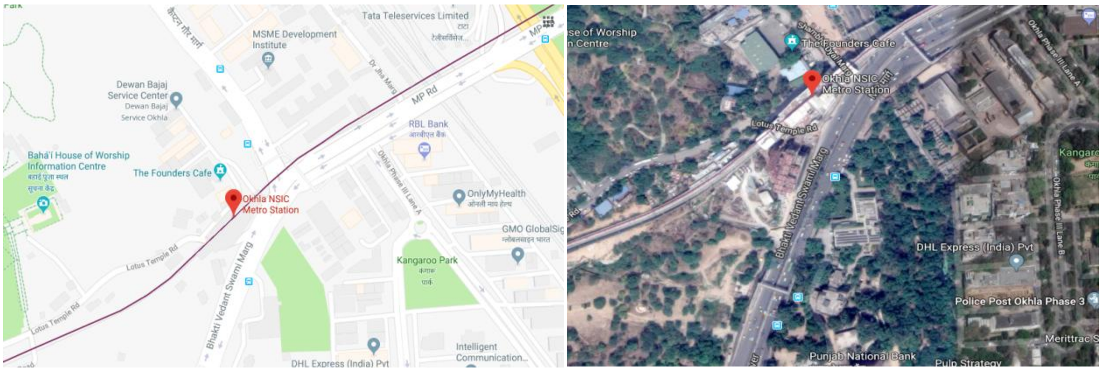


Figure 2.4 Map and Satellite image of Construction site 4

2.1.2 Location Of The Selected Residential Areas

1) Residential Area 1
Address: 3251, Street 36, Tughlakabad Extension, New Delhi, Delhi 110019
Latitude: 28.516835
Longitude: 77.254675

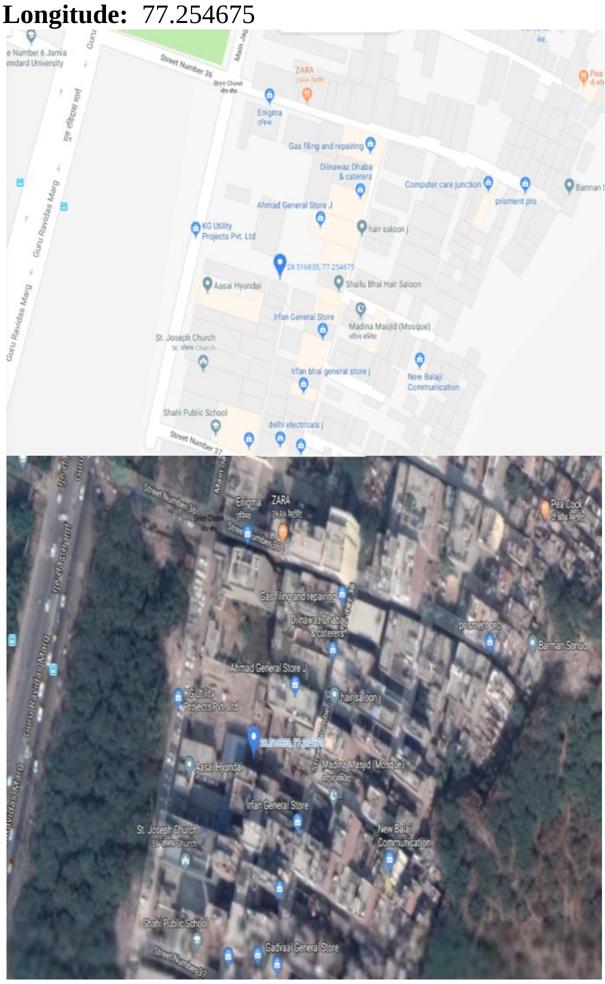


Figure 2.5 Map and Satellite image of Residential area 1

2) Residential Area 2
Address: Near Sophia Apartments, Jasola Vihar, New Delhi, Delhi 110025
Latitude: 28.545528
Longitude: 77.300192

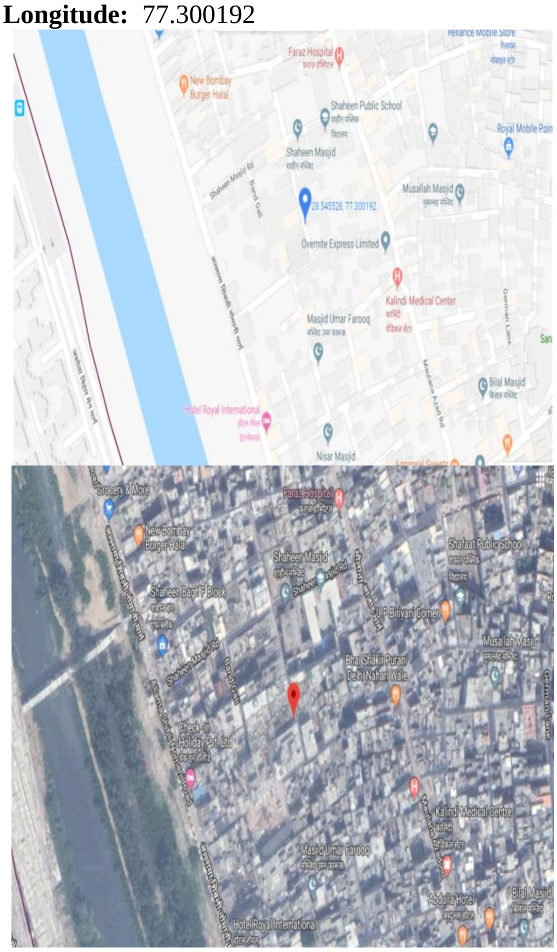


Figure 2.6 Map and Satellite image of Residential area 2

3) Residential Area 3
Address: Ali extension, saidabad, Near DMRC staff quarters Sarita vihar, New Delhi, 110076

Latitude: 28.522248
Longitude: 77.294841

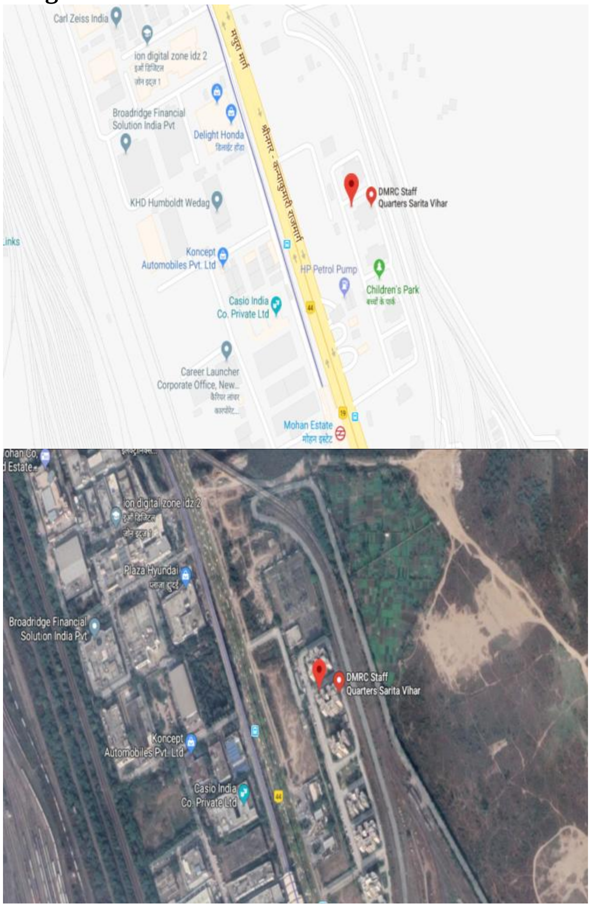
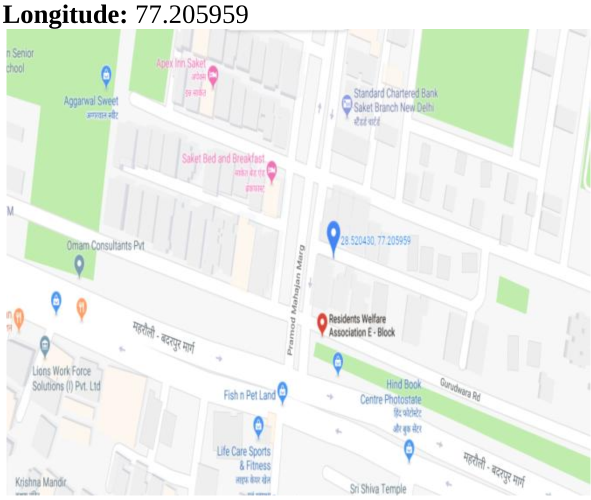


Figure 2.7 Map and Satellite image of Residential area 3

4) Residential Area 4
Address: E2, Block E, Near Pramod Mahajan Rd, Saket, New Delhi, Delhi 110017
Latitude: 28.520430
Longitude: 77.205959



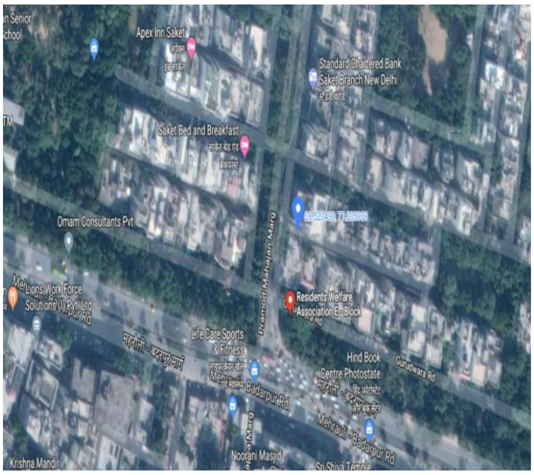


Figure 2.8 Map and Satellite image of Residential area 4

2.2 Monitoring Instrumentation

The most important measurements of particles are particle concentration and particle size. There are several instruments for measuring different characteristics of particulate matter. So, Portable pollution meter (SMILEDRIVE Portable air Quality Monitor) has been selected for taking the readings of particulate matter (PM_{10} & $PM_{2.5}$). It is extremely easy to use and it does not require any technical knowledge. Anyone can use the portable pollution meter to know the pollution level in ones surroundings in a matter of few seconds. It features a large LED display screen that shows the concentration of particulate matter, TVOCs and Formaldehyde. It is based on the laser scattering detection technology. It detects PM_1, $PM_{2.5}$, PM_{10}, formaldehyde and TVOCs. It uses a multi-layer micro-filtration mechanism to prevent ethanol and carbon monoxide from interfering with the gadgets functions.

The air pollution monitor is equipped with a high performance three core 32-bit ARM processor. It is a premium quality chip that does complex high speed calculation. Test range for formaldehyde is 0-1.999 mg/m^3, for PM_1, $PM_{2.5}$, PM_{10} it is 0-999 µg/m^3 and for TVOCs it is 0-9.999 mg/m^3

Figure 2.9 Portable Pollution Meter

2.3 Data Monitoring Procedure

The device pollution meter is calibrated in the clean air atmosphere for the purpose of minimization of errors in the data collection. The samples has been taken in morning shift and evening shift. At construction sites, the samples are taken during the construction process. In the selected time, the sample has been taken after every 15 minutes i.e, there will be 15 minute gap between every sample taken. The monitoring procedure has been summarised below:

Sr. No.	Location	Monitoring Dates	Monitoring Time	No. of Samples
1.	Construction site 1	17-03-2019	10:30am-12:00pm 5:00pm-6:30pm	14
2.	Construction site 2	24-03-2019	9:00am-10:45am 5:30pm-7:15pm	16
3.	Construction site 3	10-03-2019	9:30am-11:15am 5:30pm-7:15pm	16
4.	Construction site 4	28-03-2019	9:15am-11:15am 3:00pm-4:45pm	17
5.	Residential Area 1	05-04-2019	10:30am-11:45pm 6:00pm-7:15pm	12
6.	Residential Area 2	06-04-2019	10am-11:15am 4:00pm-5:15pm	12
7.	Residential Area 3	12-04-2019	9:00am-10:15am 5:30pm-6:45pm	12
8.	Residential Area 4	15-04-2019	9:15am-10:30am 6:45pm-8:00pm	12

Table 2.1: Data monitoring procedure

2.4 DATA ANALYSIS PROCEDURE

After the collection of data, the analysis of data collected has been done by using the Excel Sheet. Many samples are taken at every selected location and the bar graph is plotted between the maximum observation, minimum observation and mean observation by using Excel sheet. Furthermore, the comparative analysis has been done between the particulate matter (PM_{10} & $PM_{2.5}$) averages of every selected location (Construction Sites and Residential Areas), WHO standards and CPCB standards. The results after analyzing the data are shown on bar graph by using Excel Sheet. The mean (average) of the samples is obtained by the formula given as under:

$$\text{Mean/Average} = \frac{\text{Sum of samples/observations}}{\text{Total number of samples/observations}}$$

III. RESULTS AND DISCUSSIONS

At construction site 1, the minimum concentration of PM_{10} is 171µg/m^3, maximum concentration is 208µg/m^3 and the average PM_{10} is 194.2µg/m^3, while the WHO and CPCB standards (24-hourly) for PM_{10} are 50µg/m^3 and 100µg/m^3 respectively. So, the concentration of PM_{10} at construction site 1 is much higher than the standards of WHO and CPCB as well. For $PM_{2.5}$, the minimum concentration is 159µg/m^3, maximum concentration is 198µg/m^3 and Mean concentration is 180.5µg/m^3, while the WHO (24-hourly) and CPCB (8-hourly) standards are 25µg/m^3 and 100µg/m^3 respectively. So, it shows that the $PM_{2.5}$ concentration is also much higher than standards. By analyzing figure 3.1, the air quality at construction site is dangerous to human health, vegetation etc, as it has high concentration of particulate matter

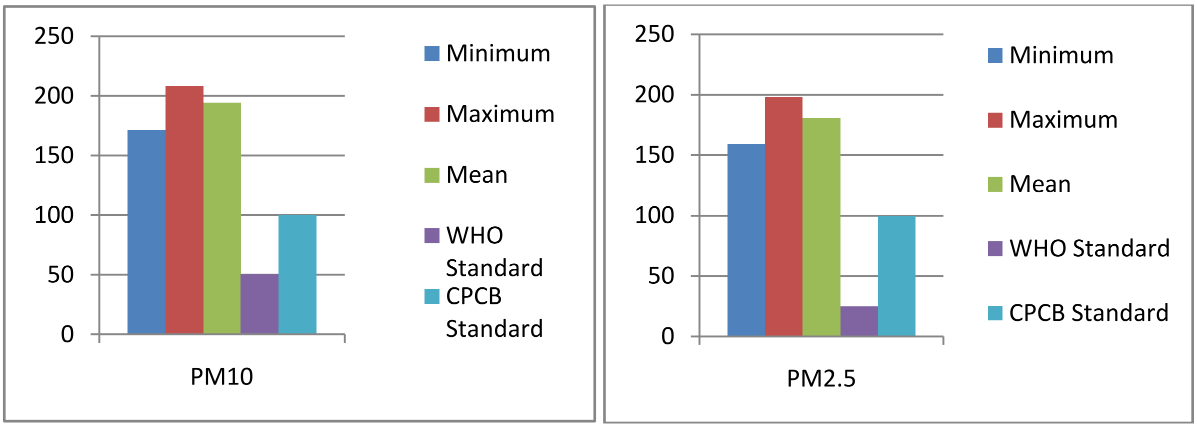


Figure 3.1: PM_{10} and $PM_{2.5}$ Concentration results at Construction site 1

At construction site 2, the minimum concentration of PM_{10} is 192µg/m^3, maximum concentration is 256µg/m^3 and the average PM_{10} is 221.125µg/m^3, while the WHO and CPCB standards (24-hourly) for PM_{10} are 50µg/m^3 and 100µg/m^3 respectively. So, the concentration of PM_{10} is much higher than the standards of WHO and CPCB as well. For $PM_{2.5}$, the minimum concentration is 163µg/m^3, maximum concentration is 213µg/m^3 and Mean concentration is 192.625µg/m^3, while the WHO (24-hourly) and CPCB (8-hourly) standards are 25µg/m^3 and 100µg/m^3 respectively. So, it shows that the $PM_{2.5}$ concentration is also much higher than standards. By analyzing figure 3.2, the air quality at construction site is dangerous to human health, vegetation etc, as it has high concentration of particulate matter.

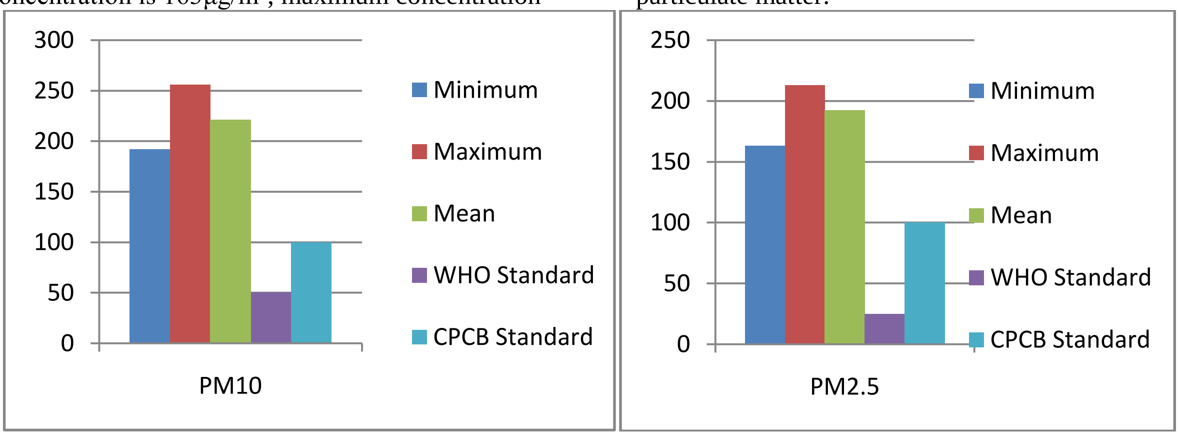


Figure 3.2: PM_{10} and $PM_{2.5}$ Concentration results at Construction site 2

At construction site 3, the minimum concentration of PM_{10} is 199µg/m^3, maximum concentration is 303µg/m^3 and the average PM_{10} is 248.75µg/m^3, while the WHO and CPCB standards (24-hourly) for PM_{10} are 50µg/m^3 and 100µg/m^3 respectively. So, the concentration of PM_{10} is much higher than the standards of WHO and CPCB as well. For $PM_{2.5}$, the minimum concentration is 162µg/m^3, maximum concentration is 252µg/m^3 and Mean concentration is 200.43µg/m^3, while the WHO (24-hourly) and CPCB (8-hourly) standards are 25µg/m^3 and 100µg/m^3 respectively. So, it shows that the $PM_{2.5}$ concentration is also much higher than standards. By analyzing figure 3.3, the air quality at construction site is dangerous to human health, vegetation etc, as it has high concentration of particulate matter.

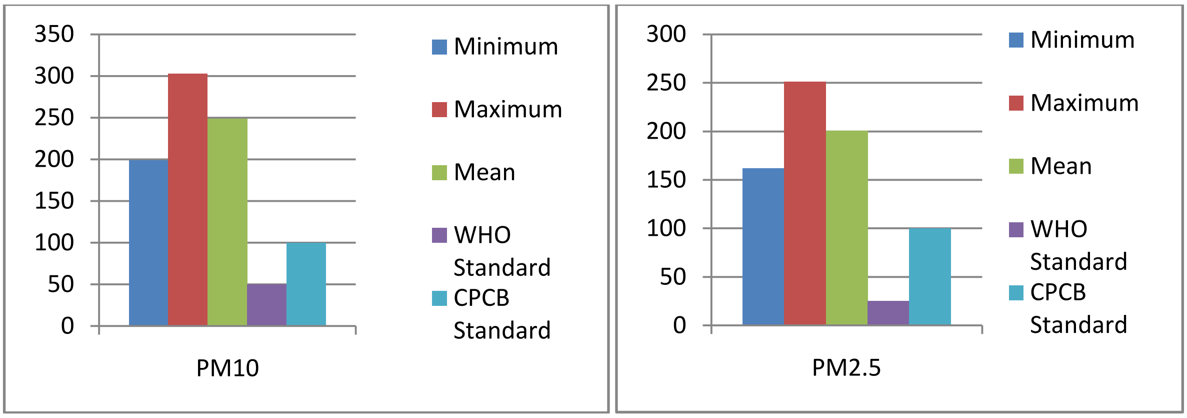


Figure 3.3: PM_{10} and $PM_{2.5}$ Concentration results at Construction site 3

At construction site 4, the minimum concentration of PM_{10} is 154µg/m^3, maximum concentration is 193µg/m^3 and the average PM_{10} is 174.23µg/m^3, while the WHO and CPCB standards (24-hourly) for PM_{10} are 50µg/m^3 and 100µg/m^3 respectively. So, the concentration of PM_{10} is much higher than the standards of WHO and CPCB. For $PM_{2.5}$, the minimum concentration is 103µg/m^3, maximum concentration is 147µg/m^3 and Mean concentration is 125.05µg/m^3, while the WHO (24-hourly) and CPCB (8-hourly) standards are 25µg/m^3 and 100µg/m^3 respectively. So, it shows that the $PM_{2.5}$ concentration is also much higher than standards. By analyzing figure3.4, the air quality at construction site is dangerous to human health, vegetation etc, as it has high concentration of particulate matter.

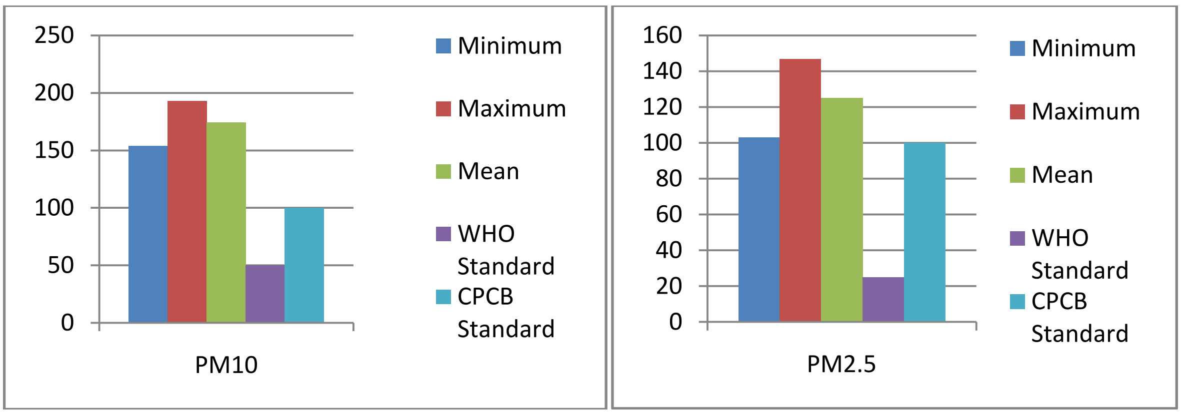


Figure 3.4: PM_{10} and $PM_{2.5}$ Concentration results at Construction site 4

At residential area 1, the minimum concentration of PM_{10} is 18µg/m^3, maximum concentration is 41µg/m^3 and the average PM_{10} is 28µg/m^3, while the WHO and CPCB standards (24-hourly) for PM_{10} are 50µg/m^3 and 100µg/m^3 respectively. So, the concentration of PM_{10} does not exceed the standards of WHO and CPCB. For $PM_{2.5}$, the minimum concentration is 10µg/m^3, maximum concentration is 28µg/m^3 and Mean concentration is 17.16µg/m^3, while the WHO (24-hourly) and

CPCB (8-hourly) standards are 25µg/m^3 and 100µg/m^3 respectively. So, it shows that the $PM_{2.5}$ concentration is very below standard limits and hence the residential area 1 is safe.

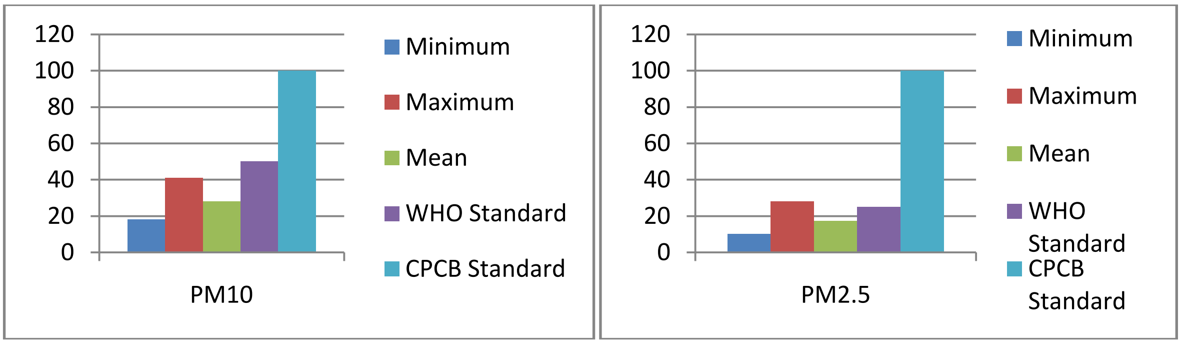


Figure 3.5: PM_{10} and $PM_{2.5}$ Concentration results at Residential Area 1

At residential area 2, the minimum concentration of PM_{10} is 28µg/m^3, maximum concentration is 53µg/m^3 and the average PM_{10} is 40.41µg/m^3, while the WHO and CPCB standards (24-hourly) for PM_{10} are 50µg/m^3 and 100µg/m^3 respectively. So, the concentration of PM_{10} sometimes goes past the WHO standard as the maximum concentration is higher than the WHO Standard limit. But the average concentration is well below WHO Standard limits and CPCB Standard limits. In case of $PM_{2.5}$, the minimum concentration is 18µg/m^3, maximum concentration is 29µg/m^3 and Mean concentration is 23.25µg/m^3, while the WHO (24-hourly) and CPCB (8-hourly) standards are 25µg/m^3 and 100µg/m^3 respectively. So, it shows that the maximum $PM_{2.5}$ concentration is above WHO Standard limit but the average concentration remains well below the WHO as well as CPCB standard limits, hence the residential area is safe.

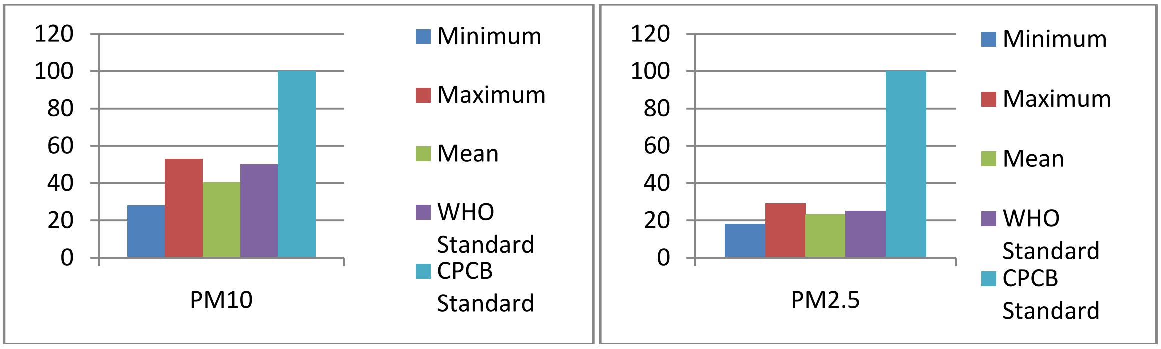


Figure 3.6: PM_{10} and $PM_{2.5}$ Concentration results at Residential Area 2

At residential area 3, the minimum concentration of PM_{10} is 19µg/m^3, maximum concentration is 43µg/m^3 and the average PM_{10} is 31.25µg/m^3, while the WHO and CPCB standards (24-hourly) for PM_{10} are 50µg/m^3 and 100µg/m^3 respectively. So, the concentration of PM_{10} is well below WHO Standard limits and CPCB Standard limits. In case of $PM_{2.5}$, the minimum concentration is 08µg/m^3, maximum concentration is 32µg/m^3 and Mean concentration is 20.83µg/m^3, while the WHO (24-hourly) and CPCB (8-hourly) standards are 25µg/m^3 and 100µg/m^3 respectively. So, it shows that the maximum $PM_{2.5}$ concentration is above WHO Standard limit but the average concentration remains well below the WHO as well as CPCB standard limits, hence the residential area is safe.

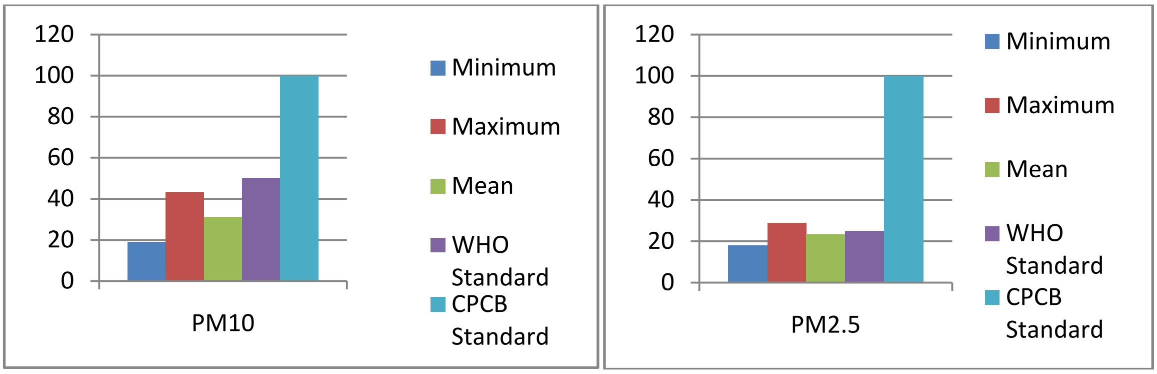


Figure 3.7: PM_{10} and $PM_{2.5}$ Concentration results at Residential Area 3

At residential area 4, the minimum concentration of PM_{10} is 13µg/m^3, maximum concentration is 34µg/m^3 and the average PM_{10} is 23.25µg/m^3, while the WHO and CPCB standards (24-hourly) for PM_{10} are 50µg/m^3 and 100µg/m^3 respectively. So, the concentration of PM_{10} does not exceed the standards of WHO and CPCB. For $PM_{2.5}$, the minimum concentration is 06µg/m^3, maximum concentration is 24µg/m^3 and Mean concentration is 14.25µg/m^3, while the WHO (24-hourly) and CPCB (8-hourly) standards are 25µg/m^3 and 100µg/m^3 respectively. So, it shows that the $PM_{2.5}$ concentration is very below standard limits and hence the residential area is safe.

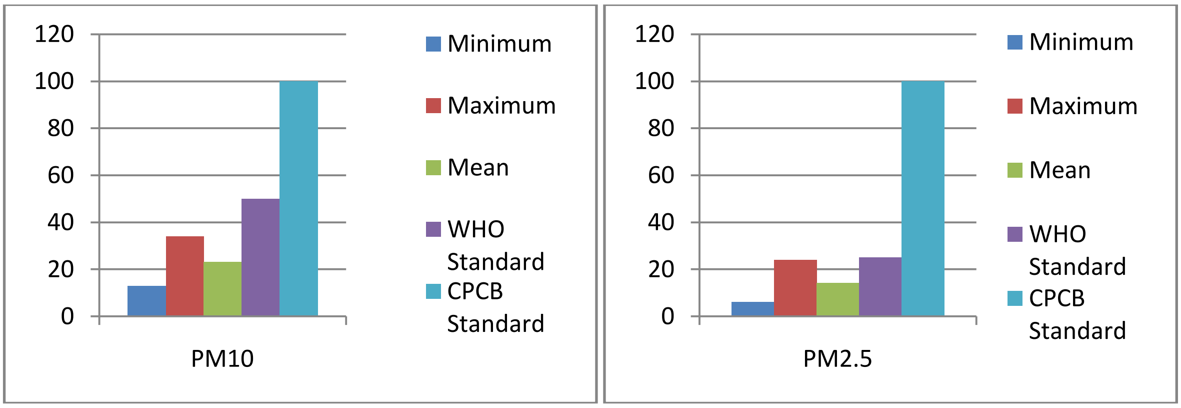


Figure 3.8: PM_{10} and $PM_{2.5}$ Concentration results at Residential Area 4

By analyzing the above figures, it is possible to notice that the PM_{10} showed the highest concentrations than $PM_{2.5}$ at both construction sites as well as at residential areas.

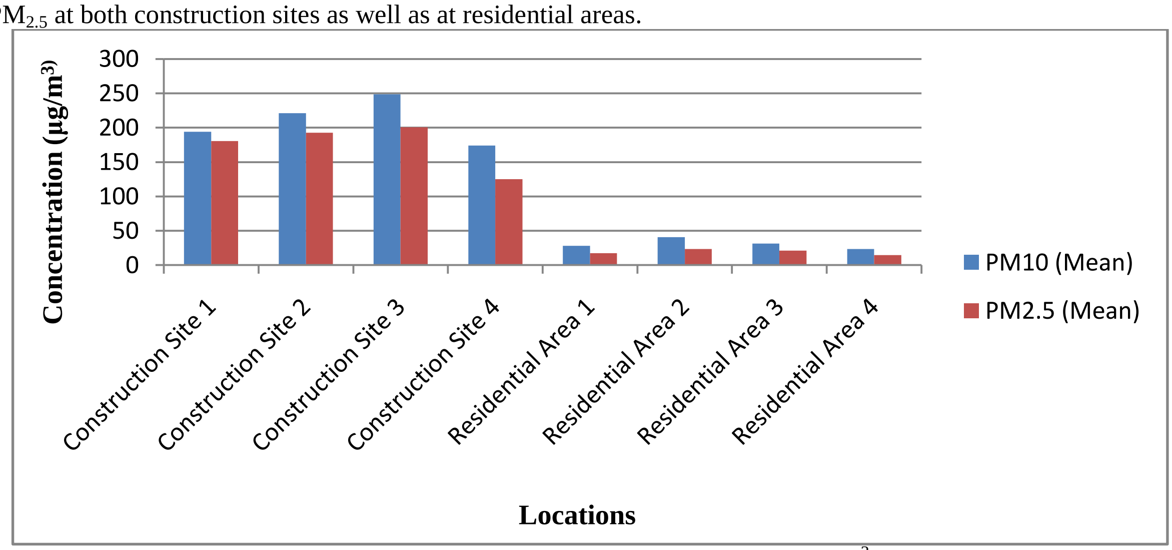


Figure 3.9: Mean concentration results of PM_{10} and $PM_{2.5}$ in µg/m^3 at all locations

By analysing figure 3.9, it is clear that the particulate matter concentration is higher at construction sites than the residential areas only because the activities going on at the construction sites like drilling, excavation, movement of vehicles, cutting of tiles etc from which PM arises.

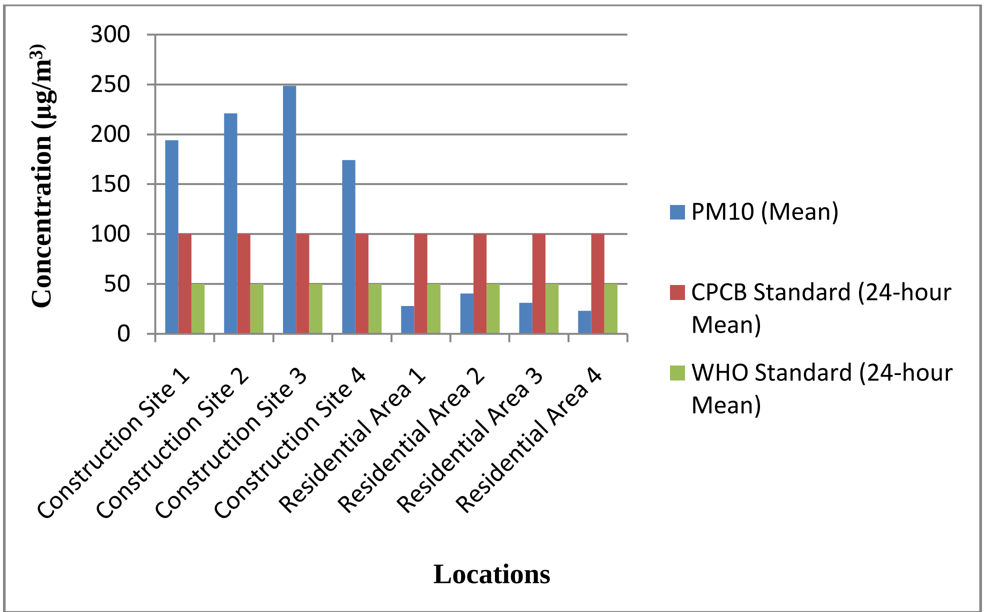


Figure 3.10: Mean concentration results of PM_{10}, WHO standard and CPCB standard in µg/m^3 at all locations

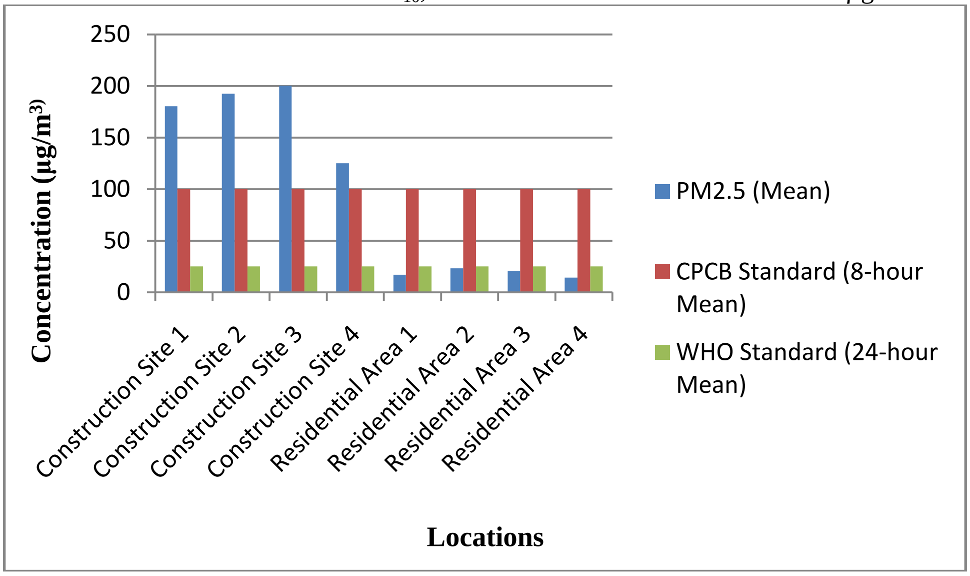


Figure 3.11: Mean concentration results of $PM_{2.5}$, WHO standard and CPCB standard in µg/m^3 at all locations

From Figure 3.10 and Figure 3.11, it can be seen that the construction site locations neither fall under CPCB standards nor under WHO standards in case of both PM_{10} as well $PM_{2.5}$. But the residential areas fall under both WHO and CPCB standard limits.

Based on the analysis of the collected data at all locations by using the proposed methodology, the need for adjustments in some of the methodological procedures adopted was observed in order to obtain satisfactory data according to the reality of the construction site. It is important to highlight that the construction sites and residential areas were chosen initially because it was possible to validate the methodology at all the four different construction sites and four different residential areas over a short time period.

However, there were many locations to monitor which include four construction site locations and four residential area locations, it was not possible to carry the high volume sampler to all the eight locations for monitoring purpose in such a short time period, so the suggestion was the installation of SMILEDRIVE Pollution Meter in order to better control the measurement process.

On the basis of analysis of collected data it is seen that among all the four construction sites there was much higher concentration at the construction site 3 as compared to other three sites. This was because, there were different activities going on simultaneously and as it was the construction of flyover, there was the continuous movement of Vehicles (private vehicles, passenger vehicles as well as vehicles used in construction process) which may have been the one of the main reason for higher concentration PM.

As per analysis of the data collected from residential areas it can be said that the selected residential locations are safe as per CPCB and WHO standards. But due to the wind movement, the residential areas near construction sites get affected. As the particulate matter remains for hours in the atmosphere, it gets carried away with the wind and pollutes the nearby residential areas, which ultimately affect the human, vegetation, buildings, etc at the nearby residential areas.

At some residential areas, the particulate matter (PM_{10} & $PM_{2.5}$) concentration sometimes goes past the standard limits (WHO and CPCB), But the 24-hour mean remains well below the standard limits. Overall, the quality of air at residential area is satisfied in terms PM_{10} and $PM_{2.5}$. But, at construction sites, the air quality is not satisfied. It has high concentration of particulate matter hence have very harmful effects on labours, machines, vegetation etc.

IV. CONCLUSIONS

Based on the observations in this paper, it can be said that the particulate matter at construction sites does not arise from single activity. As there are many activities overlapping at the same time. Due to which the high concentration of particulate matter is produced at construction sites and gets released into the atmosphere. PM remains for a long period of time in atmosphere and can get carried away for a longer distances due to the wind. So along with the constructional area, the atmosphere of nearby residential and other areas also gets polluted.

On comparison between construction sites and residential areas, the construction sites have higher concentration of particulate matter because of the undergoing activities like drilling, excavation, cement works, movement of vehicles, etc. The construction areas are unsatisfied and unsafe, as it crosses the permissible limits of WHO and CPCB for particle pollution.

This paper indicates that the particle pollution at residential areas does not cross the WHO standard limits and CPCB standard limits. Therefore, residential are satisfied and safe. At construction sites, the PM_{10} and $PM_{2.5}$ both goes past the standard limits of WHO and CPCB. Hence, are not satisfied.

PM_{10} concentration has been seen higher than $PM_{2.5}$ concentration all the time at both construction sites as well as at residential areas. $PM_{2.5}$ is more dangerous than PM_{10} as it goes deep inside the human respiratory system.

There was not much fluctuation in the concentration of particulate matter at construction sites. Because the construction activities were under process throughout the day, that does not allow the fluctuation of concentration. Also, it was seen that there were higher concentration of particulates in evening shift than morning shift at residential areas. This was because the movement of vehicles & humans was more at the evening time.

To tackle the problems of particulate matter production at construction sites and to reduce the health risks generated due to particle pollution, some recommendations are given as under:

1. To use water sprays for dust suppression, creating ridges to prevent dust, compaction of disturbed soil, prevention of dumping of earth materials along road side.
2. Masks should be provided to the labours working at the construction sites, to protect them from the health risks generated by the particle pollution.
3. Well conditioned vehicles and machines should be used at the construction sites for construction purpose.

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