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REAL-TIME AIR QUALITY MONITORING IN RESIDENTIAL CONSTRUCTION SITES: A STUDY USING LOW-COST DUST SENSORS IN PUNE

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Abstract: In order to protect public health and safety, particulate matter (PM) monitoring in residential construction sites is crucial. Traditional monitoring methods often involve expensive equipment and complex procedures, limiting their accessibility and scalability, particularly in resource-constrained settings. This study explores the feasibility of utilizing cost-effective dust sensors for real-time PM monitoring in construction residential environments, with a focus on sites in Pune. A comprehensive assessment of the performance of these sensors was conducted through deployment in various construction sites across Pune, measuring PM concentrations over extended periods. The results demonstrate the efficacy of the cost-effective dust sensors in providing timely and accurate PM data, enabling proactive management of air quality in construction areas. The findings highlight the potential of these sensors to enhance environmental monitoring practices and support sustainable development initiatives in urban construction projects. This research contributes to advancing the adoption of affordable technologies for effective PM surveillance, thereby promoting healthier and more liveable communities amidst construction activities in Pune and similar urban settings.

Index Terms – Particulate matter, Air Quality Impact, Low-cost dust sensor, Construction site, Real time monitoring

I. INTRODUCTION

Particulate matter pollution poses significant risks to human health and the environment, particularly in urban areas undergoing rapid development and construction. Construction residential sites, in particular, are hotspots for PM emissions due to various tasks including material handling, demolition, and excavation Heart difficulties and respiratory issues might result from significant PM exposure., and other adverse health effects among residents and workers in these areas. Therefore, effective monitoring and management of PM pollution in construction residential sites are crucial for safeguarding public health and promoting sustainable urban development. Traditional methods of PM monitoring typically involve sophisticated equipment and complex procedures, making them inaccessible and impractical for widespread deployment, especially in developing regions. However, recent advancements in sensor technology have led to the development of cost-effective dust sensors capable of real-time PM monitoring. These sensors offer a promising solution for enhancing environmental surveillance in construction sites by providing timely and accurate data at a fraction of the cost of traditional monitoring methods. This paper focuses on the application of cost-effective dust sensors for monitoring PM in construction residential sites, with a specific emphasis on sites located in Pune, India. Pune, a rapidly growing urban center, is experiencing significant construction activity, leading to concernsconcerning public health and air quality. Through a comprehensive analysis of the collected data, including comparison with traditional monitoring methods and assessment of sensor performance under different environmental conditions, this study seeks to provide valuable insights into the potential of cost-effective dust sensors for improving PM surveillance in construction residential sites Policymakers, urban planners, and environmental practitioners looking for practical ways to reduce PM pollution and safeguard public health in quickly expanding cities like Pun should consider the study's conclusions.

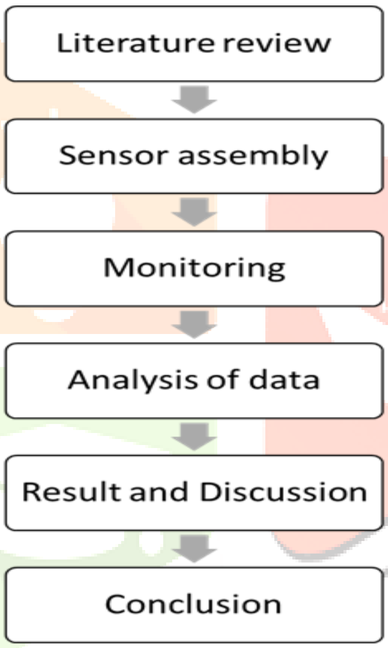
II. LITERATURE REVIEW

Sr No.	Author Name	Title of Paper	Outcomes
1	Muhammad Asifi, Rida Atizaz Ul Haq, (2022)	Particulate matter emission and their control technologies.	Highlights the global issue of PM contamination, emphasizing its impact on health and the environment. The study underscores the urgent need for pollution reduction policies and carbon control measures to mitigate the adverse effects of PM on public health.
2	Ingrid Priscylla Silva Araújo and Dayana Bastos Costa, (2022)	Measurement and Monitoring of Particulate Matter in Construction Sites: Guidelines for Gravimetric Approach.	Proposes guidelines for PM monitoring in construction, aiming to promote safety and health for workers and residents. The study emphasizes the importance of standardized monitoring procedures and equipment selection to ensure accurate and reliable measurement of PM levels in construction sites.
3	Hyunsik Kim, Sungho Tae, Pengfei Zheng, Geonuk Kang and Hanseung Lee, (2021)	Development of IoT-Based Particulate Matter Monitoring System for Construction Sites.	Discusses policies to regulate PM concentration on construction sites, focusing on South Korea's measures. The paper highlights the effectiveness of policy interventions in reducing PM emissions from construction activities and protecting public health in urban areas.
4	Daniel Cheriyan, jae-ho choi, (2020)	A review of research on particulate matter pollution in the construction industry	Examines PM exposure from construction activities, urging research to reduce PM exposure and develop effective control measures. The paper emphasizes the importance of implementing stricter regulations and guidelines to minimize PM emissions from construction sites.
5	Hai-Ying Liu, Philipp Schneider, Rolf Haugen, (2019)	Performance assessment of a low cost PM2.5 sensor for a near four-month period Osla.	Evaluates the performance of low-cost PM sensors, emphasizing potential misuse in citizen science applications and personal air quality monitoring. The study stresses the need for proper calibration and validation procedures to ensure the reliability of PM sensor data in various environmental conditions.
6	Nadezhda Menzelintseva, Natalia Karapuzova, Awadh M Redhwan, Ekaternia Fomania Volgograd State Technical University, (2019)	Study of dust particle size distribution in the air of work areas at cement production facilities.	Investigates shop air contamination with dust in cement production, highlighting the importance of particle size distribution analysis in understanding PM emissions. The study emphasizes the significance of controlling dust emissions in industrial settings to mitigate

			adverse health effects on workers and nearby residents.
7	Shafayet Ahmed, Ingrid Arocho, (2019	Emission of particulate matters during construction: A comparative study on a Cross Laminated Timber (CLT) and a steel building construction project.	Compares PM emissions from construction materials, identifying CLT as safer than steel in terms of PM emission. The study highlights the need for adopting sustainable construction practices to minimize PM emissions and protect public health in urban areas undergoing rapid development.
8	Marek Badura, Piotr Batog, Anetta Drzeniecka-Osiadacz, and Piotr Modzel, (2018)	Evaluation of low-cost sensors for Ambient PM2.5 Monitoring.	Assesses the operational stability of PM sensors, emphasizing the importance of proper use, especially outdoors, to obtain accurate and reliable data. The study underscores the need for ongoing maintenance and calibration of PM sensors to ensure their long-term performance and effectiveness in air quality monitoring.
9	Fatima Khanum, Muhammad Nawaz Chaudhry, Prashant Kumar, (2017)	Characterization of five-year observation data of fine particulate matter in the metropolitan area of Lahore.	Studies PM2.5 trends in urban areas, emphasizing the need for understanding sources and variability to develop effective air quality management strategies. The research underscores the importance of continuous monitoring and analysis of PM levels to assess the effectiveness of pollution control measures over time.
10	Rita Jane Brito de Moraes, Dayana Bastos Costa, Priscylla Silva Araújo, (2016)	Particulate Matter Concentration from Construction Sites: Concrete and Masonry Works.	Explores PM emissions during construction, advocating for more quantitative data and understanding of particle characteristics to mitigate health risks. The study emphasizes the importance of implementing dust control measures and promoting proper waste management practices on construction sites to reduce PM emissions and protect workers' health.
11	Francis Olawale Abulude, (2016)	Particulate Matter: an approach to air pollution, Research gate.	Highlights the global health implications of PM pollution, emphasizing collaborative efforts to address the issue and mitigate its impact on public health. The paper underscores the need for international cooperation and policy initiatives to combat air pollution and protect vulnerable populations from the adverse effects of PM exposure.
12	Ingrid P. S. Araújo, Dayana B. Costa 2, Rita J. B. de Moraes, (2014)	Identification and Characterization of Particulate Matter Concentrations at Construction Jobsites.	Discusses PM emissions from construction activities, emphasizing the need for more research in this area to develop effective mitigation strategies.

			The study underscores the importance of identifying and quantifying PM sources in construction sites to implement targeted control measures and minimize environmental and health risks.
13	Emily Goswami, Timothy Larson, Thomas Lumley & L.-J. Sally Liu, (2011)	Spatial Characteristics of Fine Particulate Matter: Identifying Representative Monitoring Locations in Seattle	Investigates spatial variability of PM2.5, emphasizing the importance of site selection for monitoring to accurately assess ambient exposures. The study underscores the need for strategic placement of monitoring stations in urban areas to capture representative PM concentrations and inform air quality management decisions effectively.

III. RESEARCH AND METHODOLOGY



3.1 Particulate matter emission

The project starts with gathering evaluations of the literature on particulate matter for PM monitoring, which includes a methodical process that starts with an issue and a hypothesis.The data was obtained from various finding in the literature, with the help of literature the gaps and insights were identified. Various gaps in the study of literature review werethe standard instruments available in the market for the study of particulate matter emission are costly, handling of the instruments can only be done by skilled person, data entry with the help of filter paper in air sampler can have multiple errors while handing it. The sensor assembly which is done by our group eliminates all the above gaps as the data entry is directly done in the excel sheet format per second of the analysis. There are various constructions activities on the residential constructions siteswhich cause the emission of dust during extraction of ground, drilling, steel cutting, dumping of waste from upper floor to lower floor.

3.2 Instrument assembly

This instrument represents a portable solution for measuring particulate matter (PM) concentration, incorporating the PMS7003 sensor, an Arduino microcontroller, an RTC module, an LCD display, and an SD card module, all enclosed within an acrylic housing. Capable of accurately measuring PM1.0, PM2.5, and PM10 levels, it provides real-time data visualization on an LCD screen and logs this information with precise timestamps onto an SD card for subsequent analysis. With the RTC module ensuring accurate timekeeping and the Arduino managing data collection, processing, and storage, this cost-effective tool serves as a reliable option for air quality monitoring in diverse settings, ranging from urban environments to industrial facilities.

3.3 Site selection and instrument set up

We conducted an extensive search for suitable residential construction sites across Pune, focusing on those that, while not very large, were actively engaged in typical construction activities. After careful evaluation, we identified key PM emission activities at these sites, including cutting concrete blocks, unloading cement, and cutting and polishing tiles, among others. These activities were crucial for our study as they generate significant amounts of particulate matter, making them ideal for assessing the performance and effectiveness of our dust sensor system.

Once the sites were selected, we proceeded with the setup of our monitoring instruments. We equipped the sensors with a reliable power supply using power banks, ensuring uninterrupted data collection. The sensors were strategically positioned at a height of 1.5 meters, aligning with the breathing zone, which is the typical height at which people inhale air. This placement was essential for capturing accurate and representative air quality data relevant to human exposure. In scenarios where we deployed two instruments at a single site, we maintained a distance of 5 meters between them. This spacing was carefully chosen to provide comprehensive coverage and to ensure that the data collected was representative of different points within the construction area.

3.4 Data analysis

The collected data was continuously saved onto SD cards integrated into each instrument. This approach ensured secure and efficient storage of large datasets over extended monitoring periods. Upon completion of the data collection phase, the data was extracted from the SD cards and imported into Excel for analysis. In Excel, we organized the data, performing initial cleaning and processing to eliminate any anomalies or errors. Subsequently, we conducted a detailed analysis to examine the patterns and trends in PM levels corresponding to different construction activities. The processed data was then represented in graphical formats, including line graphs, bar charts, and scatter plots, which provided clear visual insights into PM concentration variations over time and across different sites. These graphical representations enabled us to identify peak emission periods, correlate specific activities with higher PM levels, and assess the overall air quality impact of residential construction site.

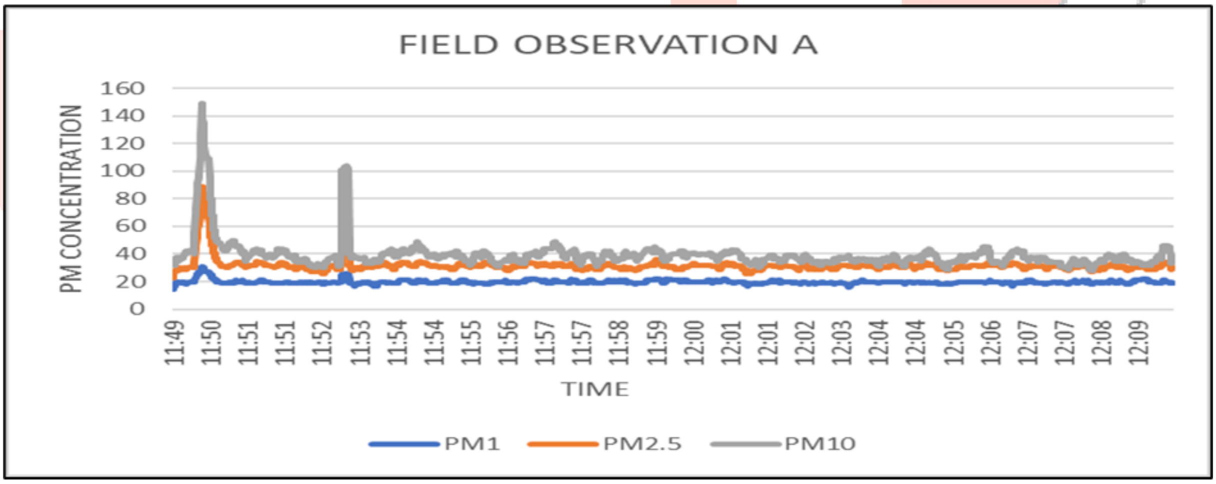
IV. OBSERVATIONS

During our field observation at the residential construction site in Ambegaon Taluka, Haveli, Pune, we monitored PM emissions using three instruments set up at strategic locations on the site. Initially, we recorded PM levels when there were no construction activities, although some vehicular activity was present. On this day, with clear skies and moderate wind, the PM levels were relatively low. The following day, we monitored the site during active construction activities under similar weather conditions. The findings showed that PM emissions have significantly increased. This sharp variation underlines how building activities have a significant impact on air quality and emphasizes the necessity of efficient dust control methods to reduce dangers to human health and the environment.

3.1 DAY 1 FIELD OBSERVATION

On the first day, we recorded PM levels when there were no construction activities, although some vehicular activity was present. There was a light breeze, clear skies, and comparatively low PM levels. This baseline data served as a point of comparison when assessing how different building projects affected the quality of the air.

Fig no. 1, 2 & 3 showing PM emission on site.

1.


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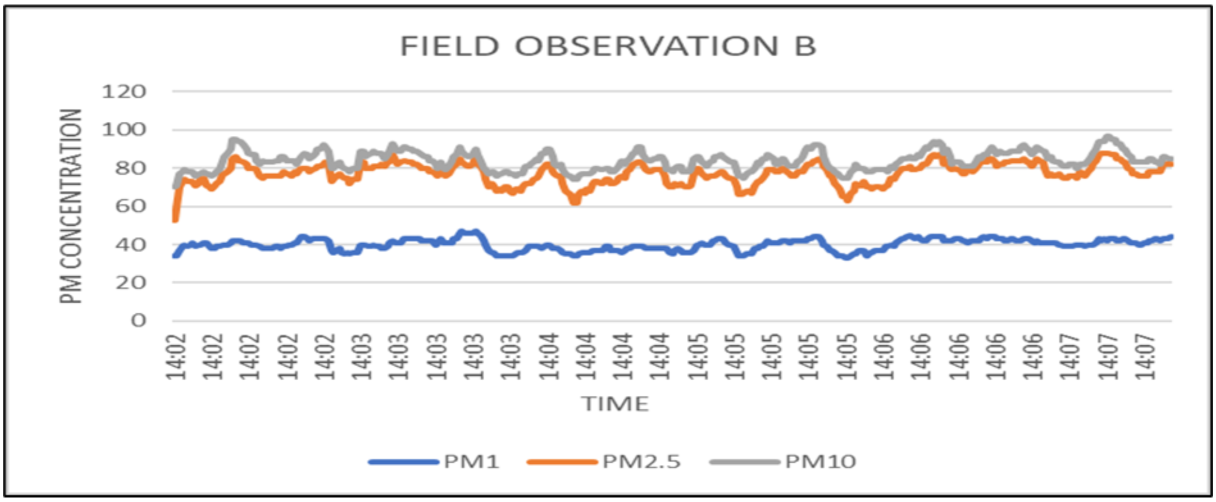

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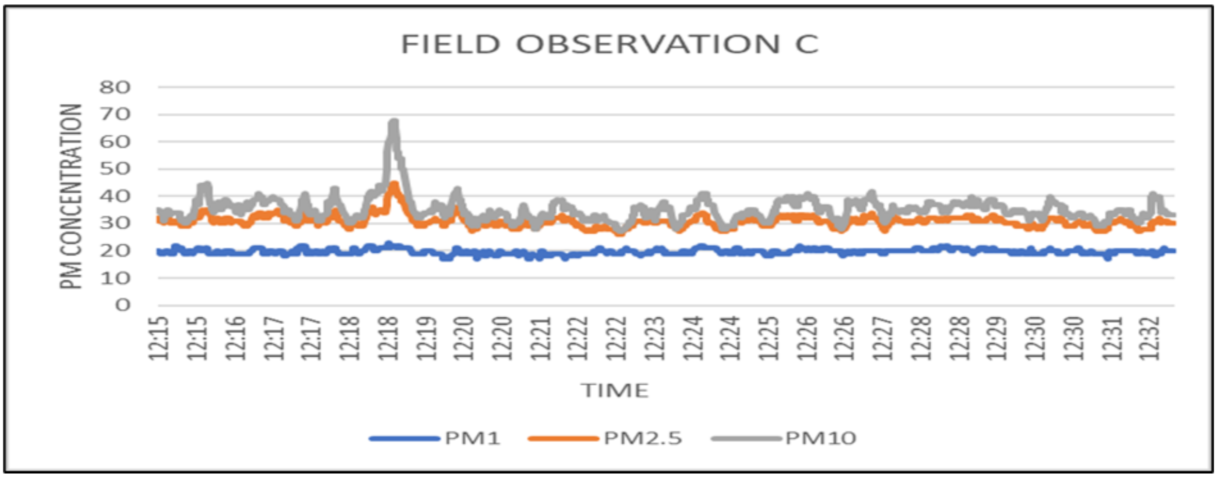


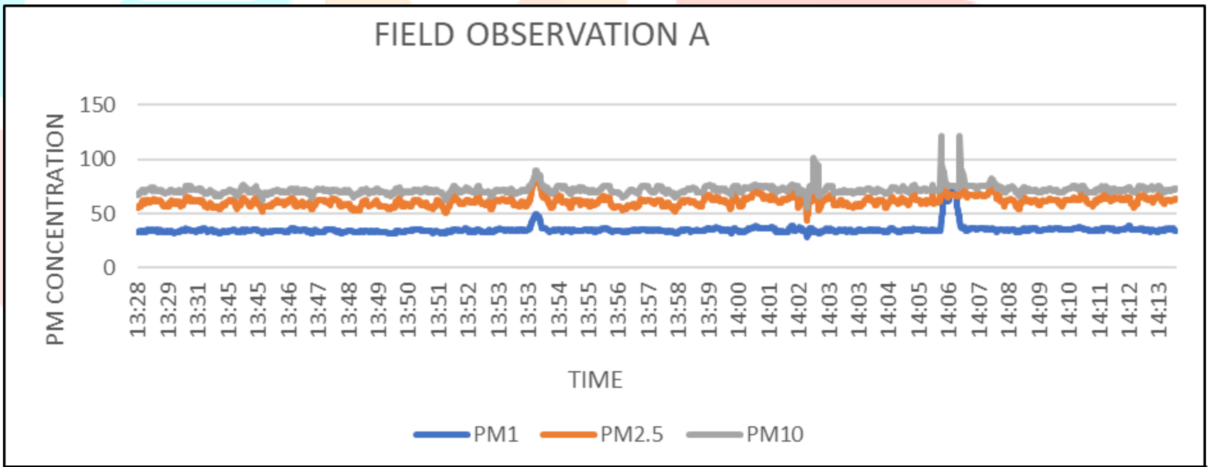
On the first day of our field observation at the residential construction site in Ambegaon Taluka, Haveli, Pune, we began by setting up our instruments and checking the parameters. The temperature was 26.7°C, the humidity was 45%, the wind speed was 4.5 m/s, the area of the site was 6,325 sqft, and the instrument height was 1.5 meters. We observed some fluctuations in PM levels due to vehicular movement, particularly when trucks were unloading aggregates.

3.2 DAY 2 FIELD OBSERVATION

On the second day of our field observation at the residential construction site in Ambegaon Taluka, Haveli, Pune, we monitored the site during active construction activities. The weather conditions were similar to the first day, with clear skies and moderate wind. Throughout the day, there were frequent movements of material trucks and unloading of cement. PM emissions increased significantly as a result of these activities in comparison to the first day. The significant influence of construction work on air quality was brought to light by the heightened PM levels during these periods, highlighting the significance of putting in place efficient dust control methods.

Fig no. 4, 5 & 6 showing PM emission on site.

4.



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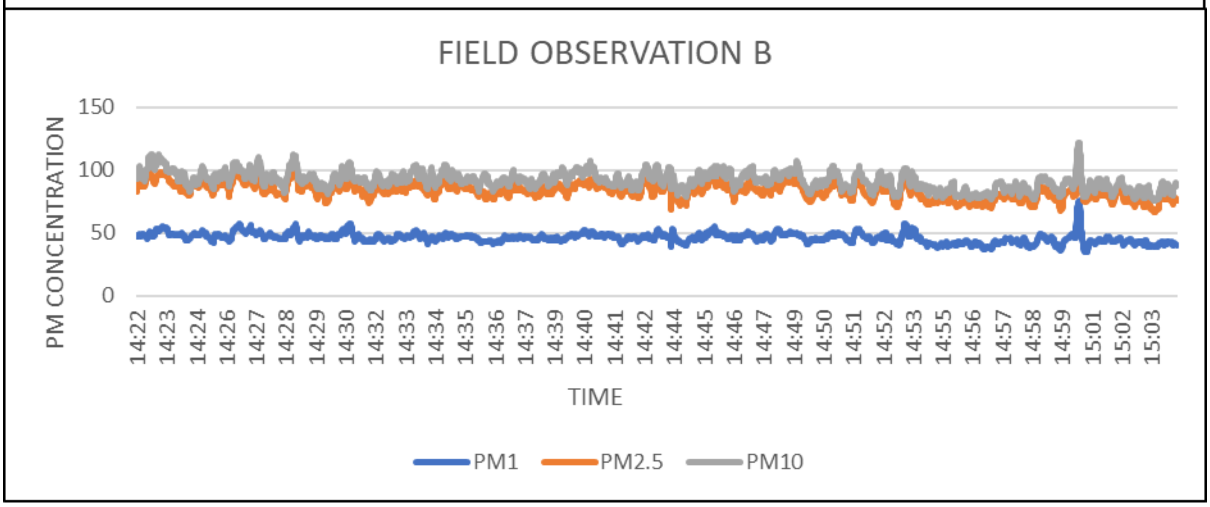

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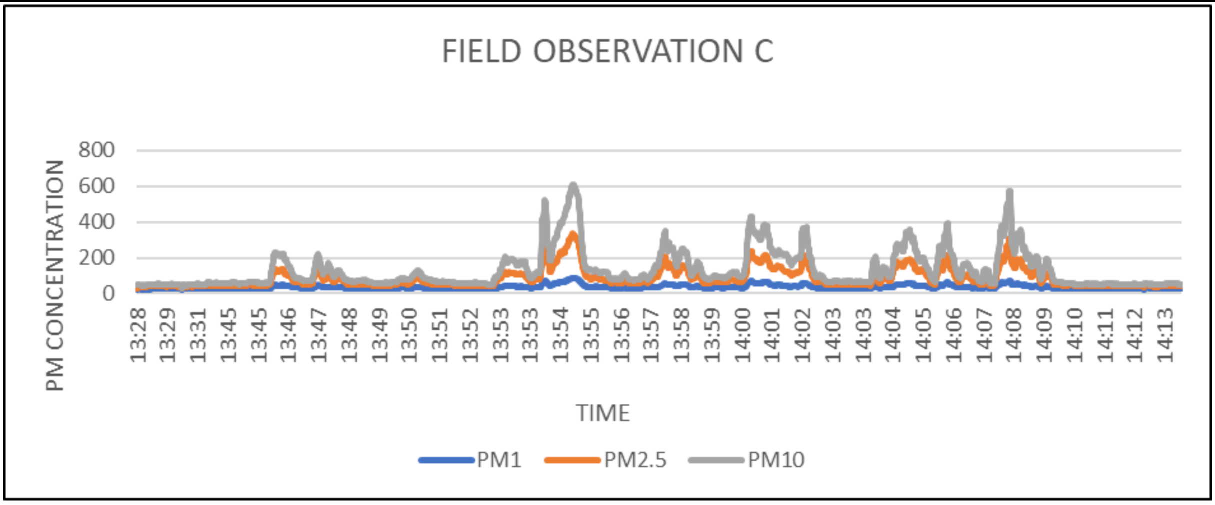

On the second day of our field observation at the residential construction site in Ambegaon Taluka, Haveli, Pune, we positioned monitoring stations A and B slightly away from the main construction activities. These stations were located approximately 5 meters apart from each other. However, there was another monitoring station, let's call it station C, situated closer to the active construction area. Station C exhibited higher fluctuations in PM concentration compared to stations A and B. This spatial distribution of monitoring stations provided insights into the spread of PM emissions from the construction activities, with station C capturing the immediate impact, while stations A and B depicted a broader dispersion pattern.

3.3 SITE PHOTOGRAPHS

V. RESULT AND DISSCUSION

4.1 DAY 1 PARTICULATE MATTER CONCENTRATION

PM (µg)	Average Concentration (µg/m^3)	Minimum Concentration (µg/m^3)	Maximum Concentration (µg/m^3)	Permissible Concentration (µg/m^3)
PM1	19	8	31	25
PM2.5	32	14	89	50
PM10	40	25	149	100

Table no.1

On day 1 of our field observation at the residential construction site in Ambegaon Taluka, Haveli, Pune, we monitored particulate matter (PM) concentrations using three different metrics: PM1, PM2.5, and PM10. The average concentrations for PM1, PM2.5, and PM10 were 19 µg/m^3, 32 µg/m^3, and 40 µg/m^3, respectively. These values represent the typical levels of particulate matter present in the air during the observation period. Additionally, we recorded the minimum and maximum concentrations for each PM metric. For PM1, the minimum concentration was 8 µg/m^3, while the maximum concentration was 31 µg/m^3. Similarly, for PM2.5, the minimum concentration was 14 µg/m^3, and the maximum concentration was 89 µg/m^3. Finally, for PM10, the minimum concentration was 25 µg/m^3, and the maximum concentration was 149 µg/m^3.
Comparing these values to the permissible concentrations set by regulatory standards, we find that all three metrics—PM1, PM2.5, and PM10—remain below their respective permissible concentrations of 25 µg/m^3, 50 µg/m^3, and 100 µg/m^3. This indicates that, on day 1, the particulate matter levels at the construction site were within acceptable limits according to regulatory standards.

4.2 DAY 1 PARTICULATE MATTER CONCENTRATION

PM (µg)	Average Concentration (µg/m^3)	Minimum Concentration (µg/m^3)	Maximum Concentration (µg/m^3)	Permissible Concentration (µg/m^3)
PM1	30	25	95	25
PM2.5	57	41	350	50
PM10	115	40	615	100

Table no.2

On day 2 of our field observation at the residential construction site in Ambegaon Taluka, Haveli, Pune, we observed notable changes in particulate matter (PM) concentrations compared to day 1. Across all PM metrics—PM1, PM2.5, and PM10—we recorded higher average concentrations. For PM1, the average concentration increased to 30 µg/m^3, with a minimum concentration of 25 µg/m^3 and a maximum concentration of 95 µg/m^3. Similarly, for PM2.5, the average concentration rose to 57 µg/m^3, with a minimum concentration of 41 µg/m^3 and a striking maximum concentration of 350 µg/m^3. These values indicate a significant increase in fine particulate matter compared to day 1. Furthermore, for PM10, we observed a substantial increase in both average and maximum concentrations. The average concentration for PM10 on day 2 reached 115 µg/m^3, with a minimum concentration of 40 µg/m^3 and a remarkable maximum concentration of 615 µg/m^3.

Comparing these concentrations to the permissible levels set by regulatory standards, we find that all three PM metrics—PM1, PM2.5, and PM10—exceeded their respective permissible concentrations of 25 µg/m^3, 50 µg/m^3, and 100 µg/m^3. This indicates a concerning elevation in particulate matter levels on day 2, suggesting a potential impact on air quality and necessitating measures to mitigate emissions from construction activities.

VI. CONCLUSION

Day 1: The observations on day 1 revealed relatively stable particulate matter (PM) concentrations at the residential construction site in Ambegaon Taluka, Haveli, Pune. Despite minor fluctuations, the average PM levels for PM1, PM2.5, and PM10 remained below their respective permissible concentrations. These findings suggest that on day 1, the construction activities had a limited impact on air quality, with measures likely in place to control dust emissions effectively.

Day 2: In contrast, the observations on day 2 presented a stark contrast, with significant increases in PM concentrations across all metrics—PM1, PM2.5, and PM10. The elevated levels, particularly the striking maximum concentrations recorded for PM2.5 and PM10, indicate a substantial deterioration in air quality. These findings underscore the significant impact of construction activities on particulate matter emissions, highlighting the urgent need for stringent dust control measures to mitigate environmental and health risks.

In summary, while day 1 demonstrated relatively acceptable air quality conditions at the construction site, day 2 revealed concerning levels of particulate matter pollution, emphasizing the importance of proactive measures to minimize emissions and safeguard both the environment and public health. Evaluating the environmental impacts and health impacts of PM from construction sites is challenging because of the harsh environment of construction sites and the complex activities performed on-site. Although building construction dust has a significant adverse impact on the surrounding environment and health, its effect has not been thoroughly studied. This project is a systematic evaluation framework for evaluating the impact on health due to the generation of building dust from construction sites. The use of this framework will eliminate the difficulty of comparing and analyzing results from different studies due to the diversity of research methods and perspectives. Gathering primary information from different construction activities and calculating the PM concentration. In There are some limitations of the study while measuring construction dust on the surrounding environment, also it measures the presence of vehicle impact. In future work, it would be particularly desirable to use this method to suggest the health measures to take based on the generation of dust on the construction site. Also, the prevention measures on building construction dust emissions.

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