

ASSESSMENT AND IMPLEMENTATION OF MITIGATION ACTIONS TO REDUCE PARTICULATE MATTER EMISSION FROM CONSTRUCTION ACTIVITIES IN RESIDENTIAL AREAS

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Abstract : With the rapid urbanization of cities like Pune, residential construction activities have significantly increased, bringing with them critical environmental challenges—chief among them being air pollution due to construction dust. Fine particulate matter such as PM_{2.5} and PM₁₀, which can deeply penetrate the respiratory system, poses serious health risks, particularly when there are construction sites nearby densely populated areas. To address this concern, the present project focuses on offering mitigation measures for controlling Particulate matter concentration causing from industry of construction.

This paper presents a comprehensive review of particulate matter generation, associated health hazards, and dust control strategies adopted in the construction sector. Various mitigation measures identified from the literature include water spraying systems, dust suppression cannons, site enclosure using dust barriers, covering of stockpiles, wheel-washing facilities, green screens, regular road cleaning, and proper waste management practices. This review provides a consolidated understanding of existing mitigation measures and their effectiveness in controlling particulate matter emissions. The increasing urbanization and infrastructure development in cities have further intensified concerns regarding dust emissions from construction activities. Therefore, Effective mitigation strategies are necessary to minimize PM emissions and improve air quality around construction sites.

Keywords: *Construction dust, Particulate matter, Air quality, Mitigation, Pune.*

I.INTRODUCTION

The construction industry plays a vital role in economic growth and infrastructure development. Rapid urbanization and rising demand for commercial, residential, and transportation infrastructure have led to a significant increase in building activities worldwide. While construction projects contribute to the advancement of society, they are also recognized as major sources of environmental pollution, particularly particulate matter (PM) emissions. Construction activities such as excavation, demolition, earthmoving, material transportation, concrete mixing, drilling, cutting, and site clearing generate large quantities of airborne dust particles that adversely affect air quality.

Particulate matter is generally classified into PM₁₀ and PM_{2.5} based on particle diameter. According to numerous research, extended exposure to particulate matter can lead to respiratory illnesses, Chronic obstructive pulmonary disease, bronchitis, and asthma (COPD), cardiovascular disorders, reduced lung function, and other negative impacts on health. Workers in construction are especially at risk because of their direct exposure to dust-generating operations, while nearby residents are also affected through the dispersion of airborne particles.

To overcome these obstacles, a number of mitigation measures have been suggested and implemented in the construction sector. Common dust-control techniques include water spraying, dust suppression systems, enclosure barriers, covering of stockpiles, wheel-washing facilities, road cleaning, and vegetation barriers.

Vina Kukadia et.al 2003 explains ways to reduce dust during construction and demolition. It covers sources of dust, health risks, and methods like water spraying, barriers, and proper planning to control it, helping workers maintain a safer and cleaner site.

Dr. Subramanian Narayan et.al 2019 suggest that Air pollution is a major health problem worldwide, responsible for about 1 in 9 deaths. In 2016, around 4.2 Millions of individuals perished from outdoor pollution and 3.8 million from indoor pollution, mostly in poorer countries, often due to heart disease and lung cancer.

Mekhala Kaluarachchi, et.al 2021 looks at how workers' behavior impacts dust control on construction sites. It discovered that when employees are more aware and feel accountable, they are more inclined to follow dust reduction practices. The authors recommend regular training and awareness programs to encourage better behavior and reduce dust pollution.

P. Bishnoi et.al 2018 examined air and noise pollution at Lucknow construction sites. Dust (PM) levels exceeded safety limits, especially from metro construction, posing health risks, while noise was less of a concern due to existing commercial activity. Manisha Tikader et.al 2021 conclude that Sustainable construction practices, strict enforcement of environmental regulations, and the adoption of advanced pollution-control technologies are essential for minimizing particulate matter emissions in residential areas. These measures contribute to protecting public health, reducing environmental degradation, and promoting sustainable urban development.

Arpan Patra et.al 2025 observes that Construction activities are a major source of PM₁₀ and PM_{2.5} emissions, which have a negative impact on human health and environmental quality. Effective dust suppression measures such as regular water spraying, covering of construction materials, and proper waste handling can significantly reduce particulate matter concentrations and improve air quality.

Daniel Cheriyan 2025 concludes that construction activities are one among the primary contributions to particulate matter emissions, especially PM_{2.5} and PM₁₀, in urban environments. It emphasizes that conventional dust control methods such as water spraying, material covering, and dust barriers can significantly reduce dust emissions when properly implemented. The authors also recommend integrating real-time monitoring systems with effective site management practices to achieve sustainable dust control and improve air quality.

P. R. Janani Priyanka et.al 2022 indicates that targeted dust-control measures based on real-time particulate matter monitoring are more effective than applying uniform mitigation techniques across all construction activities. The study highlights that identifying high dust-generating operations allows timely implementation of appropriate control measures, reducing particulate emissions efficiently. A combination of smart sensors and automated dust suppression systems can significantly improve environmental performance at construction sites.

Xiaohang Li et.al 2024 highlights that recent advances in IoT technology and low-cost air quality sensors have greatly improved the monitoring of construction-related particulate matter. Constant observation allows for the early identification of excessive dust levels and supports timely mitigation measures. The study recommends integrating smart monitoring systems with construction management practices to protect workers and nearby residential communities.

P. R. Janani Priyanka, Daniel Cheriyan & Jae-ho Choi et.al 2024 describes that automated sprinkler systems effectively reduce particulate matter concentrations generated during construction activities. Their performance is highest when operated based on real-time PM measurements rather than fixed schedules. The authors recommend sensor-controlled sprinklers as an efficient and sustainable solution for construction dust mitigation.

Chao Li et al. 2019, highlights that workers involved in excavation, demolition, and material handling are exposed to high levels of construction dust. It concludes that engineering controls, proper housekeeping, worker training, and personal protective equipment are essential for minimizing dust exposure. The study also stresses that effective dust management improves occupational health and environmental sustainability.

Jian Zuo et al. 2017, concludes that the success of dust mitigation largely depends on the awareness and commitment of construction site managers. Strong environmental policies, regular inspections, and proper worker supervision lead to better implementation of dust-control measures. The authors recommend continuous training and stricter enforcement of environmental regulations to improve compliance.

Daniel Cheriyan & Jae-ho Choi et.al 2020, concludes that particulate matter concentrations vary depending on the type of construction activity and meteorological conditions. PM₁₀ was found to dominate during excavation and earthwork, while finer particles remained airborne for longer periods, posing greater health risks. The authors recommend continuous monitoring and activity-specific mitigation measures to effectively control dust emissions.

Chen, G., Li, X., & Tam, V. W. Y. et.al 2021, finds that combining water spraying with physical barriers provides better dust suppression than using a single control method. It also highlights that site-specific dust management plans significantly improve mitigation efficiency. The authors recommend integrating engineering and administrative controls to minimize particulate emissions throughout the construction process.

Wu, Z., Zhang, Y., & Shen, L. et.al 2019, found that excavation, demolition, and material transportation are the primary sources of particulate matter emissions. Regular water spraying and covering of construction materials substantially reduce airborne dust. The study recommends strict environmental supervision to ensure compliance with dust-control measures.

Huang, Y., Wang, J., & Li, H. et.al 2020, concludes that vegetation barriers significantly reduce the movement of dust from construction sites to nearby residential areas. Green buffers improve local air quality while also enhancing the surrounding environment. The authors recommend incorporating green belts into construction planning wherever space permits.

Fang, D., Ding, L., & Luo, H. et.al 2018, demonstrates that integrating Building Information Modeling (BIM) with IoT sensors improves environmental monitoring and dust management. Real-time data allows construction managers to respond quickly to excessive particulate emissions. The study recommends adopting smart technologies for sustainable construction practices.

Wang, X., Zhao, Y., & Chen, H., et.al 2022, found that fog cannon systems effectively reduce PM₁₀ and PM_{2.5} concentrations, especially during demolition and earthwork activities. Their efficiency increases when combined with continuous air quality monitoring. The authors recommend fog cannons as a practical solution for large-scale construction projects.

Li, J., Xu, P., & Zhang, L. et.al 2023 concludes that proper material storage, waste management, and traffic control significantly reduce dust emissions. Worker awareness and regular inspections improve compliance with environmental regulations. Sustainable site management practices contribute to healthier working conditions and reduced community exposure.

Tam, V. W. Y., Le, K. N., & Wang, J. et.al 2020, concludes that environmental performance improves when dust mitigation measures are implemented throughout all stages of construction. Combining engineering controls with regular monitoring produces better results than relying on individual methods. The authors emphasize continuous environmental audits for effective dust management.

Singh, A., Sharma, R., & Gupta, P. et.al 2022, examines that integrated mitigation strategies, including water spraying, dust barriers, wheel-washing systems, and vehicle speed control, significantly reduce particulate matter emissions. Public awareness and strict enforcement of environmental regulations further enhance dust-control effectiveness. The authors recommend adopting comprehensive dust management plans for all urban construction projects.

Y. Guo et al. 2023, concludes that prolonged exposure to construction dust, particularly PM_{2.5} and PM₁₀, significantly increases respiratory and cardiovascular health risks. It recommends implementing effective dust suppression methods, continuous air quality monitoring, and strict use of personal protective equipment (PPE) to reduce exposure.

Singh and R. Kumar, et.al found that construction activities substantially increase ambient PM concentrations in surrounding areas. It concludes that mitigation measures such as water sprinkling, covering construction materials, and regular road cleaning effectively reduce particulate emissions when consistently implemented.

K. Khamraev, D. Cheriyan, and J.-H. Choi et.al 2021, demonstrates that construction workers experience higher health risks due to

long-term exposure to fine particulate matter. It recommends comprehensive dust control strategies, routine health monitoring, and the adoption of real-time PM monitoring systems to protect workers.

WHO 2021, Air Quality Guidelines: Global Update The WHO concludes that even low concentrations of PM_{2.5} and PM₁₀ can adversely affect human health. It recommends achieving lower air quality limits through effective emission control policies and preventive measures across all pollution-generating sectors, including construction.

CPCB 2023, Guidelines for Dust Mitigation at Construction and Demolition Sites The guidelines recommend mandatory dust control practices such as barricading sites, water sprinkling, covering transport vehicles, wheel washing, and proper debris management. Effective implementation of these measures can significantly reduce construction-related particulate emissions and improve urban air quality.

Kumar and P. Goyal, et.al concludes that neural network models combined with principal component analysis accurately predict air quality trends. Such forecasting can support authorities in implementing timely dust mitigation measures during periods of expected high particulate concentrations.

M. Azarmi, G. Kumar, and A. Marsh et.al 2016, concludes that construction-generated airborne particulate matter can travel considerable distances, affecting nearby residents and the environment. It recommends source control, dust suppression technologies, and strategic site planning as the most effective methods to reduce particulate dispersion.

II. METHODOLOGY

This study adopts a systematic literature review approach to investigate particulate matter (PM) pollutants produced by building operations and the mitigation measures used to control dust emissions. The research is based entirely on secondary information gathered from published scientific literature, technical reports, government guidelines, and industry standards.

Relevant literature was gathered from various sources, including peer-reviewed publications from government agencies, journals, and conference proceedings and international organization reports. Databases such as Google Scholar, ScienceDirect, SpringerLink, ResearchGate, and IEEE Xplore were used to identify studies related to construction dust, particulate matter emissions, health impacts, and dust-control technologies. Keywords like these were used in the literature search. Construction dust, Particulate matter (PM₁₀ and PM_{2.5}), Air pollution in construction, Dust mitigation measures, Construction site monitoring, Occupational health hazards, Sustainable construction practices

The gathered research was filtered according to their relevance to the research objectives. Publications focusing on particulate matter generation from construction activities, health impacts of dust exposure, and mitigation techniques were selected for detailed review. Duplicate studies and unrelated publications were excluded from the analysis.

The mitigation measures reported in previous studies were reviewed and evaluated based on their ability to reduce particulate matter concentration at construction sites. Commonly adopted measures such as water spraying, dust barriers, covering of stockpiles, wheel-washing systems, road cleaning, and personal protective equipment were examined. Advanced techniques including real-time air quality monitoring, IoT-based sensors, automated misting systems, and smart dust-control technologies were also assessed. Based on the findings from the reviewed literature, suitable recommendations were developed for reducing particulate matter concentration in construction activities. The recommendations emphasize the adoption of sustainable dust-management practices, continuous monitoring, and integration of engineering and administrative control measures.

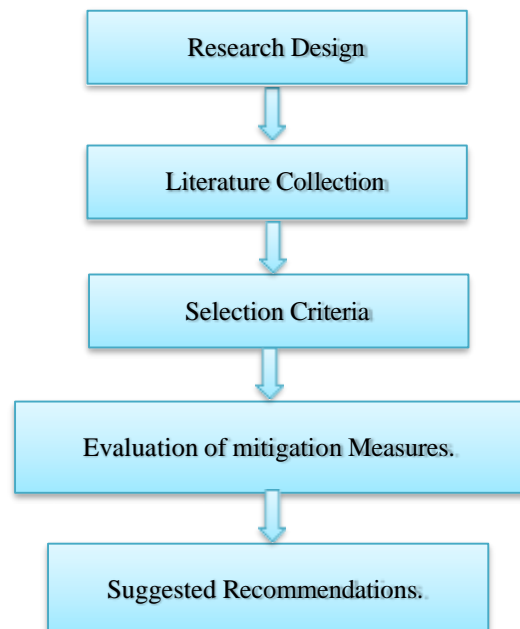


Fig. 1 Methodology Flow Chart

III. RESULTS AND DISCUSSION

This study's review of the literature shows that construction activities are significant contributors to particulate matter (PM) pollution in urban areas. Activities such as excavation, demolition, concrete mixing, drilling, cutting, material transportation, and debris handling generate large quantities of PM₁₀ and PM_{2.5}. Numerous investigations have revealed that particulate matter concentrations near construction sites frequently exceed the permissible limits prescribed by environmental regulatory agencies. A comparison of the reviewed studies indicates that no single mitigation measure is sufficient to completely control dust emissions. Instead, a combination of engineering controls, administrative practices, and technological interventions provides the best results. Engineering measures such as water spraying, dust barriers, and stockpile covering directly reduce dust generation, while administrative controls such as worker training and site management improve the efficiency of measures.

The literature evaluation consistently shows that integrated dust management strategies can reduce particulate matter concentrations by more than 50% under appropriate site conditions. Furthermore, the implementation of personal protective equipment (PPE), including dust masks and respirators, significantly reduces health risks for construction workers.

Overall, the findings emphasize that effective particulate matter mitigation requires continuous monitoring, proper planning, and the adoption of sustainable construction practices. The reviewed studies support the implementation of a comprehensive dust-control framework that combines conventional mitigation measures with modern monitoring technologies. Such an approach can improve air quality, protect worker health, and promote environmentally sustainable construction activities.

Table 1: Details of Construction Activities & Suggested Mitigation Measures

Sr. No	Construction Activity	PM Type Generated	Impact on Labour	Impact on Nearby Residents	Control / Mitigation Measures	References
1	Site clearing	PM10	Eye irritation, cough	Dust nuisance	Water sprinkling, PPE	Cecala, et.al 2012
2	Excavation	PM10	Breathing difficulty	Reduced air quality	Wet excavation	Cecala, et.al 2012
3	Backfilling	PM10	Respiratory stress	Dust deposition	Moist soil filling	Cecala, et.al 2012
4	Earth compaction	PM10	Chest discomfort	Dust dispersion	Water spraying	Brunekreef, B..et.al (2002).
5	Demolition	PM2.5, PM10	Severe lung exposure	Heavy dust pollution	Barricading, mist spray	Brunekreef, B..et.al (2002).
6	Concrete breaking	PM2.5, PM10	Silicosis risk	Air contamination	Wet cutting	Brunekreef, B..et.al (2002).
7	Drilling	PM1, PM2.5	Deep lung penetration	Irritation	Vacuum drilling	Pope, et.al (2006).
8	Blasting	PM2.5, PM10	Acute respiratory risk	Dust clouds	Controlled blasting	Pope, et.al (2006).
9	Stone cutting	PM2.5	Silicosis	Long-term illness	Wet cutting, masks	Pope, et.al (2006).
10	Brick cutting	PM2.5	Lung irritation	Reduced visibility	Local exhaust	Kumar, et.al . (2014).
11	Sand handling	PM10	Allergies	Dust nuisance	Covered storage	Kumar, et.al . (2014).
12	Cement unloading	PM2.5	Skin & lung irritation	Air pollution	Enclosed unloading	Kumar, et.al . (2014).
13	Cement mixing	PM2.5	Asthma trigger	Dust spread	Mechanical mixers	Shi, T., Schins, et.al (2003).
14	Concrete mixing	PM2.5	Chronic exposure	Air degradation	Enclosures	Shi, T., Schins, et.al (2003).

Sr. No	Construction Activity	PM Type Generated	Impact on Labour	Impact on Nearby Residents	Control / Mitigation Measures	References
15	Concrete pouring	PM1, PM2.5	Eye irritation	Minor dust	Proper handling	Shi, T., Schins, et.al (2003).
16	Curing	PM1	Minimal	Negligible	Controlled curing	Sousan, S..et.al (2016)
17	Plastering	PM2.5	Breathing issues	Indoor dust	PPE usage	Sousan, S..et.al (2016)
18	Wall chasing	PM2.5	Lung irritation	Dust & noise	Wet grinding	Sousan, S..et.al (2016)
19	Floor grinding	PM1, PM2.5	Deep lung damage	Indoor pollution	Dust collectors	Sousan, S..et.al (2016)
20	Tile cutting	PM2.5	Respiratory stress	Dust dispersion	Wet cutting	World Health Organization (2021).
21	Marble cutting	PM2.5	Silica exposure	Health risk	Masks, wet process	World Health Organization (2021).
22	Asphalt laying	PM2.5	Headache	Odour discomfort	Proper ventilation	World Health Organization (2021).
23	Bitumen heating	PM1, PM2.5	Toxic inhalation	Air pollution	Temperature control	World Health Organization (2021).
24	Road milling	PM2.5, PM10	Lung stress	Traffic dust	Water spray	World Health Organization (2021).
25	Dry sweeping	PM10	Eye irritation	Dust clouds	Wet sweeping	Central Pollution Control Board (2021).
26	Vehicle movement	PM10	Chronic exposure	Dust nuisance	Paved roads	Central Pollution Control Board (2021).
27	Material loading	PM10	Respiratory irritation	Air degradation	Gentle loading	Central Pollution Control Board (2021).
28	Material unloading	PM10	Breathing discomfort	Dust deposition	Covered unloading	Central Pollution Control Board (2021).
29	Welding	PM1	Toxic inhalation	Minor pollution	Local exhaust	Central Pollution Control Board (2021).
30	Gas cutting	PM1	Lung damage	Health nuisance	Ventilation	Central Pollution Control Board (2021).

IV. SUGGESTED MITIGATION MEASURES

Construction dust can be effectively controlled by adopting proper site management practices and source-control techniques. Regular water sprinkling on exposed soil, haul roads, excavation areas, and active work zones helps suppress airborne dust particles. The use of high-pressure mist cannons further improves dust suppression by generating fine water droplets that capture particulate matter. Wet cutting, wet drilling, pre-wetting of excavation areas, and continuous water spraying during demolition activities significantly reduce dust generation at the source. Limiting open excavation areas, carrying out rapid backfilling, and scheduling dust-generating activities during periods of low wind also contribute to minimizing particulate emissions.

Proper handling, storage, and transportation of construction materials play a crucial part in reducing dust pollution. Fine materials such as cement, sand, fly ash, and aggregates should be stored in enclosed sheds or covered with tarpaulin sheets to prevent wind erosion. Construction and demolition debris should be stored in covered containers or designated enclosed areas, while stockpiles should remain compact and protected. Trucks transporting materials and waste must be covered with tarpaulin sheets to prevent dust dispersion. Additionally, using ready-mix concrete and prefabricated construction components reduces on-site material handling, mixing, and cutting, thereby lowering dust generation.

Engineering controls and effective traffic management further enhance dust mitigation. Temporary dust barriers and green mesh fencing installed around construction sites help contain airborne particles within the project boundary. Enclosed material handling systems, dust extraction units, and local exhaust ventilation should be used during cutting, grinding, and material transfer operations. Internal haul roads should be paved wherever possible, and wheel-washing facilities should be installed at site exits to prevent soil from being carried onto public roads. Vehicle speeds within the building site have to be restricted, unnecessary vehicle movement minimized, and surrounding roads cleaned regularly using water-assisted or mechanical vacuum sweepers. Routine maintenance of construction machinery and vehicles also helps reduce dust leakage and exhaust emissions.

Environmental management practices provide additional long-term benefits in controlling particulate matter. The application of environmentally friendly chemical dust suppressants and soil stabilizers on exposed surfaces reduces wind-blown dust, while plantation of trees, grass, and green buffer zones around construction sites helps trap airborne particles naturally. Proper construction waste management, including timely collection, disposal, and prevention of waste accumulation, further minimizes dust emissions. Open burning of construction waste and vegetation should be strictly prohibited, and all activities should comply with environmental regulations and dust-control guidelines issued by regulatory authorities such as CPCB and MPCB.

V. CONCLUSION

The building sector is a primary source of particulate particles (PM) emissions due to activities such as excavation, demolition, material handling, concrete mixing, drilling, and transportation of construction materials. This study's review of the literature shows that excessive concentrations of PM₁₀ and PM_{2.5} generated at construction sites pose significant health risks to workers and nearby residents. Exposure to these pollutants can result in respiratory illnesses, cardiovascular diseases, eye irritation, reduced lung function and other negative impacts on health.

This review highlights various mitigation measures that have been successfully implemented to control dust emissions from construction activities. Conventional methods such as water spraying, dust barriers, covering of stockpiles, wheel-washing facilities, and regular road cleaning were found to be effective in reducing particulate matter concentrations. In addition, advanced technologies including real-time air quality monitoring systems, IoT-based sensors, automated misting systems, and dust suppression cannons have shown promising results in improving dust management practices.

The findings of the reviewed studies suggest that no single mitigation measure can completely eliminate dust emissions. Instead, a combination of engineering controls, administrative measures, worker awareness programs, and modern monitoring technologies provides the most effective approach for particulate matter reduction. Implementation of control measures are essential for maintaining acceptable air quality levels at construction sites.

VI.

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