FUGITIVE DUST MONITORING AT UNDER CONSTRUCTION ROADS WITH AND WITHOUT WATER SPRINKLING IN LAHORE CITY

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ABSTRACT: This study investigates the effectiveness of water sprinkling in reducing PM10 levels in Lahore, Pakistan. The data collected over a period of several days shows that water sprinkling significantly reduces PM10 concentrations in the air. The average PM10 value before water sprinkling was consistently above the PEQS, indicating poor air quality. However, after water sprinkling, the average PM10 value decreased by 49%, demonstrating a substantial improvement in air quality. The most notable reduction in PM10 levels was observed during the immediate hours following water sprinkling, suggesting that its effectiveness is most pronounced in the short term. However, the reduction gradually decreased over time as the dust particles settled and the moisture evaporated. While water sprinkling is a viable method for reducing fugitive dust pollution, it is important to consider its limitations and potential drawbacks. Excessive water use can lead to waterlogging and other environmental issues, and its effectiveness may be limited during dry seasons or in regions with limited water resources. Therefore, a combination of control measures, including proper wetting of dusty areas, covering stockpiles of materials, and using dust suppressants, is essential for achieving long-term improvements in air quality.

Key words:

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INTODUCTION

Fugitive dust, particulate matter that becomes airborne from various sources, significantly contributes to air pollution. These sources include construction sites, unpaved roads, agricultural activities, and industrial operations. The fine particles emitted from these activities can penetrate deep into the lungs, causing respiratory problems, cardiovascular diseases, and other health issues. Studies have shown that fugitive dust can exacerbate existing respiratory conditions, particularly in vulnerable populations such as children, the elderly, and individuals with asthma (Zhang et al., 2018). Additionally, fugitive dust can reduce visibility, impair air quality, and contribute to acid rain (Li et al., 2020).

To mitigate the impact of fugitive dust, various control measures can be implemented, such as proper wetting of dusty areas, covering stockpiles of materials, and using dust suppressants. By addressing fugitive dust emissions, we can improve air quality and protect public health (Wang et al., 2022).

In addition to its adverse effects on human health and air quality, fugitive dust also plays a role in climate change. Fine particulate matter emitted from fugitive dust sources can act as aerosols, reflecting solar radiation back into space and cooling the Earth's surface. This phenomenon is known as the aerosol forcing effect. However, the overall impact of fugitive dust on climate is complex and depends on various factors, including the type and size of the particles, their geographic location, and their interactions with other atmospheric components (Ramanathan et al., 2001).

Furthermore, fugitive dust can influence the hydrological cycle by acting as cloud condensation nuclei, promoting cloud formation and precipitation. This can have implications for regional climate patterns and water resources. Understanding the impact of fugitive dust on climate change is crucial for developing effective mitigation strategies and adapting to future climate challenges (IPCC, 2021).

Lahore, a densely populated city in Pakistan, faces significant challenges due to fugitive dust pollution. The rapid urbanization and industrialization of the city have led to an increase in construction activities, unpaved roads, and industrial emissions, all of which contribute to the generation of fugitive dust. Studies have shown that the levels of particulate matter (PM) in Lahore's air often exceed the national and international air quality standards, posing a serious threat to public health (Khan et al., 2020).

The impact of fugitive dust in Lahore is particularly severe during the dry season, when strong winds can stir up dust and pollutants from various sources. This can exacerbate respiratory problems, cardiovascular diseases, and other health issues, especially among vulnerable populations such as children, the elderly, and individuals with pre-existing conditions. Additionally, fugitive dust can reduce visibility, impair air quality, and contribute to the deterioration of historical monuments and buildings (Asif et al., 2021).

To address the problem of fugitive dust in Lahore, it is essential to implement effective control measures and improve urban planning. This includes promoting sustainable construction practices, improving road infrastructure, and adopting green spaces and urban forestry. By taking these steps, Lahore can reduce its reliance on fossil fuels, improve air quality, and create a healthier and more sustainable environment for its residents (Siddiqui et al., 2022).

METHODOLOGY

Selection of Sites: This study was conducted at currently available three under construction roads of the city to evaluate the magnitude of dust pollution generation from such projects. It was also carried out to asses the role of water showering/sprinkling to suppress the SPM generation.

The aim of the study was to assess the quantity of fugitive dust produced due to under construction roads with and without water showering**.** For this purpose LDA Road engineering Department officer were consulted and currently available three under construction roads were selectednamely as

1- Service road of Band road near Sanda Under pass.
2- Govt Pilot School to Pak Block Road Allama Iqbal Town Lahore.
3- Walton Road near Qainchi Flyover Lahore.

The selection was based on the following criteria to conduct a meaningful study.

i- Having heavy traffic load round the clock
ii- Connecting maximum areas of city
iii- Being Under construction

Technique used: BAM Technique (Beta Attenuation Method) was used to monitor the value of PM_{10} that is internationally accepted and used methodology for PM_{10} and $PM_{2.5}$ monitoring.

In this technique the source emits the beam of beta radiations which strike the target particles. These radiations may be absorbed, reflected or pass directly through the dust material. The attenuation of intensity in beta rays is proportional to the amount of material present. The attenuation through most materials is relatively consistent and is based on the electron density of the material (calculated by dividing the atomic number by the atomic mass).

Monitoring Strategy: As per monitoring plane, the monitoring was carried out in two conditions of road.

i- In dry conditions
ii- In wet conditions after sprinkling water

Equipment Installation: The equipment was installed following the international protocol as per SOPs

i- 20 meters away from trees.
ii- Sampling Inlet tube opening was at 2 meter high from ground to air.
iii- More than 2 meters away from supporting source like generator ,vehicle etc
iv- Away from any air flow obstacle.

Monitoring Time Span: The fugitive dust was monitored for 7 hours to 9 hours depending upon the weather conditions of month July.

At all site the monitoring was carried out continuously so that a smooth line data can be achieved showing dust pollution trends in a stream manner.

RESULTS AND DISCUSSIONS

The study on road fugitive dust emissions, has been carried out at three under construction road sites of Lahore which are one of the busiest roads of Lahore city and the findings of the study are summarized as

1- **Service Road along band Road near Sanda under pass Lahore:** The said road site is the part of Lahore ring road and bears a heavy load of large number of different types of vehicles including trucks, buses, cars and motor cycle rickshaws etc. The fugitive dust in terms of PM10 was measured first in dry condition .The maximum value of PM10 was measured as 390 µg/m³and lowest value was 353 ug/m3. The average PM10 concentration was calculated 375 µg/m³., this makes it the most polluted road of the city. The Table 1 demonstrates a significant reduction in PM10 levels after water sprinkling. The average PM10 value before water sprinkling was 375 µg/m³, which exceeds the PEQS of 150 µg/m³. After water sprinkling, the average PM10 value decreased to 191 µg/m³, indicating a 49% reduction in particulate matter.

The most notable reduction was observed between 7 PM and 9 PM, where PM10 levels dropped by 54% and 47% respectively. This suggests that the immediate impact of water sprinkling is most pronounced during these hours. However, the reduction in PM10 levels gradually decreased over time, indicating that the effectiveness of water sprinkling may diminish as the dust particles settle and the moisture evaporates.

While water sprinkling is an effective method for reducing fugitive dust pollution, it is important to consider its limitations and potential drawbacks. For example, excessive water use can lead to waterlogging and other environmental issues. Additionally, water sprinkling may not be feasible in all areas, particularly during dry seasons or in regions with limited water resources. Therefore, it is essential to explore and implement a combination of control measures, including proper wetting of dusty areas, covering stockpiles of materials, and using dust suppressants, to achieve long-term improvements in air quality.

Table 1: PM10 monitoring at Service Road along band Road near Sanda under pass Lahore.

Sr#	Time	PM_{10}Value (ug/m^3) before water sprinkling	PM_{10}Value (ug/m^3) after water sprinkling	PEQS (ug/m^3)	Remarks
01	2-00 Pm	390	-	150	Exceeds the PEQS
02	3-00 Pm	353	-	150	Exceeds the PEQS
03	4-00 Pm	381	-	150	Exceeds the PEQS
04	5-00 Pm	372	-	150	Exceeds the PEQS
05	6-00 Pm	370	-	150	Exceeds the PEQS
06	7-00 Pm	384	-	150	Exceeds the PEQS
07	8-00 Pm	-	172 (54% reduction)	150	Exceeds the PEQS
08	09-00 Pm	-	199 (47% reduction)	150	Exceeds the PEQS
09	10-00pm	-	228 (39% reduction)	150	Exceeds the PEQS
Average value		**375**	191 (49% reduction)	150	Exceeds the PEQS

The next step was to see the impact of road water showering on air quality of site. For this purpose water bowser was used for water sprinkling on road, after that the concentration of PM_{10} was measured which showed that more than half of the dust pollution was reduced due to water showering. The water molecules adhere the dust particles and bound them into a mud type semisolid condition. After water sprinkling in first hour the pollution reduction was 54% and in 2nd hour was 47% .at third hour there was 39 % reduction as shown in Table 2. The decrease in reduction efficiency with the passage of time was directly related to the dryness of road due to hot emissions of vehicles and hot weather conditions. It can be concluded that if the road site is watered after two or three hours interval then the dust pollution control can be enhanced after every interval.

2- **Govt. Pilot High School To Pak Block Road Allama Iqbal Town Lahore:** This site was also monitored in dry and wet conditions. The maximum value of PM_{10} was 370 ug/m$_3$ and lowest PM_{10} value was 346 ug/m$_3$. The average value of fugitive dust was remained 357 ug/m$_3$ in dry conditions. This road was somehow small in width than others but has high speed heavy LTV traffic load. One side of the road was closed for traffic due to reconstruction and all traffic was passing through the other one side. Being a small road there was a traffic congestion causing extensive fugitive dust generation on road.

The provided data demonstrates a significant reduction in PM10 levels after water sprinkling. The average PM10 value before water sprinkling was 357 µg/m³, which exceeds the PEQS of 150 µg/m³. After water sprinkling, the average PM10 value decreased to 195 µg/m³, indicating a 45% reduction in particulate matter.

The most notable reduction was observed between 11:30 PM and 1:30 PM on April 7th, where PM10 levels dropped by 54% and 46% respectively. This suggests that the immediate impact of water sprinkling is most pronounced during these hours. However, the reduction in PM10 levels gradually decreased over time, indicating that the effectiveness of water sprinkling may diminish as the dust particles settle and the moisture evaporates.

While water sprinkling is an effective method for reducing fugitive dust pollution, it is important to consider its limitations and potential drawbacks. For example, excessive water use can lead to waterlogging and other environmental issues. Additionally, water sprinkling may not be feasible in all areas, particularly during dry seasons or in regions with limited water resources. Therefore, it is essential to explore and implement a combination of control measures, including proper wetting of dusty areas, covering stockpiles of materials, and using dust suppressants, to achieve long-term improvements in air quality.

The impact of road water sprinkling was also assessed here which showed the same reduction efficiency. After watering the road, the PM_{10} was reduced to 165 ug/m$_3$ in first hour and pollution reduction was 54%. In 2nd hour the reduction was 46% with PM_{10} value of 1192 ug/m$_3$. During third hour the reduction in dust pollution was 36% as the road was becoming dry the value of dust pollution was again attaining to its original position. The decrease in reduction efficiency with the passage of time was directly related to the dryness of road due to hot emissions of vehicles and hot weather conditions. It can be concluded that if the road site is watered after two or three hours interval then the dust pollution control can be enhanced after every interval.

3- **Walton Road near Qainchi Flyover Lahore:** This is a main road connecting DHA and cantonment areas with a trunk road known as Ferozepur road. It bears heavy LTV traffic load daily and due to being under construction producing fugitive dust on both sides service roads. The maximum PM_{10} concentration monitored was

362 ug/m_3 and lowest value of PM_{10} was 344 C. The average value of 349 ug/m_3 was observed during study.
The provided data demonstrates a significant reduction in PM10 levels after water sprinkling. The average PM10 value before water sprinkling was 349 µg/m³, which exceeds the PEQS of 150 µg/m³. After water sprinkling, the average PM10 value decreased to 191 µg/m³, indicating a 49% reduction in particulate matter.

The most notable reduction was observed between 7:30 PM and 9:30 PM, where PM10 levels dropped by 52% and 37% respectively. This suggests that the immediate impact of water sprinkling is most pronounced during these hours. However, the reduction in PM10 levels gradually decreased over time, indicating that the effectiveness of water sprinkling may diminish as the dust particles settle and the moisture evaporates.

While water sprinkling is an effective method for reducing fugitive dust pollution, it is important to consider its limitations and potential drawbacks. For example, excessive water use can lead to waterlogging and other environmental issues. Additionally, water sprinkling may not be feasible in all areas, particularly during dry seasons or in regions with limited water resources. Therefore, it is essential to explore and implement a combination of control measures, including proper wetting of dusty areas, covering stockpiles of materials, and using dust suppressants, to achieve long-term improvements in air quality.

Table 2: PM10 monitoring Govt Pilot High School To Pak Block Road Allama Iqbal Town Lahore

Sr#	Time	PM_{10}Value (µg/m^3)	PM_{10}Value (µg/m^3) after water sprinkling	PEQS(µg/m^3)	Remarks
01	3-00 am 3/7/24	370	-	150	Exceeds the PEQS
02	4-00 Pm 3/7/24	355	-	150	Exceeds the PEQS
03	5-00 Pm 3/7/24	360	-	150	Exceeds the PEQS
04	6-00 Pm 3/7/24	346	-	150	Exceeds the PEQS
05	7-00 Pm 3/7/24	357	-	150	Exceeds the PEQS
06	8-00 Pm 3/7/24	365	-	150	Exceeds the PEQS
07	9-00 Pm 3/7/24	350		150	Exceeds the PEQS
08	11-30 Pm 4/7/24	-	165 (54% reduction)	150	Exceeds the PEQS
09	12-30pm 4/7/24	-	192 (46% reduction)	150	Exceeds the PEQS
10	01-30pm 4/7/24		230 (36% reduction)		
Average value		**357**	195 (45% reduction)	150	Exceeds the PEQS

Table 3: PM10 monitoring at Walton Road near Qainchi Flyover Lahore.

Sr#	Time	PM_{10}Value (ug/m^3)	PM_{10}Value (ug/m^3) after water sprinkling	PEQS(ug/m^3)	Remarks
01	3-30 Pm	344	-	150	Exceeds the PEQS
02	4-30 Pm	350	-	150	Exceeds the PEQS
03	5-30 Pm	335	-	150	Exceeds the PEQS
04	6-30 Pm	362	-	150	Exceeds the PEQS
05	7-30 Pm	355	-	150	Exceeds the PEQS
06	8-30 Pm		168 (52% reduction)	150	Exceeds the PEQS
07	9-30 Pm		221 (37% reduction)	150	Exceeds the PEQS
Average value		**349**	191 (49% reduction)	150	Exceeds the PEQS

The water sprinkling was carried out like other road sites to assess its impact on dust pollution. During first hour after water showering the value of PM_{10} concentration was reduced to 168 ug/m_3 from average value of 349 ug/m$_{3.}$ having 52% reduction in dust pollution. Similarly in 2nd hour after showering the reduction in dust pollution was 37 % but PM_{10} concentration was increased from 168 to 221 ug/m$_{3.}$ With the passage of time as has already mentioned above the road becomes dry due to hot weather conditions, hot emissions of vehicles and pulverization & abrasion processes which again starts to produce dust particles. That is why after water showering the reduction efficiency decreases and PM_{10} concentration increases as the time passes. Therefore water sprinkling should be repeated after two or three hours intervals on daily bases. After each batch of water showering the dust pollution control will be better than each first.

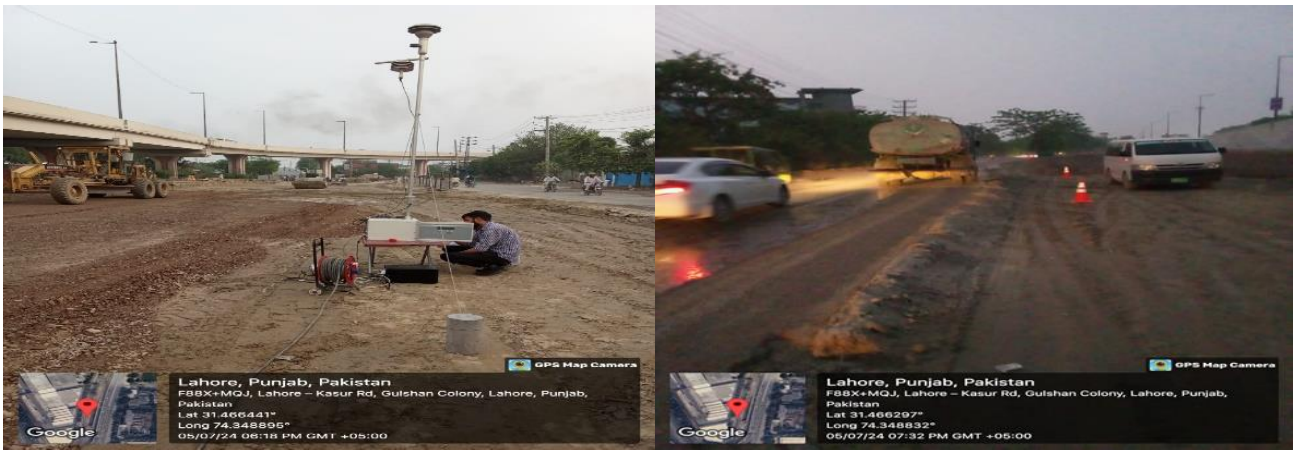

Fig. 1: PM10 monitoring before and after the sprinkling of water on roads

Conclusion: The data presented in the table demonstrates a significant reduction in PM10 levels after water sprinkling. The average PM10 value before water sprinkling was consistently above the PEQS, indicating poor air quality. However, after water sprinkling, the average PM10 value decreased significantly, with a 49% reduction observed overall.

The most notable reduction in PM10 levels occurred during the immediate hours following water sprinkling, suggesting that its effectiveness is most pronounced in the short term. However, the reduction gradually decreased over time as the dust particles settled and the moisture evaporated.

While water sprinkling is a viable method for reducing fugitive dust pollution, it is important to consider its limitations and potential drawbacks. Excessive water use can lead to waterlogging and other environmental issues, and its effectiveness may be limited during dry seasons or in regions with limited water resources. Therefore, a combination of control measures, including proper wetting of dusty areas, covering stockpiles of materials, and using dust suppressants, is essential for achieving long-term improvements in air quality.

Recommendations: Based on the findings of this study, the following research recommendations are proposed:

1. **Long-term monitoring:** Conduct long-term monitoring of PM10 levels in Lahore, both before and after the implementation of water sprinkling and other control measures. This will help to assess the long-term effectiveness of these measures and identify any potential unintended consequences.

2. **Comparative analysis:** Compare the effectiveness of water sprinkling with other fugitive dust control measures, such as chemical dust suppressants, road paving, and construction site management practices. This will help to identify the most effective and cost-efficient strategies for reducing fugitive dust pollution in Lahore.

3. **Economic analysis:** Conduct an economic analysis to evaluate the costs and benefits of implementing different fugitive dust control measures. This will help to identify the most sustainable and economically viable strategies for improving air quality in Lahore.

4. **Public awareness campaigns:** Develop and implement public awareness campaigns to educate the public about the health risks associated with fugitive dust pollution and the importance of adopting sustainable practices. This will help to foster public support for efforts to reduce fugitive dust emissions.

5. **Policy development:** Advocate for the development and implementation of policies and regulations that require the adoption of fugitive dust control measures in construction, industrial, and agricultural activities. This will help to ensure that these measures are consistently applied throughout the city.

6. **International collaboration:** Collaborate with researchers and policymakers from other cities facing

similar challenges to share knowledge, experiences, and best practices for reducing fugitive dust pollution. This will help to accelerate progress and identify innovative solutions.

7. **Technological advancements:** Explore the potential of new technologies, such as drones and satellite imagery, for monitoring fugitive dust emissions and evaluating the effectiveness of control measures. This will help to improve the efficiency and accuracy of air quality management efforts.

Findings

- The average value of PM10 at under construction road sites ranges between 349 to 375 ug/m3 in dry conditions
- After water sprinkling the value of PM10 reduces about 54 % .However PM10 value starts to increase again with the passage of time because of dryness of road as the sprinkled water vaporizes, soaked by road and transferred by vehicles tyre rapidly and road becomes dry within one or two hours
- The monitoring results shows that the source of PM10 is not only the current road site but it also comes from surrounding localities / areas having poor conditions of roads and cleanliness.
- Continuous water sprinkling with two or three hours interval may cause very effective reduction in road site dust pollution generation.

Way forward

- Extensive water showering and cleaning of roads must be done regularly adjacent to under construction sites.
- Unpaved surface along roads must be covered with gravels or vegetation cover.
- Speed breakers must be constructed at dust sensitive roads near construction site projects to reduce the speed of vehicles. High speed causes heavy dust clouds on roads.
- Early repair of broken roads must be ensured.
- In time completion of development projects is very compulsory this may reduce duration of painful era for community.

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