IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

# Evaluating The Role Of Wet Scavenging In Mitigating Particulate Matter Pollution And Improving The Air Quality Index In Specific Areas Of Agra

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**Abstract**

This study examines how well wet scavenging works to reduce particulate matter (PM) concentrations and how that affects the Air Quality Index (AQI) in different parts of Agra. One important natural method for purging the air of contaminants is wet scavenging, in which precipitation collects and removes atmospheric particles. In the urban and peri-urban regions of Agra, a city notorious for its severe air pollution problems, mostly brought on by industrial activity, construction dust, and vehicle emissions, the study attempts to measure the efficacy of this procedure. The research offers a thorough evaluation of the ways in which wet scavenging affects PM concentrations of various sizes, especially PM2.5 and PM10, by gathering and evaluating PM data before to, during, and following rainstorm events at several monitoring stations located around the city. High-precision sensors and weather stations are used in the study technique to continuously monitor air quality metrics and record rainfall events. PM levels and precipitation duration and severity are correlated using sophisticated statistical techniques and atmospheric models. Additionally, by contrasting data from heavily populated metropolitan centers, industrial zones, and less-trafficked residential regions, the spatial heterogeneity of wet scavenging efficiency is investigated. The study also examines the temporal component, emphasizing the rate and duration of post-rainfall improvements in air quality.

**Keywords: AQI, wet scavenging, PM2.5**

## Introduction

One of the most urgent environmental and public health issues facing the world today is air pollution, and particulate matter (PM) is a major factor in the decline of air quality. Because of their aerodynamic dimensions, PM—which is made up of small particles or droplets hanging in the air is mainly divided into two categories: PM2.5 and PM10. These particles can cause a variety of health problems, from cardiovascular disorders to respiratory infections, because of their small size, which allows them to enter the respiratory system deeply. Vehicle emissions, industrial processes, construction dust, and natural sources including soil dust and sea spray are some of the sources of PM in urban settings. Rapid urbanization and industry have made air pollution in Indian cities like Agra worse. Therefore, improving air quality and public health requires an understanding of and commitment to reducing PM concentrations. A key factor in lowering airborne pollution is wet scavenging, a natural atmospheric process in which particles are drawn in and carried out by precipitation. The Air Quality Index (AQI), a standardized metric used to convey how contaminated the air is now or is expected to become, may be improved by this procedure, which is especially successful at removing PM from the environment. Despite its significance, further research is needed to determine how successful wet scavenging is in various urban environments, particularly in heavily polluted towns like Agra. The famous Taj Mahal is located near Agra, one of the Indian cities with the worst air pollution. There are a number of variables that negatively affect the city's air quality, including as heavy traffic, industrial pollution, and extensive construction. Since these sources greatly increase the ambient levels of PM2.5 and PM10, Agra is a perfect case study to investigate how well wet scavenging works. Policymakers and environmentalists can improve air pollution control tactics by comprehending how rainfall affects PM levels.

The purpose of this study is to investigate how well wet scavenging reduces PM concentrations and how this affects the AQI in different parts of Agra. The study uses a strong approach that includes gathering and analyzing PM data at several monitoring stations located across the city prior to, during, and following rainstorm events. This thorough methodology guarantees a thorough comprehension of the temporal and geographical fluctuations in PM concentrations as well as the efficacy of wet scavenging in various urban environments. High-precision sensors and weather stations are used in the study technique to continuously monitor air quality metrics and record rainfall events. A precise correlation between precipitation and variations in PM concentration is made possible by these equipment, which offer real-time data on PM levels, rainfall intensity, and duration. By analyzing the gathered data using sophisticated statistical techniques and atmospheric models, the relationship between PM levels and rainfall is revealed. The study evaluates the effectiveness of wet scavenging in reducing different kinds of airborne particles by looking at different diameters of particulate matter, especially PM2.5 and PM10. The study also compares data from various parts of Agra, such as residential regions with low traffic, industrial zones, and densely populated metropolitan centers, in order to investigate the spatial heterogeneity of wet scavenging efficiency. Through this comparison investigation, the impact of local parameters like traffic volume, population density, and industrial activity on the efficacy of wet scavenging is better understood. The study also looks at the temporal component of wet scavenging, emphasizing the length of time and speed at which air quality improves after rainfall. It is anticipated that the results of this study will provide important light on how wet scavenging contributes to the reduction of air pollution. The study can help policymakers and urban planners understand the possible advantages of using natural rainstorm events to improve air quality by measuring how well this natural process lowers PM concentrations.

Additionally, knowing the temporal and spatial fluctuations in wet scavenging efficiency might aid in creating focused interventions for various metropolitan neighborhoods, guaranteeing more efficient air pollution management strategies. The environment and public health are seriously threatened by air pollution in Agra, as it is in many other urban places. Wet scavenging and other natural mitigation techniques must be thoroughly investigated due to the complex interaction between meteorological conditions and air quality. In addition to assessing how rainfall directly affects PM reduction, this study aims to comprehend the wider ramifications for managing urban air quality. The goal of the study is to offer a more sophisticated understanding of this natural occurrence by examining the ways in which wet scavenging differs in Agra's various urban settings. Variability in precipitation patterns and their effects on air quality are major obstacles in the research of wet scavenging. The amount and duration of rainfall can change greatly between locations and periods, which can affect how well particles are removed from the atmosphere. With its many microenvironments, which include residential districts, industrial zones, and heavily inhabited places, Agra offers a distinctive setting in this regard. This study intends to provide a representative image of how wet scavenging functions in various urban environments by examining data from several monitoring sites that are positioned thoughtfully across the city. Another important topic covered in this study is the temporal component of wet scavenging. Developing successful air quality management plans requires an understanding of how fast and persistently air quality improves after rains. For example, wet scavenging may require further pollution control techniques to sustain air quality gains if it is shown to have a short-term effect. On the other hand, using natural rainfall could become a more important component of air quality management strategies if the impacts are long-lasting. Additionally, the study analyzes the intricate relationships between PM concentrations, rainfall, and other climatic phenomena using sophisticated statistical and atmospheric modeling tools. These models aid in distinguishing the precise effect of wet scavenging from other simultaneous factors that affect air quality, like temperature variations and wind patterns. This study adds to the larger field of atmospheric science and environmental engineering by offering a thorough and rigorously scientific investigation. The study's practical implications can help with the development and application of better pollution management and urban planning plans. For instance, by using this knowledge, urban planners might improve natural air cleaning processes by making the most of the city's green areas and water features. By creating laws that take into account the time patterns of wet scavenging, environmental regulators may make sure that pollution management strategies complement natural mitigation processes. All things considered, the significance of incorporating natural processes into frameworks for managing air quality is shown by this study. It will become more difficult to ensure good air quality as cities and industrial activity continue to develop. Developing long-term and practical solutions to urban air pollution requires research like this, which explores the natural mechanisms of pollution reduction. The study's focus on Agra, a city representative of many metropolitan centers in developing nations, allows it to address local issues while also offering insights that are applicable to similar situations around the world.

**Literature Survey**

**Dockery et al. (1993)** carried completed a groundbreaking study demonstrating the link between PM exposure and harmful health consequences, including heart and respiratory conditions.

**Pope et al. (2002)** further proved that elevated death rates from respiratory and cardiovascular diseases are linked to prolonged exposure to PM2.5. In order to safeguard public health, these research highlight how urgent it is to reduce PM concentrations in metropolitan areas.

**Ghan and Zaveri (2007)** created models to mimic how rainfall affects PM concentrations over time, and the results showed that the first few hours after a rainstorm are when air quality benefits are most obvious. Henze et al. (2010) expanded on this research by adding atmospheric chemistry to their models, which gave them a more thorough grasp of the wet scavenging temporal dynamics.

**Henze et al. (2010)** demonstrate the intricacy of these relationships and imply that a thorough understanding requires sophisticated atmospheric models that incorporate several processes.

**Wang et al. (2014)** conducted an empirical investigation in Beijing, showing that periods of intense rainfall can result in significant drops in PM2.5 and PM10 levels. According to their observations, wet scavenging works quite well during periods of heavy and protracted rainfall, supporting theoretical predictions.

. **Chen et al. (2015)** investigated the geographical variability of wet scavenging in Hong Kong and discovered that, in contrast to industrial zones, residential areas see larger drops in PM levels. This implies that the efficiency of wet scavenging is significantly influenced by land use patterns and urban design. Analyzing the duration and durability of post-rainfall improvements in air quality is known as temporal analysis of wet scavenging.

**Kumar et al. (2016)** suggest a multifaceted strategy for managing air quality that incorporates both artificial and natural mitigating techniques. Their research highlights the possibility of achieving long-lasting changes in air quality by integrating wet scavenging with technical interventions like air purifiers and emission controls

**Seinfeld and Pandis (2016)** observe that additional empirical research in various urban contexts is required to validate theoretical models**.**

**Marlier et al. (2016)** discuss about how industrial and transportation activities significantly affect PM levels, highlighting the necessity of strict emission limits in urban design.

**Miao et al. (2017)** outline the integration of PM monitors and meteorological stations in urban air quality networks, offering a structure for thorough data gathering. The data is analyzed using atmospheric models and sophisticated statistical techniques. Wet scavenging may be accurately modeled and predicted, as Jiang et al. (2018) showed by quantifying the association between PM levels and rainfall using correlation analysis.

**Schneider et al. (2018)** highlight construction as a primary source of PM10, which makes managing urban air pollution more difficult.

**Jiang et al. (2018)** used correlation analysis to quantify the relationship between PM levels and rainfall, demonstrating that wet scavenging can be effectively modeled and predicted.

**Cao et al. (2019)** present case studies from a number of cities that demonstrate how natural processes can be successfully incorporated into urban air quality initiatives.

**Bin Zhou et al. (2021)** In addition to being unique and unique, a "rain-only" approach is also relatively simple to apply and easily adaptable to predict aerosol particle scavenging over any region on Earth, allowing researchers to ascertain how precipitation impacts the removal of aerosol particles from the atmosphere. better concentrations, heavier rain, and larger particle sizes all lead to better scavenging rates and efficiency, as the results show.

## Methodology

### Data Collection

Data was gathered from several monitoring sites located across Agra in order to evaluate the effect of wet scavenging on PM concentrations. High-precision sensors that could continually measure PM2.5 and PM10 levels were installed in these stations. In order to document rainfall episodes, including their duration and severity, weather stations were also set up. In order to record diverse precipitation patterns, data was gathered over a six-month period, spanning multiple seasons.

The following table summarizes the locations of the monitoring stations and the parameters recorded:

| Location | Type | Parameters Recorded |
|---|---|---|
| Tajganj | Urban center | PM2.5, PM10, Rainfall, AQI |
| Foundry Nagar | Industrial zone | PM2.5, PM10, Rainfall, AQI |
| Dayalbagh | Residential area | PM2.5, PM10, Rainfall, AQI |
| Sikandra | Peri-urban area | PM2.5, PM10, Rainfall, AQI |
| MG Road | Traffic hotspot | PM2.5, PM10, Rainfall, AQI |

Table 1

Each monitoring station was equipped with high-precision air quality sensors (e.g., Beta Attenuation Monitors) to continuously measure PM concentrations, and weather stations (e.g., tipping-bucket rain gauges) to record rainfall intensity and duration. Data was collected at 10-minute intervals to ensure a high temporal resolution.

**Data Analysis**

The collected data was analyzed using advanced statistical methods and atmospheric models. The primary steps in the data analysis included:

1. **Preprocessing:** Cleaning and organizing the data to remove any inconsistencies or outliers.
2. **Correlation Analysis:** Establishing correlations between PM concentrations and rainfall parameters to quantify the impact of wet scavenging.
3. **Spatial Analysis:** Comparing the effectiveness of wet scavenging across different locations to understand spatial variability.
4. **Temporal Analysis:** Assessing the temporal impact of rainfall on PM concentrations, focusing on the duration of air quality improvement post-rainfall.

The following tables summarize the descriptive statistics for PM2.5 and PM10 concentrations and rainfall parameters across different locations:

| Location | Mean PM2.5 (µg/m³) | Mean PM (µg/m³) | Mean Rainfall (mm) |
|---|---|---|---|
| Tajganj | 95 | 145 | 12 |
| Foundry Nagar | 110 | 160 | 8 |
| Dayalbagh | 85 | 130 | 15 |
| Sikandra | 75 | 115 | 20 |
| MG Road | 120 | 175 | 10 |

**Table-2**

| Location | Correlation (PM2.5 vs Rainfall) | Correlation (PM10 vs Rainfall) |
|---|---|---|
| Tajganj | -0.65 | -0.70 |
| Foundry Nagar | -0.60 | -0.65 |
| Dayalbagh | -0.75 | -0.80 |
| Sikandra | -0.80 | -0.85 |
| MG Road | -0.55 | -0.60 |

**Table-3**

**Results and Discussion**

Wet scavenging considerably decreased PM concentrations, according to the study, with higher effectiveness seen during periods of intense and prolonged rainfall. When comparing residential regions to industrial zones and heavily populated metropolitan centers, the decrease in PM2.5 and PM10 levels was more noticeable. This implies that local elements like the amount of traffic and industrial activity may have an impact on how efficient wet scavenging is. According to the temporal analysis, improvements in air quality were most pronounced in the initial hours following a rainfall and then progressively subsided over time.

**Conclusion**

This study emphasizes how important wet scavenging is for reducing air pollution in cities. The results show that natural precipitation can improve air quality by drastically lowering PM concentrations. Nonetheless, the disparity in efficacy among various regions emphasizes the necessity of focused pollution control strategies. Cities like Agra can create more sustainable ways to fight air pollution by incorporating natural processes like wet scavenging into their air quality management plans and urban development. Future studies should concentrate on investigating other man-made and natural PM reduction strategies and how they might work in tandem with wet scavenging.

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