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Investigating the water mist as a potential solution for the dust settlement on the construction site

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Abstract:
Construction sites are great sources of particulate matter in airborne emissions, thereby causing greater health hazards among the workers involved and people who stay closer to such constructions. Some of the diseases caused as a result of exposure to respirable crystalline silica in construction dust include lethal respiratory diseases silicosis, lung cancers, and COPD. In the UK alone, more than 500 construction worker deaths are caused by silica exposure every year, and millions in the US face the same risks. Traditional dust suppression methods, such as water spraying and conventional dust collectors, often suffer from inefficiencies, excessive water usage, and limited effectiveness, particularly in regions with water scarcity. This study proposes an IoT-based mist-making system for dust suppression, which optimizes water usage while enhancing PM control efficiency on construction sites. A scale-model prototype was developed to replicate construction site conditions within a controlled 30x30 cm test box. The system consists of two GP2Y1014AU0F optical dust sensors to detect PM concentrations before and after mist deployment, a mist maker module to generate fine water droplets and a 70 CFM fan for air circulation. Experimentation was done using one to four mist makers. Results obtained showed a strong positive relationship between water usage and dust suppression efficiency. Specifically, the 15 ml and 20 ml water consumptions resulted in settling efficiencies of 15% and 18%, respectively. A considerable increase in the number of mist makers significantly enhanced the rate of dust settling. This work demonstrates the ability of the system to mitigate health risks and address water sustainability concerns, thus making it a practical and scalable solution for construction environments.

Keywords: *Optical dust sensors, Construction sites, worker health hazards, IoT-based mist-making system, Dust suppression*

I. INTRODUCTION

Construction sites are significant sources of high PM emissions with possible serious health risks for the construction workforce and residents in adjacent communities. Airborne dust, especially respirable crystalline silica, can cause severe respiratory diseases, including silicosis, lung cancer, and Chronic Obstructive Pulmonary Disease (COPD). According to the Health and Safety Executive, more than 500 construction worker deaths annually in the UK result from silica exposure. Some 2.2 million workers in the United States suffer from this disease; inhaling dust containing fine particles can lead to long-term complications in health conditions, hence effective management of dust becomes very important for safety among workers and public health.[1]

Current methods used in dust suppression, such as water spraying and conventional dust collectors, have a number of outstanding disadvantages. The creation of mud from using water spraying affects the construction activity progression.[2] Conventional dust collectors do not collect all the particulate matter in the air during the working process.[3] Additionally, these methods depend significantly on the use of massive amounts of water, which makes them raise sustainability issues in areas where water is scarce.[4]

The mechanism proposed in this research is based on the design of a new system to form fogs with the objective of improving dust-suppression efficiency and reducing the quantity of water used. This mechanism integrates a sensor device for monitoring the dust sensor and a mist-making device that may allow real-time monitoring and management of airborne particulate levels.[5] It will measure the concentrations of dust in the air before the mist is applied and after it, ensuring optimization of both the usage of water and dust control efficiency.

The research methodology is to develop a scale model, which uses IoT technology for the dynamic monitoring of construction sites' PM. One sensor will determine the quantity of dust produced, while the other sensor will measure how much settles after the application of mist.[6] This dual sensor will enable accurate calculations regarding the efficiency with which the mist maker has reduced airborne particulates; it will also provide data on the time and water usage for effective dust suppression.

Beyond health benefits, the implementation of this fog generation mechanism would have more potential: it would impact the broader community also. It can significantly reduce workers' and near-site residents' respiratory health risks in the presence of improvements in air quality at construction sites.[7] Above all, the requirement for better measures of dust control can lead to healthier community relationships, investments in construction projects, and general economic development within the urban area. Thus, the problem of dust management would come on the agenda with regard to sustainable growth and improvement in living conditions for cities.

A. Motivation

Construction sites are significant contributors to airborne particulate matter (PM), posing severe health risks such as silicosis, lung cancer, and COPD to workers and nearby communities. Traditional dust suppression methods, including water spraying and mechanical collectors, suffer from inefficiency, excessive water consumption, and impracticality in water-scarce regions. In the UK alone, over 500 construction workers die annually due to silica exposure, while millions globally face similar risks. These challenges underscore the urgent need for sustainable, cost-effective solutions that balance dust control efficacy with resource conservation. This research is motivated by the dual imperative of safeguarding human health—particularly for vulnerable construction workers—and addressing environmental sustainability through optimized water usage. By integrating IoT technology with mist-based suppression, the study aims to mitigate health hazards while promoting eco-friendly practices in construction, aligning with global goals for occupational safety and sustainable urban development.

B. Novelty

This study introduces an IoT-enabled mist-making system that uniquely combines real-time dust monitoring with adaptive water mist deployment. Unlike conventional methods, the system employs dual optical dust sensors to measure PM concentrations pre- and post-mist application, enabling dynamic adjustments for optimal efficiency. The compact, portable prototype integrates a 30x30 cm test box with configurable mist makers (1–4 units) and a 70 CFM fan to simulate real-world conditions, ensuring scalability. By leveraging ultrasonic mist generation, the system produces fine droplets that maximize dust-particle coalescence while minimizing water consumption—achieving 18% settling efficiency with only 20 mL of water. The integration of Arduino Nano for sensor data acquisition and analysis further enhances precision, offering a novel framework for low-cost, high-efficacy dust control. This approach bridges the gap between technological innovation and practical applicability, setting a precedent for IoT-driven environmental management in construction.

II. REVIEW OF THE CONTEMPORARY LITERATURE

Zhian Huang et. al [8] developed this research in the quest to find solutions to the inefficient suppressive properties as well as poor enhancement of mechanical properties associated with dust suppressants in general used traditionally in construction works. They attempted to engineer a new binding agent such as SPC through polymer blending from sodium alginate, polyvinyl alcohol, and carboxymethyl cellulose. The whole methodology entailed, the optimum mass concentration of SPC, BS-12, and CMCS was achieved at 0.317%, 0.197%, and 0.626%, respectively. High performance with a compressive strength of 313.93 kPa and a low wind erosion rate of 2.73%, was found in the dust suppressant formulation of SPC/CMCS/BS-12 in strong wind with a velocity of 12 m/s. It was able to remove as much as 86.67% respirable dust and up to 93.21% total dust. The improvement in the dust's mechanical properties could be attributed to hydrogen bonding between polymer chains and the adsorption interaction between the developed suppressant and the surfaces of the dust. Long-term stability and environment compatibility of such polymers led to the requirement for further studies regarding durability under various conditions.

the researcher Augustine Appiah et. al [9] addressed health risks related to coal dust exposure for an extended period, such as the advancement of coal workers' pneumoconiosis (CWP) among underground miners. It summarized recent advances in various control technologies related to dust-fog-curtains, including chemical suppressants, foam removal, ultrasonic atomization, magnetized water, double curtains of wind and fog, biological nano-films, and microbial suppressants. From the study of the above scopes, the authors deduced the important scope for dust prevention areas, which are: management of respirable dust; hydrophobic treatment of dust; and secondary dust control. The publication attracted attention to further study of the mechanisms of generating dust and developed numerical models applied to studies of dust dynamics. For the case of hydrophobic dust, the authors recommended further studies of the microphysical properties of coal dust and optimization of wetting agents. Other scaling limitations and practical issues were also found in some new emerging technologies.

The author Mekhala Kaluarachchi et. al [10] explained the environmental impacts of dust pollution from construction operations, emphasizing the usually ignored context in terms of their impact on health. The research aimed to test and validate an intention prediction model for modifying behavior based on dust control by construction workers. Using structural equation modeling, with the Norm Activation Model as the applied theory, the research was conducted. The outcome provided an insight into the employee's awareness regarding dust hazards and their personal responsibility in controlling them, along with a need for company support. Recommendations The campaign for education should be enhanced with the objective of developing employees' knowledge about the harmful impacts of dust pollution on the environment and to enhance a sense of responsibility in workers. In doing so, it adds strength to the current literature on factors that affect the dust control behavior of employees.

The authors Ming-qing Sun et. al [11] designed a CBSS, a cement-based strain sensor with greatly improved strength and self-sensing properties for the structural health monitoring of UHSC columns. The sensor showed substantial piezoresistivity with minimal noise and smooth changes in resistance with strain, particularly after oven-drying, which improved its repeatability and sensitivity. When embedded in UHSC columns, the CBSS satisfactorily monitored damage through irreversible changes in resistance as it effectively sensed strain and stress levels up to 154 MPa. The sensor showed three clear phases in its piezoresistive responses under monotonic loading: a sensitive linear phase, an intermediate sensitivity nonlinear phase, and a low sensitivity linear phase with increased load. However, some critical limitations were addressed, such as sensor life span and environmental tolerance, which are good areas of future work.

The research by Liu Lihong [12] proposed a dry fog dust suppression system that could considerably reduce the problem of dust pollution from any industrial source. Through methodological design, the system is enabled in achieving precise mixing and spraying of the dust suppressant solution, therefore achieving 80% higher efficiency on dust suppression as compared with conventional systems while requiring only 10-20% of the water used in traditional systems. Indeed, results were shown concerning how dry fog captured airborne dust without generating wastewater, hence making it a suitable system for working conditions. Some benefits identified are low operational costs and minimum effects on the environment. However, the limitations include a lack of scalability in larger operations and potential issues in maintaining its performance over variable environmental conditions, thus requiring further studies and development to be done.

Zhou Qingguo et. al [13] noticed that a dust suppression system, consisting of charged fog technology, designed to control the major problem of airborne dust pollution on construction sites has been designed. It consists of an atomization device, electrostatic generator, mixing reaction chamber, and two draught fans, so connected to maximize proper suppression of dust. The system had a methodological design in producing charged fog balls, thus intensifying its capacity to remove dust more efficiently due to the increased rate of adsorption and provision for coverage variability. The results show a considerably improved capability in dust suppression against this traditional practice through this innovative approach, thus presenting an efficient means for the control of dust under diverse working conditions. It was also easy and flexible to use, thus suitable for different applications in construction sites. However, the electrostatic ones were claimed to have some restraints on potential energy consumption and must be serviced from time to time.

Yang Mei et. al [14] proposed a dust removal device that is designed only for building sites due to the massive issue of airborne dust pollution. The system consists of a frame, a rotating device, and two cannon fog cylinders placed symmetrically at the top of the device. Both the fog cylinders house a cannon fog assembly and a fan connected through water supply pipes. Using the developed methodological design of a device, water spraying in various directions is efficiently carried out for dust removal. The test showed that this improvement in working efficiency was accompanied by labor cost savings and promises successful practical application in various construction environments. Structural simplification of the device provides for simple operation and service. Areas for improvement with respect to the maximum possible efficiency of dust suppression and performance in the most adverse possible weather conditions were, however, reported and thereby indicated the potential avenues for future study in order to enhance those aspects.

Feng Zhi et. al [15] developed a dry fog dedusting control system for effective dust pollution control as it is one of the common difficulties faced in numerous industrial settings. The mechanism in the system consists of dry fog dedusting, water and air pressure sensors, dust concentration detection sensors, and a fuzzy controller. This method involved the measurement of the variation in concentration through fuzzification and then utilizing fuzzy inference. The fuzzy controller applied predefined control rules that controlled the operational movement of functional sprayers in real time for each detected level of dust. Results showed the system dynamically set the sprayer positions and quantities to optimize the efficiency of dust suppression. However, dependency on the system's accuracy of sensor readings and potential exposure to harsher environmental conditions presented another issue and generally called for more research into completing the reliability and adaptability of the developed system.

The Akshay Gharpure et. al [16] examined the occupational health risks due to construction dust, primarily in terms of its size distribution of particulates and chemical content, which significantly impacts respiratory health. The comprehensive methodology was conducted by using techniques such as transmission electron microscopy, scanning electron microscopy, dynamic light scattering, and laser diffraction for particle size analysis. Isolated phases were chemically analyzed by combining energy dispersive spectroscopy, X-ray photoelectron spectroscopy, and X-ray diffraction to determine the presence of phases and degrees of crystallinity. Concluded that the presence of metals and high silica content posed a serious health hazard to workers in the construction industries; effective dust control measures were in order. Limitations have been found regarding the variability of the dust generation conditions. Some further suggestions for relevant future research directions are proposed to conduct further investigation into long-term exposure effects.

The author Nadezhda Menzelintseva et. al [17] conducted an experimental study in order to find the size distribution of dust particles suspended in the cement plant work area, cement milling, and packing shops. A holistic methodology was undertaken, incorporating multiple measurement techniques aimed to address a wide range of characteristics of dust in different environmental conditions. Humidity and mobility of air were significant influencers on particle size distribution, providing greater insight into the overall behavior of the dust in such industrial environments. Development of a mathematical model was identified for prediction of the dust particle size distribution to enhance predictability in the management of cement plant dust. The conclusion was that medium and fine-dispersed dust were generally predominant throughout work areas with associated potential health risks to workers. Limitations included the applicability of the model to any number of operational conditions and the likely need for validation over multiple environments found within a typical cement plant with an indication that additional research opportunities exist to enhance dust control strategies.

Ilci et. al [18] measured the aerodynamic and physical diameters, chemical composition, and concentrations of ambient aerosols that carry such particles in construction environments. Particles of such nature are characterized based on their capability to calculate the toxic potential. The authors used a cascade impactor in the collection of particles, using TEM and EDS for the analysis of size distribution by type, including silica and soot. Results showed that diameters ranged from 0.99 nm to 10,500 nm and that 89.3% fell within the classification of ultrafine particles with diameters smaller than 100 nm; these are considered of serious health consequences because they are respirable. Unfortunately, sample representativeness and a variety of environmental aspects during the sampling periods constitute significant drawbacks in assessing these hazards. Further research is, therefore, essential to improve understanding and control strategies in relation to particulate hazards at occupational workplaces.

Research by Tianxin Cui et. al [19] found that construction site dust was the most critical issue contributing to urban air pollution. Thus, it posed health hazards to both workers and residents. It described a comprehensive approach to dust monitoring along with its importance for a civilized construction environment and green urban development. Recommendations were enhancing collaboration among the units involved in construction work, regulatory bodies, and supervision units in establishing sound control mechanisms toward effective dust control strategies. In this sense, the results highlight that rigorous dust monitoring enhances not only the beautification of cities but also attracts investments and helps the economy grow. However, limitations in terms of scaling up monitoring technologies and constant adjustment to the changes in construction practices were noted as suggestions of needs in future research and development of dust management strategies.

The authors Wang Li et. al [20] provided dust control equipment, specifically designed for the construction site to mitigate the severeness of dusty air pollution. The methodology incorporated the novelty in the hourglass-shaped compression cover that is included in the spray cylinder, facilitating a high-speed water-air flow collision for atomization purposes. The equipment mechanism allows the swing of the spray cylinder both horizontally and vertically. For this, spray angles change automatically to optimize coverage. Sprays at the construction sites were huge and effective controls of emissions of dust were realized. Improved air quality and lessened health risks for workers were realized as a result of the versatility and efficiency attributed to the equipment by the authors. However, it was realized that the limitation of the technique imposed by the use of diesel power and possible operating costs means that there is a potential for further research into energy sources that are more sustainable with applications in constructional environments for dust control systems.

Wooseok Sung et. al [21] especially proposed specifically designed dust control equipment for the construction site in order to combat the major problem of airborne dust pollution. The methodology formed an hourglass-type compression cover inside the spray cylinder with an innovative design; collisions between water and airflow are increased at high speed, thus making atomization easier. The researchers have found that it significantly improves dust suppression efficiency because of its wide range of spray and effervescent control of its contents at construction sites. Therefore, the authors concluded that the versatility and efficiency of equipment in their design may lead to better air quality and lower health risks for the workers. There were also acknowledged limitations in relation to the reliance on diesel power, and possible further research in terms of the overall operational costs, thereby suggesting potential avenues for future research and how such systems could be made even more sustainable for dust control applications in construction environments.

Hyunsik Kim et. al [22] considering the need for the development of real-time management systems that might quantify PM levels at several points. They sought to make the construction site PM monitoring system (CPMS), which employed the IoT technology; in their research, there were the measurement instruments, network, and software service specifically customized in view of the distinct characteristics of the construction environment. The methodology incorporated all these components into an overall monitoring solution. The CPMS achieved grade 1 levels in reproducibility, relative precision, and data acquisition rate but scored grade 2 levels for accuracy and coefficient of determination at an overall accuracy of 74.2%. In a nutshell, this developed system greatly improves PM management on construction sites, enhancing air quality and worker health. Also, there is a limitation that the accuracy of the light-scattering measurement method still needs further refinement to increase its reliability in real-world applications.

III. CASE STUDY

A controlled 30x30 cm test environment was designed to replicate construction site conditions, incorporating dual GP2Y1014AU0F optical dust sensors, an Arduino Nano for data logging, and ultrasonic mist makers. The study evaluated dust suppression efficiency by varying water volumes (10–20 mL) and mist-maker counts (1–4 units). A 70 CFM fan ensured consistent airflow, while cement dust (5g/test) simulated real particulate emissions. Results demonstrated a direct correlation between mist-maker quantity, water usage, and settling efficiency, with 4 mist makers achieving a 0.042 μg/m³/min settling rate. The system's IoT capabilities enabled real-time PM monitoring, validating its potential for scalable deployment in construction environments.

3.1. Problem Statement:

Construction activities generate respirable crystalline silica and PM, causing lethal respiratory diseases and environmental pollution. Existing dust suppression methods, such as water spraying, are inefficient, water-intensive, and impractical in arid regions. This study addresses these limitations by developing a system that optimizes water usage while enhancing PM control. Key challenges include balancing mist droplet size for effective particle aggregation, ensuring real-time monitoring accuracy, and achieving portability for diverse construction sites.

3.2. Assumptions:

In formulating the proposed solution, several key assumptions underlie the research methodology and system design. First, it is assumed that the environmental conditions within the test environment accurately replicate those found on active construction sites, including similar particulate matter types and concentrations. The system presumes that the optical dust sensors are calibrated correctly and deliver precise, real-time measurements of particulate levels both before and after mist application. It is also assumed that the mist makers produce droplets of a consistent size and distribution, which are crucial for effective dust capture and settling. The IoT framework is expected to provide reliable, uninterrupted data transmission and remote control capabilities. Furthermore, the research assumes that the water mist, when optimally applied, will interact effectively with airborne dust particles, leading to significant reductions in particulate concentration. Additional assumptions include the availability of sufficient water resources for testing and the scalability of the prototype system to real-world construction environments.

Key Assumptions

1. Dust distribution within the test box is homogeneous.
2. Cement dust (0.1–10 μm) represents typical construction-site PM.
3. The 70 CFM fan replicates natural airflow patterns.
4. Sensor readings are unaffected by humidity from mist.
5. IoT components function reliably under controlled conditions.

Lastly, it is assumed that the user inputs, such as water volume and the number of mist makers, can be adjusted dynamically, allowing for a thorough exploration of the system's performance across various operational scenarios. These assumptions form the basis for experimental design and subsequent data analysis, ensuring that the study remains focused on validating the core hypothesis of enhanced dust suppression efficiency.

3.3. Problem Formulation:

The problem formulation for this research is centered on developing a quantifiable, efficient solution for mitigating airborne dust on construction sites. The goal is to establish a relationship between water usage, mist maker configurations, and dust suppression efficiency. The primary variables include the volume of water applied, the number of mist makers deployed, and the resulting reduction in particulate matter as measured by dual optical dust sensors. Mathematically, the problem is formulated as an optimization model where the objective function maximizes dust settling efficiency while minimizing water consumption. Constraints include the physical limitations of the mist maker devices, the ambient conditions of the construction environment, and the accuracy of sensor measurements. A set of differential equations is used to model the dynamic behavior of airborne dust particles under the influence of water mist and airflow generated by a fan. The IoT-based control system further integrates real-time feedback to adjust water flow and mist dispersion automatically.

The research formalizes dust suppression as an optimization problem:

Objective: Maximize settling efficiency $\eta = \frac{C_{\text{initial}} - C_{\text{final}}}{C_{\text{initial}}} \times 100$

Constraints:

- Water usage ≤ 20 mL
- Mist droplet size: 1–10 μm
- System portability and energy efficiency

Variables include mist-maker count, fan speed, and sensor placement.

The formulation also accounts for temporal variations in dust concentration, necessitating the use of time-series analysis to predict and respond to changes in real time. By defining these parameters and constraints, the research seeks to derive an optimal operational strategy that ensures maximum dust suppression with minimal resource utilization, ultimately providing a robust, scalable solution for improving air quality on construction sites.

IV. METHODOLOGY

Based on the systematic literature review, the mechanism proposed includes using a water mist as a possible solution for dust settlement on construction sites. This captures airborne dust particles, causing them to settle quickly, enhancing air quality and supporting optimal conditions for cement curing.

Design Principles of a Compact Scale Model Prototype-

The design of the scale model prototype is based on the following essential factors:

Coverage Area: The prototype is designed to replicate a typical construction site area with an approximate surface area range of 30x30cm box to allow manageable testing while still being representative.

Particle Size Concentration Dust: The system aims for dust particles with a diameter ranging from 0.1 to 10 micrometers. This range is considered one of the dominant sizes at any construction site, contributing directly to human health hazards.

Optimize Water Use, Maximizing Dust Suppression: The machine is built as compact as possible so that it consumes less water while maximizing its effectiveness in terms of dust suppression. A compact size also means it is portable and can be taken inside the test box and set up.

Components of the Experiment and Their Explanation-

The following components are utilized in the experiment:

Arduino Nano-

Figure 1: Arduino Nano

The combination of a dust sensor with an Arduino Nano is the most effective way to monitor airborne particles, highly necessary for applications like dust suppression and air quality management. Both the Dust sensors are connected to the different digital pins of Arduino, which provide real-time monitoring of dust density and voltage levels. Through its serial interface, data is smoothly transmitted to the serial monitor, where the values are displayed for analysis.

GP2Y1014AU0F Optical Dust Sensor-

Figure 2: Optical Dust Sensor

Figure 2 shows an optical dust sensor which has three main components of the sensor: an LED, a photodiode, and lenses. The LED and photodiode are aligned across the detection area. When dust or smoke is detected, it causes light to scatter back, and therefore this changes the current in the photodiode with the intensity of scattered light. The current is then converted and amplified to a voltage signal so that output is presented. For the prototype, I used two dust sensors. The First Dust Sensor is used to measure the concentration of dust particles before spray application, And The second one is placed inside the test box to measure the dust concentration after the spray has been applied.
Mist Maker-

Figure 3: Mist Maker Module

Figure 3 shows DC 5V Humidifier Spray Module utilizing a piezoelectric sensor to produce mist. When the sensor is energized by a 5V input, it vibrates at high speed, thus converting water into tiny droplets through ultrasonic waves. The mist maker is used to produce fine droplets of water that interact with airborne dust particles, this device effectively causes the dust particles to settle. The ideal mist maker has to produce large droplets just big enough not to evaporate before they hit the ground and small enough to encapsulate the dust particles well.

Testing Methodology-

In order to evaluate the performance of the low-cost IoT-based dust suppression system, the following systematic testing methodology was followed:

1. Experimental Setup:

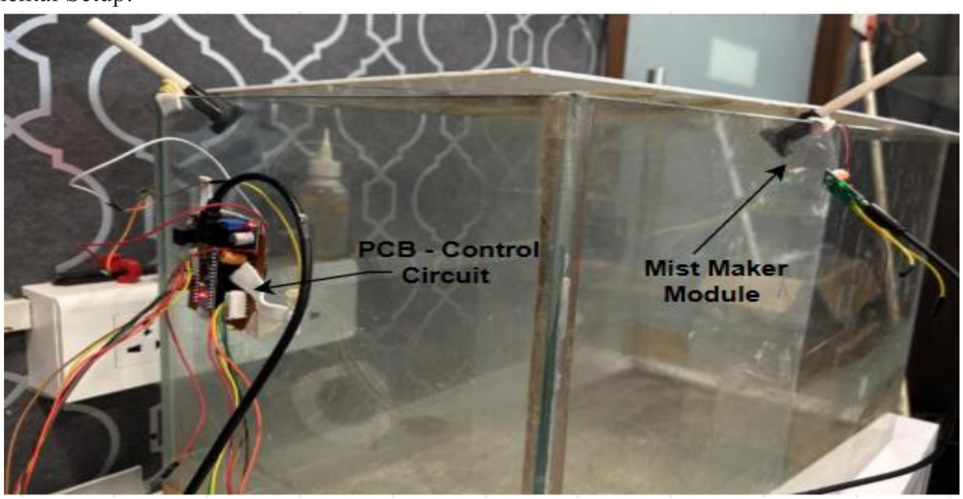

Figure 4: Testing Physical Prototype with two Mist Maker Module

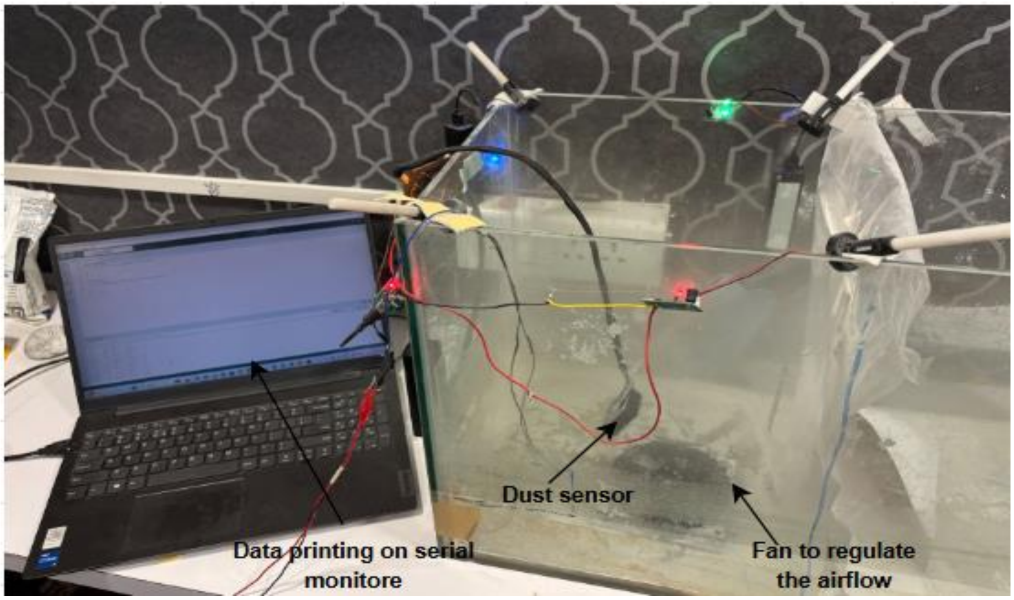

Figure 5: Testing Physical Prototype with Four Mist Maker Module

Figure 4 shows an enclosed box of size 30x30 cm, which contains two mist makers mounted on opposite sides. Figure 5 shows the complete physical prototype testing setup, where four modules of mist makers are used to simulate controlled conditions that can be seen in a construction site. The testing arrangement consisted of a 70 CFM fan to regulate the airflow, four mist makers for humidity, and openings for wind effects were adjustable in order to bring the actual conditions close to the tests.

Two dust sensors were installed inside the testing setup one closer to the inlet, used to determine the concentration at which dust was added in, and The second dust sensor monitored the amount of dust that settled every minute and recorded the corresponding water usage required for dust settlement. Readings were taken at 1-minute intervals over a 5-minute period for each test run.

Testing Procedure-

Each test started with adding a constant amount of 5 grams of cement dust to the controlled box through the inlet. The 70 CFM fan ran at a constant speed to ensure an equal distribution of dust particles across the testing environment.

Sequential tests were performed using a series of one, two, three, and four mist makers. For each configuration data were collected from the second sensors at 1 minute intervals over a total of 5 minutes. Amounts of settled dust and therefore corresponding water usage required to settle were continuously recorded throughout the interval by the second dust sensor.

The recorded readings were then analyzed to evaluate the efficiency of the mist makers in reducing the dust concentration and settling particles. In addition, the time required for dust settlement and the water consumption under different configurations were compared.

V. RESULTS

Result and discussion-

This section has focused on experimentation results that assess the effect of water use as well as how many mist makers are applied to the dust-settling process.

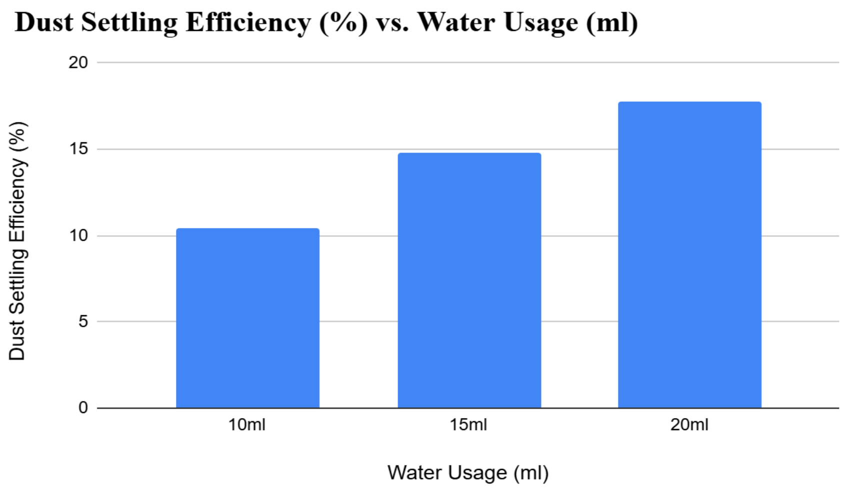

Figure 6: Effect of Water Usage on Dust Settling Efficiency

Figure 6 identifies the relationship between water use and dust settling efficiency. The efficiency exhibits a clear upward trend when considering that under 10-20 ml added quantity, the dust efficiency settles from around 10% to 15% and 18% for 15 ml and 20 ml respectively. This shows that the more the water used, the more enhanced the process of dust settling owing to the increased surface area coverage and density of the mist where maximum dust particles are allowed to settle.

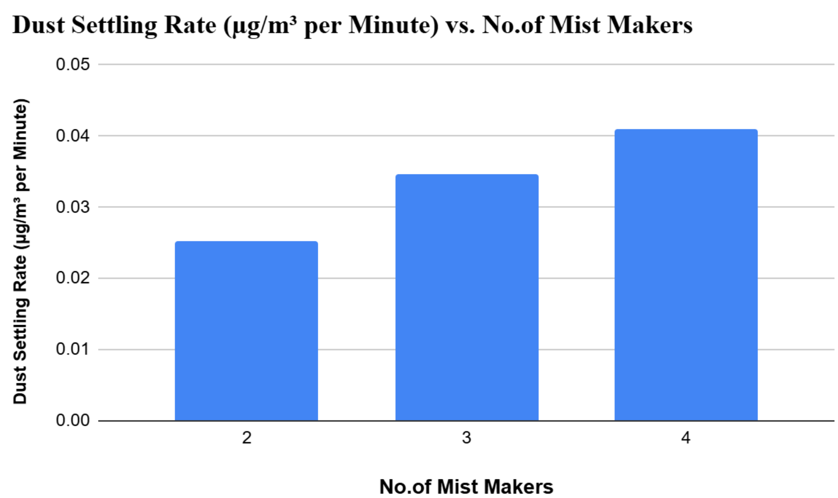

Figure 7: Impact of Number of Mist Makers on Dust Settling Rate

Figure 7 shows the influence of mist makers concerning the settling rate of dust. The study results showed positive correlation results with the influence of the number of mist makers on dust settling rate. For instance, at 2 mist makers, the dust settling had a rate of about 0.026 µg/m3/min, at 3 mist makers it was 0.035 µg/m3/min and at 4 mist makers it was just about 0.042 µg/m3/min. The effect most definitely suggests that adding even more mist makers will greatly quicken the dust settling process by increasing both the amount of mist produced and the combining and falling speed of particles. The performance of the system in general and its enhancement possibilities for use in varying dust densities environments are well demonstrated by this linear increase in settling rate.

It was found in both experiments that both increased water application and the number of mist generators have a significant effect on the dust settling operation; more water increases efficiency while additional mist generators quicken the settling rate, showing that this system has further potential performance under different dust conditions.

VI. CONCLUSION

This study successfully demonstrates an innovative IoT-based mist-making system that optimizes water usage while effectively suppressing airborne dust particles on construction sites. Results showed that increasing water usage and the number of mist makers significantly improved dust suppression efficiency. Specifically, water applications of 15 ml and 20 ml achieved dust settling efficiencies of 15% and 18%, respectively. The settling of the dust had a progressive rate with increases in the number of mist makers, going as high as 0.042 µg/m3/min. This indicates quickness and speed in dust collection within the system.

The suggested system mitigates the potential health and environmental hazards arising from respiratory diseases like silicosis and COPD, and conserves the supply of water. Its portability is extremely high due to the compactness of the structure, thus making it relatively easier to deploy across different sites. In addition, continuous time monitoring of dust concentration levels guarantees adjustment towards optimal performance.

The IoT technology for dust suppression offers a scalable and sustainable means of improving air quality and reducing health risks to workers and communities. Future upgrades may include the integration of advanced sensors for wider PM size detection, automation for dynamic mist control, and adaptation for larger-scale operations. By addressing both environmental and health concerns, this system opens up ways for safer and more sustainable construction practices that support long-term urban development goals.

VII.FUTURE ENHANCEMENTS

Future work will integrate advanced PM2.5/PM10 sensors for granular particle analysis and machine learning for predictive mist control. Solar-powered modules could enhance sustainability, while wireless mesh networks may enable multi-node monitoring across large sites. Scaling the prototype for real-world deployment requires testing under variable humidity and wind conditions. Collaborations with construction firms will validate long-term efficacy, and biodegradable additives could further reduce environmental impact.

VIII. Application to Society:

The application of this IoT-based dust suppression system has significant societal implications, primarily in improving public health and environmental sustainability. Construction sites are major contributors to air pollution, releasing fine particulate matter that poses severe health risks to workers and communities in proximity. By effectively reducing airborne dust, this system can decrease the incidence of respiratory diseases such as silicosis, lung cancer, and chronic obstructive pulmonary disease (COPD). The implementation of a smart, water-efficient mist-making mechanism not only minimizes water waste—a critical concern in drought-prone regions—but also enhances the overall quality of the air we breathe. Urban areas, in particular, stand to benefit as the reduction in dust pollution can lead to better living conditions, lower healthcare costs, and improved productivity among residents. Moreover, the real-time monitoring and adaptive control aspects of the system provide valuable data that can inform regulatory bodies and policymakers, leading to better enforcement of environmental standards on construction sites. This system also has the potential to stimulate further innovations in sustainable construction practices, encouraging investment in technologies that prioritize both human health and environmental preservation. Ultimately, the adoption of such advanced dust suppression techniques could pave the way for greener, safer cities, ensuring that infrastructural growth does not come at the expense of public well-being.

This system directly benefits construction workers by reducing silicosis and COPD risks through improved air quality. Communities near sites experience lower PM exposure, enhancing public health. By conserving water—15 mL achieves 15% efficiency—the technology supports sustainability in water-scarce regions. Its IoT framework enables real-time compliance monitoring, aiding regulatory enforcement. Economically, reduced healthcare costs and minimized project delays from dust-related stoppages foster productivity. The prototype's scalability allows adaptation to mining and industrial sectors, broadening its societal impact.

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