

## Air Pollution Control Using Ionizer

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**Abstract** – Rapid urbanization and vehicular growth have significantly increased roadside air pollution levels, particularly particulate matter such as PM10 and PM2.5. Prolonged exposure to these pollutants causes serious respiratory and environmental health issues. This research presents the design and development of a low-cost roadside air purification prototype using ionizer technology. The developed system consists of a DC fan for air intake, a negative ion generator for charging dust particles, Whatman filter paper for particulate filtration, and activated carbon for harmful gas adsorption. The ionizer electrically charges suspended particles, making them easier to trap within the filter media. The prototype was tested under semi-outdoor conditions, and visible particulate reduction was observed within the filtration chamber. The system operates on a 12V DC supply and consumes low power. The developed model demonstrates potential application for small-scale roadside pollution control and can be further enhanced for large-scale deployment

**Key Words:** Roadside Air Pollution; Ionizer Technology; PM2.5 and PM10; Electrostatic Filtration; Activated Carbon; Low-Cost Air Purifier.

### 1. INTRODUCTION

Air pollution is one of the most critical environmental challenges faced by urban and semi-urban regions due to rapid industrialization, urbanization, and vehicular emissions. Road transport is a major contributor to atmospheric pollution, releasing harmful pollutants such as particulate matter (PM10 and PM2.5), carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO<sub>2</sub>), and hydrocarbons into the environment.

Among these pollutants, fine particulate matter (PM2.5 and PM10) poses severe health risks as it can penetrate deep into the respiratory system and bloodstream, leading to respiratory diseases, asthma, cardiovascular problems, and long-term lung damage.

In cities with heavy traffic density, roadside air quality becomes highly deteriorated, directly affecting pedestrians, traffic police, and roadside vendors.

Traditional large-scale air purification systems are expensive, bulky, and unsuitable for localized roadside pollution control. Therefore, there is a growing need for a compact, cost-effective, and energy-efficient air purification system that can reduce particulate concentration in outdoor environments.

The present project focuses on the design and development of a prototype air pollution control system using ionizer technology combined with mechanical filtration and activated carbon adsorption. The system is designed to purify polluted air by charging airborne particles and capturing them through filter media, thereby improving air quality at a localized level

### 2. KEY OBJECTIVES :-

1. To Mitigate Urban Heat Island Effect
2. To Lower the Surface Temperature of Concrete
3. To Increase the Safety of Road Users by Reducing the Heating of Concrete
4. To Enhance Energy Efficiency
5. To Increase the Strength of Concrete

### 3. LITERATURE REVIEW :-

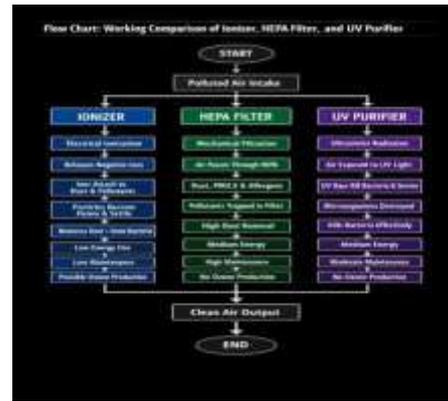
Numerous studies have reported that ionizer-based air purification systems are effective in removing airborne particulate pollutants from contaminated air. Ionizers generate negatively charged ions that attach to suspended particles such as dust, smoke, pollen, and fine particulate matter (PM2.5 and PM10). This charging process causes particles to agglomerate, increase in weight, and either settle down or get efficiently captured by filtration media, thereby improving overall air purification efficiency.

Research on electrostatic air cleaning technologies, especially electrostatic precipitation, has demonstrated high efficiency in the removal of fine particulate matter

from polluted air streams. These systems operate on the principle of electrically charging airborne particles and collecting them on oppositely charged surfaces, which significantly enhances the removal of microscopic pollutants compared to conventional filtration methods. Such techniques are widely used in industrial and environmental applications for air pollution control due to their effectiveness and relatively low energy consumption.

Activated carbon has also been extensively studied and utilized in air purification systems because of its high adsorption capacity, porous structure, and large surface area. It is particularly effective in adsorbing harmful gases, odors, and volatile organic compounds (VOCs), making it a suitable material for improving air quality in polluted environments. When combined with electrostatic and mechanical filtration methods, activated carbon enhances the overall purification performance by targeting both particulate and gaseous pollutants.

Furthermore, several air purification models incorporate mechanical filtration media, such as fine filter papers and fibrous filters, to physically trap suspended particles. Experimental studies have shown that the integration of ionization, mechanical filtration, and adsorption techniques provides a multi-stage purification mechanism that improves pollutant removal efficiency compared to single-stage systems. However, most of the existing research and commercial air purification technologies are primarily focused on indoor environments, where airflow and pollutant levels are more controlled. Limited research has been conducted on portable and localized outdoor air purification systems, particularly for roadside applications where pollutant concentration is significantly higher due to vehicular emissions and traffic density. Outdoor environments also present additional challenges such as continuous pollutant generation, variable wind conditions, and open atmospheric dispersion, which reduce the effectiveness of conventional indoor air purifiers. Therefore, a clear research gap exists in the development of compact, low-cost, and energy-efficient air purification systems specifically designed for roadside and semi-outdoor environments. The present research addresses this gap by proposing an ionizer-based air pollution control prototype integrated with mechanical filtration and activated carbon adsorption for localized roadside air quality improvement.



Tablet.1.WORKING COMPARISON OF IONIZER

4. METHODOLOGY :-

The methodology of the present research is based on the systematic design, fabrication, integration, and performance evaluation of a compact ionizer-based air pollution control system intended for roadside and semioutdoor environments. The adopted methodology follows a multi-stage purification approach combining electrostatic ionization, mechanical filtration, and activated carbon adsorption to enhance the removal of particulate and gaseous pollutants from polluted air.

1. System Design and Concept Development

The first stage of the methodology involved the conceptual design of a duct-type air purification chamber to ensure controlled and directional airflow through successive purification stages. The system was designed as a compact and portable prototype suitable for localized roadside air pollution control. Special emphasis was given to maintaining a linear airflow path so that polluted air could pass sequentially through ionization, filtration, and adsorption units without turbulence or leakage.

Design parameters considered during system development included airflow efficiency, structural compactness, low energy consumption, ease of fabrication, and cost-effectiveness. The chamber dimensions were selected in such a way that sufficient residence time of air is achieved inside the purification chamber, allowing effective particle charging and filtration. The structural body was fabricated using lightweight and rigid materials to ensure durability and ease of handling during testing.

2. Fabrication of Purification Chamber

After finalizing the design, the purification chamber was fabricated in a duct configuration with a defined

inlet and outlet section. The internal compartment was divided into multiple stages to accommodate the fan, ionizer, filter media, and activated carbon layer. Proper sealing was ensured to prevent air leakage and to maintain directional airflow inside the system. Mounting supports were provided inside the chamber to securely hold each component in position and to allow easy replacement of filter media during maintenance.

### 3. Air Intake Mechanism

An air intake mechanism was incorporated at the inlet section of the chamber using a 12V DC brushless fan. The primary function of the fan is to draw polluted ambient air from the surroundings into the purification system. The brushless DC fan was selected due to its low power consumption, stable airflow generation, reduced noise level, and longer operational life.

The fan creates a continuous and uniform airflow that carries suspended particulate matter such as dust, smoke, and fine particles (PM<sub>2.5</sub> and PM<sub>10</sub>) into the ionization zone. Maintaining a steady airflow rate is essential for ensuring proper exposure of airborne particles to the ionization field and filtration media.

### 4. Ionization Process

A high-voltage negative ion generator was installed inside the purification chamber as the primary active air treatment component. The ionizer generates negatively charged ions that interact with airborne pollutants present in the incoming air stream. These ions attach to suspended particles such as dust, smoke, pollen, and fine particulate matter, causing them to acquire an electrical charge.

Once charged, the particles undergo agglomeration, where smaller particles combine to form larger and heavier clusters. This increase in particle mass reduces their suspension time in air and enhances their probability of being captured by the filter media. The ionization process significantly improves the overall particulate removal efficiency compared to conventional single-stage filtration systems. The ion generator operates at high voltage and low current, ensuring effective ion production with minimal power consumption and safe operation.

### 5. Mechanical Filtration Stage

Following the ionization stage, the charged air passes through the mechanical filtration unit where Whatman filter paper is used as the primary filter media. The purpose of this stage is to physically trap suspended particulate matter including PM<sub>2.5</sub> and PM<sub>10</sub> that have been electrically charged in the previous stage.

Whatman filter paper was selected due to its fine pore structure, good filtration efficiency, availability, and suitability for experimental prototype applications. The charged particles exhibit higher attraction towards the filter surface due to electrostatic forces, thereby increasing the filtration efficiency. This dual mechanism of electrostatic charging and mechanical trapping enhances the removal of fine particulate pollutants from the air stream.

### 6. Gas Adsorption Using Activated Carbon

After particulate filtration, the partially purified air flows through the gas adsorption layer consisting of activated carbon discs. Activated carbon is widely known for its high adsorption capacity, large surface area, and highly porous structure, which makes it effective in removing gaseous pollutants and odors.

This stage is responsible for adsorbing harmful gases such as carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), sulfur dioxide (SO<sub>2</sub>), and volatile organic compounds (VOCs) present in polluted roadside air. The adsorption process occurs due to physical and chemical interactions between pollutant molecules and the porous surface of activated carbon. The inclusion of this stage ensures multi-pollutant control by addressing both particulate and gaseous contaminants.

### 7. Clean Air Outlet Mechanism

After passing through the ionization, filtration, and adsorption stages, the purified air is discharged through the outlet pipe provided at the end of the chamber. The outlet section was designed to allow smooth release of treated air into the surrounding environment without back pressure or recirculation. Proper outlet positioning also helps in maintaining continuous airflow within the system and improves overall operational efficiency.

### 8. Power Supply and Energy Considerations

The entire system operates on a 12V DC power supply, making it energy-efficient and suitable for small-scale and portable applications. The low power requirement of the fan and ion generator ensures continuous operation with minimal energy consumption. This feature makes the system economically viable for roadside and semi-outdoor deployment where large power sources may not be available.

### 9. Performance Evaluation and Testing Procedure

The fabricated prototype was tested under semi-outdoor environmental conditions to analyze its performance in a realistic polluted setting. During testing, the system was

exposed to ambient roadside air containing visible dust and suspended particles. Observations were made based on dust accumulation on filter media, particle deposition inside the chamber, and visual clarity of the discharged air.

The evaluation focused on:

- Reduction in visible particulate concentration
  - Dust deposition on Whatman filter paper
  - Effectiveness of ionization in particle agglomeration
  - Overall operational stability of the system
- The results indicated noticeable accumulation of particulate matter on the filter surface and inside the ionization chamber, demonstrating the effectiveness of the multi-stage purification mechanism.

#### 10. Overall Methodological Approach

Thus, the adopted methodology integrates aerodynamic airflow design, electrostatic ionization, mechanical filtration, and activated carbon adsorption in a sequential purification process. This systematic approach ensures enhanced removal of particulate and gaseous pollutants while maintaining low cost, compact size, and energy efficiency, making the system suitable for localized roadside air pollution control applications.



FIGURE.NO.1 MODEL OF IONIZER

#### 5. COMPONENTS USED IN THE SYSTEM

1. DC Brushless Fan (12V)
2. Negative Ion Generator Module
3. Whatman Filter Paper
4. Activated Carbon Filter Disc

5. Plastic/ Acrylic Chamber
6. PVC Pipes
7. Rechargeable Battery
8. Switch and Wiring System



#### 6. Working Principle :-

The proposed air pollution control system works on the combined principle of electrostatic ionization, mechanical filtration, and adsorption to purify polluted air in roadside and semi-outdoor environments. The system is designed as a multi-stage purification unit where each stage performs a specific function to remove particulate and gaseous pollutants effectively. When the system is operated, the 12V DC fan draws polluted ambient air containing dust, smoke, and fine particulate matter (PM2.5 and PM10) into the purification chamber through the inlet. The airflow is directed in a controlled path so that the air passes sequentially through all purification stages. Inside the chamber, a high-voltage negative ion generator produces negatively charged ions. These ions attach to suspended airborne particles present in the incoming air. As the particles become electrically charged, they attract each other and form larger and heavier clusters through a process called agglomeration. This increase in particle size and mass reduces their suspension in air and makes them easier to remove during filtration. After ionization, the charged and agglomerated particles pass through the mechanical filtration stage, where Whatman filter paper is used as the filter media. The filter paper traps the suspended particulate matter such as PM2.5 and PM10. Since the particles are already charged and heavier, the filtration efficiency increases due to both mechanical trapping and electrostatic attraction between particles and the filter surface.

Following the filtration stage, the air moves through the activated carbon layer. Activated carbon has a highly porous structure and large surface area, which makes it effective in adsorbing harmful gases, odors, and certain pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), and volatile organic compounds (VOCs). This adsorption process helps in improving the overall air quality by removing gaseous contaminants that cannot be captured by filters alone. Finally, the purified air is discharged through the outlet of the chamber. The combination of ionization, filtration, and adsorption results in effective reduction of particulate matter and harmful gases. Thus, the system provides a compact, energy-efficient, and cost-effective solution for localized air purification in polluted roadside environments.



FIGURE NO.2. WORKING OF IONIZER ON ROAD

**9. RESULTS AND OBSERVATIONS:-**

The developed ionizer-based air pollution control prototype was tested under semi-outdoor environmental conditions to evaluate its purification performance. During continuous operation, noticeable dust accumulation was observed on the Whatman filter paper, which indicates effective trapping of suspended particulate matter such as PM2.5 and PM10. This confirms that the combined process of ionization and mechanical filtration was functioning efficiently.

A visible reduction in dust concentration inside the purification chamber was observed over time, showing that the system was capable of removing airborne particles from the incoming polluted air. The airflow generated by the 12V DC fan remained stable throughout the testing period, ensuring consistent air intake and smooth operation of the purification process.

The system also demonstrated low power consumption due to its 12V DC supply, making it energy-efficient and suitable for small-scale and portable applications. Additionally, the activated carbon layer contributed to effective odor reduction by adsorbing gaseous pollutants and unpleasant smells present in the air.

Overall, the prototype showed satisfactory performance in localized air purification under semi-outdoor conditions, with effective particulate removal, stable airflow, and energy-efficient operation, indicating its potential application for small-scale roadside air pollution control.

TEST NO	INITIAL WEIGHT	FINAL WEIGHT	DIFFERENCE
1.	1.245g	1.252g	0.007g
2.	1.310g	1.318g	0.008g
3.	1.198g	1.204g	0.006g

Average particulate collection ≈ 0.007 g

FIGURE.NO.3.RESULT OF IONIZER (WHEN WE TAKE A RESULT ON ROAD)

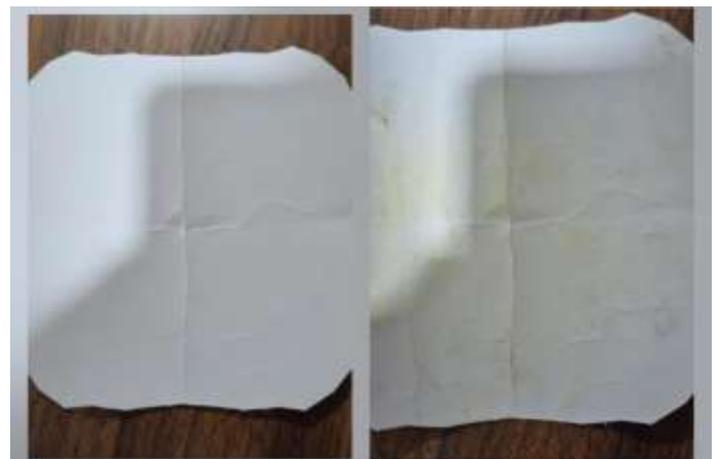


FIGURE NO.6. BEFORE TESTING AND AFTER TESTING (FILTER PAPER CONDITION)

**10. Conclusion :-**

The developed ionizer-based air pollution control system successfully demonstrates the feasibility of reducing

airborne particulate matter at a prototype level. The experimental results indicate that the integration of electrostatic ionization, mechanical filtration using Whatman filter paper, and activated carbon adsorption forms an effective multi-stage purification mechanism for treating polluted roadside air.

The ionization process enhances particle agglomeration, which improves the efficiency of the subsequent filtration stage in capturing fine particulate matter such as PM<sub>2.5</sub> and PM<sub>10</sub>.

Additionally, the activated carbon layer contributes to the removal of gaseous pollutants and unpleasant odors through adsorption, thereby improving overall air quality.

The system operates on a 12V DC power supply, ensuring low energy consumption and making it suitable for portable and small-scale applications. Its compact design, economical fabrication cost, and simple operational mechanism make it a practical solution for localized roadside air pollution control in urban and semi-urban areas.

Although the prototype demonstrates satisfactory performance under semi-outdoor conditions, further improvements such as the integration of air quality sensors, real-time monitoring systems, and enhanced filtration media can increase its efficiency and reliability. With technological advancements and structural optimization, the model can be further developed and scaled for application in smart city environmental pollution management systems.

#### 11. Acknowledgement :-

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