Journal of Thermal and Fluid Science
Volume 7, Issue 1, May 2026, pp 13 - 20
https://doi.org/10.26706/jtfs.7.1.20260302

Review on Ambient Air Quality Control System and Pollutants Present in Air

Abhijeet P. Thakare*, Shreya J. Borkar[2], Gauri S. Akotkar[3], Kshitij S. Kale[4]

Department of Mechanical Engineering, Prof. Ram Meghe Institute of Technology and Research, Badnera, Maharashtra, India

*Correspondence: abhijeetthakare007@gmail.com

Abstract: Air pollution has become a critical environmental issue due to the increasing concentration of harmful gases such as carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC), and nitrogen oxides (NO_x). These pollutants negatively affect human health by disturbing the oxygen transport mechanism in the body and contributing to environmental problems like smog formation. This paper presents an Online Air Pollution Control System based on the generation of negative ions to reduce atmospheric pollution. The proposed system uses a high-voltage ionizer circuit to release negatively charged ions, which attract positively charged pollutant particles. These particles combine to form heavier clusters and settle down due to gravity, thereby reducing air pollution. The system is designed for installation on streetlights and urban infrastructure, enabling continuous air purification in open environments. Experimental results indicate a significant reduction in pollutants such as CO, CO_2, and HC, along with a slight increase in oxygen levels. The system is energy-efficient, cost-effective, and safe for long-term use, making it suitable for large-scale implementation in urban areas.

Keywords: Air Pollution Control, Negative Ion Generation, High-Voltage Ionizer, Atmospheric Pollutant Removal, Urban Air Purification

Review – Peer Reviewed
Received: February 12, 2026
Accepted: May 10, 2026
Published: May 25, 2026

Cite this article: Abhijeet P. Thakare, Shreya J. Borkar, Gauri S. Akotkar, Kshitij S. Kale, "Review on Ambient Air Quality Control System and Pollutants Present in Air", *Journal of Thermal and Fluid Science*, RAME Publishers, vol. 7, issue 1, pp. 13-20, 2026. https://doi.org/10.26706/jtfs.7.1.20260302

1. Introduction

Air is essential for human survival as it provides oxygen required for cellular respiration. Oxygen is carried in the blood by hemoglobin and delivered to body tissues. However, due to rapid industrialization and the growing number of vehicles, air pollution levels have increased significantly. Harmful gases such as carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC), and nitrogen oxides (NO_x) are continuously released into the atmosphere.

These pollutants have serious effects on human health. For example, carbon monoxide binds strongly with hemoglobin, reducing its ability to carry oxygen, which can lead to severe health problems. In addition, air pollution contributes to environmental issues such as smog formation and degradation of air quality, especially in urban areas.

Existing air pollution control methods are mostly limited to industrial applications and are not effective in open environments such as roads and public places. Therefore, there is a need for a system that can control pollution in outdoor urban areas.

This paper proposes an Online Air Pollution Control System, which is based on a concept inspired by natural phenomena. In environments like waterfalls, negative ions are naturally generated and help in cleaning the air by attracting dust and pollutant particles. The proposed system artificially generates these negative ions using a high-voltage ionizer circuit.

When released into the atmosphere, these negative ions attract positively charged pollutants, forming clusters that become heavy and settle down under gravity. The system is designed to be installed on streetlights and road dividers, allowing continuous and large-scale air purification. This method provides a simple, efficient, and cost-effective solution for reducing air pollution and improving urban air quality.

2. Literature Survey

Air pollution has become a major concern due to the rapid increase in vehicular emissions, industrial activities, and urbanization. Various studies have shown that pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC), and nitrogen oxides (NO_x) have harmful effects on human health. These gases interfere with hemoglobin in the blood, reducing its oxygen-carrying capacity and causing respiratory and cardiovascular problems

Several conventional air pollution control techniques have been developed, including filtration systems, scrubbers, and electrostatic precipitators. These methods are effective in controlling pollution at the source, especially in industries. However, they are not suitable for open environments such as roads and public areas, where pollutants are continuously released and spread over large regions.

Research has also focused on natural air purification processes. It has been observed that negative ions are generated in natural environments such as waterfalls, rainfall, and ocean waves due to the collision of water droplets. These negative ions attract positively charged dust particles and pollutants, forming heavier clusters that settle down under gravity. This natural mechanism helps reduce air pollution levels.

Recent advancements in air purification technology include the use of artificial ionization systems. Negative ion generators are designed to emit negatively charged ions into the atmosphere. These ions attach to airborne pollutants such as dust, smoke, and harmful gases, causing them to combine and form larger particles that can be removed from the air. This method has shown promising results in improving air quality.

In addition to pollutant removal, ionization technology has also been studied for its ability to reduce biological contaminants such as bacteria and viruses. Negatively charged ions interact with positively charged components on the surface of microorganisms, leading to their neutralization or deactivation. This expands the application of ionization systems beyond pollution control to include air sanitization and health protection.

From the above studies, it is clear that negative ion-based air purification is an effective approach for improving air quality. However, there is still a need for a system that can be applied in open urban environments, energy-efficient, and cost-effective. The proposed Online Air Pollution Control System addresses this gap by introducing a compact ionizer circuit that can be installed on streetlights for continuous air purification.

3. Proposed Methodology

The proposed system is an Ambient Air Pollution Control System that works on the principle of negative ion generation and electrostatic attraction to reduce air pollution in open environments. The methodology is inspired by natural processes where negative ions are generated in environments such as waterfalls and rainfall, helping to purify the air.

3.1 System Design

The system consists of a negative ion generator circuit mounted on streetlights or roadside structures. The main components of the system include a high-voltage generation circuit, electrodes for ion emission, and a protective casing for safe operation.

The circuit is designed using a multi-stage voltage multiplier composed of diodes and capacitors arranged in a ladder configuration. This setup increases the input AC voltage to a high negative voltage required for ionization.

3.2 Working Principle

The methodology is based on the concept that most air pollutants carry a positive or neutral charge, while the system generates negatively charged ions (electrons). When these negative ions are released into the atmosphere, they attract positively charged pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC), nitrogen oxides (NO_x), dust particles, bacteria, and other airborne contaminants. Due to electrostatic attraction, these particles combine to form larger clusters (clumps). These clumps become heavier and eventually settle down on the ground due to gravity. As a result, the concentration of pollutants in the air decreases, leading to improved air quality.

3.3 Ion Generation Mechanism

The system uses a half-wave rectified high-voltage ionizer circuit to generate negative ions. The voltage is typically maintained in the range of –2 kV to –4 kV, which is sufficient to initiate ionization without producing harmful effects.

At this voltage, electrons are emitted from pointed electrodes (such as sharp pins or carbon fiber tips) into the surrounding air. These emitted electrons act as negative ions and spread into the atmosphere, where they interact with pollutants.

3.4 Deployment Strategy

The system is designed for installation on streetlights, road dividers, and public infrastructure. This allows continuous operation in areas with high pollution levels, especially due to vehicular emissions. Multiple units can be installed along roads to create a network of air purification points, ensuring effective coverage of large urban areas.

3.5 Performance Characteristics

- Negative ion output: approximately 7.89×10^{14} to 1.22×10^{15} ions per second
- Power consumption: about 0.32 watts
- Low operating cost and safe design with proper insulation
- Continuous operation with minimal maintenance

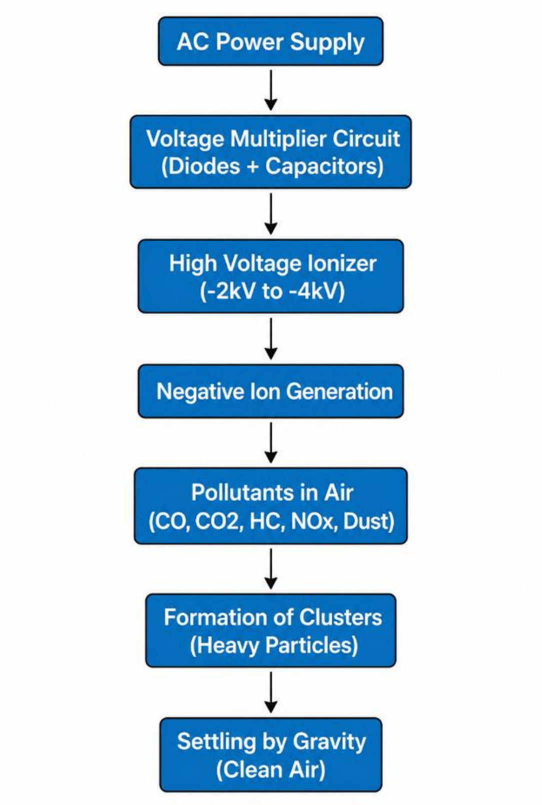

Figure 1. AC power supply process flowchart

4. Results and Discussion

The proposed system was tested under controlled conditions using polluted air samples collected from vehicle exhaust. The performance of the system was evaluated by comparing pollutant levels before and after the installation of the ionizer assembly.

The results show a significant reduction in major pollutants. Carbon monoxide (CO) levels were reduced by approximately 60%, hydrocarbons (HC) by around 67%, and carbon dioxide (CO_2) by about 61%. Additionally, a slight increase in oxygen (O_2) levels was observed, indicating improvement in air quality.

These results confirm that the negative ion generation system is effective in removing airborne pollutants. The emitted ions successfully attach to pollutant particles, forming heavier clusters that settle down due to gravity.

The system also demonstrates low power consumption, operating at approximately 0.32 watts, making it energy-efficient and suitable for continuous operation. Overall, the results validate that the proposed system can improve air quality in polluted environments.

4.1 Reduction in Pollutants

Experimental observations show that the system is effective in reducing major air pollutants. The results indicate that:

- Carbon monoxide (CO) is reduced by approximately **60%**
- Hydrocarbons (HC) are reduced by around **67%**
- Carbon dioxide (CO_2) is reduced by nearly **61%**

This reduction is achieved due to the interaction between negatively charged ions and positively charged pollutant particles, which form heavier clusters and settle down due to gravity.

4.2 Improvement in Air Quality

Along with the reduction in pollutants, a slight increase in oxygen levels was observed. This indicates an overall improvement in air quality. The removal of harmful gases allows cleaner air to remain in the environment, making it safer for human health.

4.3 Discussion

The results confirm that the proposed system is capable of reducing air pollution in open environments. Unlike traditional systems that work only in closed spaces or industries, this system can be installed on streetlights and public infrastructure for continuous air purification.

However, environmental factors such as wind speed, humidity, and large-scale pollution sources may affect overall performance. Despite these limitations, the system provides a cost-effective, energy-efficient, and scalable solution for improving urban air quality.

Observation table

Table 1. Effect of Negative Ion Generation System on Air Pollutant Concentrations – Experiment No. 1

Polluted Air Contents	Values Before Installing Assembly	Values After Installing Assembly	Percentage Change
CO	0.97	0.39	59.79% (Reduction)
HC (In 1000)	0.746	0.252	66.21% (Reduction)
CO2	1.7	0.8	52.94% (Reduction)
O2 (In 100)	0.2164	0.2254	4.16% (Increment)

Table 2. Effect of Negative Ion Generation System on Air Pollutant Concentrations – Experiment No. 2

Polluted Air Contents	Values Before Installing Assembly	Values After Installing Assembly	Percentage Change
CO		0	100% (Reduction)
HC (In 1000)	0.382	0.109	71.46% (Reduction)
CO2	0.4	0	100% (Reduction)
O2 (In 100)	0.2043	0.2089	2.25% (Increment)

Table 3. Effect of Negative Ion Generation System on Air Pollutant Concentrations – Experiment No. 3

Polluted Air Contents	Values Before Installing Assembly	Values After Installing Assembly	Percentage Change
CO	1.97	1.62	17.76% (Reduction)
HC (In 1000)	0.381	0.285	25.20% (Reduction)
CO2	5.6	4.2	25% (Reduction)
O2 (In 100)	0.208	0.208	0% (Remains Same)

4.4 Result Data Interpretations

- From the Experiment no. 1, pollutants like CO, CO2, HC reduced by approximate 50-70%.
- O_2 level is increased by 4.16%.
- From the Experiment no. 2, pollutants like CO, CO2 reduced by 100%
- HC are reduced by 71.46%.
- O_2 level is increased by 2.25%.
- From the Experiment no. 3, pollutants like CO, CO2 reduced by approximately 20%.
- HC are reduced by almost 30%

Thus, looking at the assembly cost, pollutant reducing results and positive effects on health, this invention will be the most economical and effective way to improve ambient air quality.

The Efficiency

1 Coulomb (C) is equal to the charge flowing in 1 second when current is 1 Ampere (A).

So, 1 A = 1 C/sec

The charge of one electron is: 1.602×10^{-19} C

Therefore, the number of electrons in 1 Coulomb is: $1/1.602\times 10^{-19} = 6.24\times 10^{18}$ electrons

So, 1 A current = 6.24×10^{18} electrons per second

Current Calculation using Ohm's Law

According to Ohm's Law: $I = V/R$

For the given circuit:

- Output voltage ≈ 2530 V (for 11-stage multiplier)
- Total resistance = 20 MΩ = $20\times 10^{6}\ \Omega$

$$I = 2530/ 20\times 10^{6} = 1.265 \times 10^{-4}\ \text{A}$$

Number of Electrons Emitted

Now, multiplying current with number of electrons per Coulomb:

Electrons per second = $(1.265 \times 10^{-4})\times(6.24 \times 10^{18}) = 7.89\times 10^{14}$ electrons per second

So, 11 stage voltage multiplier circuits will emit 7.89×10^{14} number of electrons in one second

The power of consumption can be calculated as,

$$W= V\times I = 2530 \times 1.265 \times 10^{-4} = 0.32 \text{ watts.}$$

For 1 year power consumed, $P = 0.32\times 24\times 365/ 1000 = 2.8032$ (kwh)

4.5 Case Study

To evaluate the performance of the proposed system, a case study is considered based on the highest recorded pollution level. The PM2.5 concentration was recorded as 296µg/m³ in January 2016 at IHBAS, Dilshad Garden, which is much higher than the standard limit of 60µg/m³.

For analysis, carbon monoxide (CO), one of the most harmful pollutants, is considered at the same pollution level.

First, the mass of one CO molecule is calculated. The atomic mass of CO is 28, and the mass of one atomic unit is 1.66×10^{-24} grams. Therefore,

Mass of one CO molecule = $28\times 1.66\times 10^{-24} = 4.648\times 10^{-23}$ g

Next, the number of CO molecules present in the air is calculated using the given pollution level:

Number of CO molecules= $296\times 10^{-6} / 4.648\times 10^{-23} = 6.63 \times 10^{18}$ molecules /m³

The developed system can generate approximately 7.89×10^{14} ions per second

To estimate the time required to remove the pollutants is $6.63 \times 10^{18}/ 7.89 \times 10^{14} \approx 2.22$hours

4.6 The Prototypes

Operating principle:

When activated, the negative ion generator will emit negative ions.

Then the blower will push them out of the model into the surrounding,

causing small dust particles (PM2.5, PM10...) in the air to stick to them.

Together thanks to electrostatic attraction. These dust particles can settle on the floor.

While the exhaust fan sucks, the suspended dust around the room is closer to the model to increase processing efficiency.

Figure 2. PCB mounted prototypes

4.7 Advantages

Unlike traditional air purifiers (HEPA/Carbon), this system is solid-state. It eliminates the recurring cost and environmental waste of replacing physical filters, as it does not rely on mechanical trapping.

Active Purification Mechanism: While passive filters only clean air that passes through the unit, the bipolar ionizer actively disperses OH ions into the entire room at volume. This allows for the neutralization of pollutants on surfaces (walls, tables) and in the air simultaneously.

High Energy Efficiency: By utilizing an 11-stage Cockcroft-Walton voltage multiplier, the system achieves a massive voltage gain of 7kv to 10kv with extremely low power consumption (approximately 0.32W). This makes it suitable for 24/7 operation at a negligible cost.

Pathogen Inactivation: The generation of hydroxyl radicals (OH) provides a chemical "kill" mechanism. Research shows these ions disrupt the lipid envelope and protein spikes of airborne viruses (including SARS-CoV-2) and bacteria.

Enhanced Flocculation: The high-voltage potential forces fine particulate matter (PM {2.5} and PM10) to become polar-charged, causing them to clump together and settle out of the breathing zone rapidly.

4.8 Limitations

A side effect of high-voltage corona discharge is the production of ozone. While useful for sterilization in small amounts, concentrations exceeding 0.05ppm can cause respiratory irritation and must be monitored.

The "Black Wall" Effect: Because the ions cause particles to settle on the nearest grounded surface, dust may accumulate on walls and floors near the device rather than being collected inside a tray.

Electromagnetic Interference (EMI): The rapid switching and high-voltage arcs inherent in an 11-stage multiplier can create localized EMI, potentially affecting unshielded electronic sensors or nearby communication devices.

Sensitivity to Ambient Humidity: The efficiency of the ion discharge is affected by air moisture. High humidity can lead to "tracking" or leakage across the circuit board, while very dry air can reduce the total ion yield.

Selective Gas Removal: While excellent for particulates and biologicals, ionization alone is less effective at removing complex Volatile Organic Compounds (VOCs) like formaldehyde compared to high-grade activated carbon.

4.9 Challenges in Ambient Air Quality Control

- Despite advancements, several challenges persist:
- Economic Growth vs. Environment:
- Developing nations often prioritize industrial growth over environmental regulations, leading to the "pollution haven" hypothesis.
- In many jurisdictions, laws exist, but enforcement is weak due to corruption or lack of resources.
- Complexity of Secondary Pollutants: Ground-level ozone is a secondary pollutant; reducing its precursors (VOCs and NOx) is complex because their ratios determine ozone formation. Sometimes, reducing NOx alone can increase ozone in urban areas (the "NOx disbenefit").
- Climate Change Link: Climate change exacerbates air quality issues; for instance, higher temperatures increase the rate of ozone formation and the frequency of wildfires.

5. Conclusions

This paper presents an Online Air Pollution Control System based on negative ion generation for reducing air pollution in open environments. The system works on the principle of electrostatic attraction, where negatively charged ions attach to positively charged pollutants and form heavier particles that settle down due to gravity.

The experimental results show that the system effectively reduces harmful pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), and hydrocarbons (HC). In addition, a slight improvement in oxygen levels was observed, indicating better air quality. The system operates with very low power consumption (approximately 0.32 watts), making it energy-efficient and suitable for continuous operation. The case study analysis further demonstrates that the system can significantly reduce pollution levels within a reasonable time. Therefore, the proposed system provides a simple, cost-effective, and scalable solution for improving air quality in urban areas.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] K. P. Thakare, “Online Air Pollution Control System,” Indian Patent Application No. 201721014397.
[2] K. P. Thakare, “Ambient Air Quality Control System,” PCS Product Report.

[3] S. Jiyal and R. K. Saini, "Prediction and Monitoring of Air Pollution Using Internet of Things (IoT)," in *Proc. 6th Int. Conf. Parallel, Distributed and Grid Computing (PDGC)*, Nov. 2020, pp. xx–xx.

[4] S. Ali, T. Glass, B. Parr, J. Potgieter, and F. Alam, "Low Cost Sensor With IoT LoRaWAN Connectivity and Machine Learning-Based Calibration for Air Pollution Monitoring," *IEEE Transactions on Instrumentation and Measurement*, vol. 70, pp. 1–11, 2021.

[5] V. K. S. Yadav, et al., "Room Temperature Air Pollutants Sensors Using Printed ZnO Single-Nanowire Schottky Diodes," *IEEE Transactions on Nanotechnology*, vol. 20, pp. 338–345, 2021.

[6] G. Kalaivani and P. Mayilvahanan, "Air Quality Prediction and Monitoring using Machine Learning Algorithm based IoT Sensor," in *Proc. Int. Conf. Communication, Computing and Electronics Systems (ICCES)*, 2021, pp. xx–xx.

[7] T. Madan, et al., "Air Quality Prediction using Machine Learning Algorithms – A Review," in *Proc. Int. Conf. Advances in Computing, Communication Control and Networking (ICACCCN)*, 2020, pp. xx–xx.

[8] J. Yun and J. Woo, "IoT-Enabled Particulate Matter Monitoring and Forecasting Method Based on Cluster Analysis," *IEEE Internet of Things Journal*, vol. 8, no. 9, pp. 7390–7402, 2021.

[9] P. S. Acharya, et al., "Data-Driven Models Support a Vision for Over-the-Air Vehicle Emission Inspections," *IEEE Transactions on Intelligent Transportation Systems*, vol. 23, no. 1, pp. 695–706, 2022.

[10] P. Ferrer-Cid, et al., "Graph Learning Techniques Using Structured Data for IoT Air Pollution Monitoring Platforms," *IEEE Internet of Things Journal*, vol. 8, no. 17, pp. 13652–13663, 2021.