New Development of Mathematical and Statistical Model for Predicting AQI in Urban Areas by Using Traffic and Meteorological Data: Mathematical and Statistical Model for Predicting AQI in Domestic Areas

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Abstract: The present invention introduces an innovative air pollution control system to combat air quality degradation in urban and industrial environments. The system integrates advanced technologies, including vacuum pumps, electrostatic precipitators (ESP), multi-layered air filters, and a chimney system, to efficiently extract, purify and release air back into the environment. Central to the system is a vacuum pump that creates a partial vacuum, drawing in polluted air. The air then undergoes purification in the electrostatic precipitator (ESP), where matter particles are removed through corona discharge technology with exceptional efficiency (>99%). Consequent purification using many layers of air filters guarantees that airborne particles and contaminants are removed. The chimney system improves airflow, hence increasing air extraction and purifying efficiency. This all-inclusive approach to air pollution control provides a scalable solution that can be applied in a variety of contexts, thereby improving air quality and increasing environmental sustainability. The system's novel design and integration of crucial components offer a viable solution for reducing air pollution and improving public health.

Keywords: Air Quality Index, Vacuum pump, Electrostatic precipitator, Air Pollution, Air filters, Chimney.

Objective:

The aim of all this type of researches are to reduce air pollution at particular level, but in our research paper the system's equipment is of higher quality and quantity and are more capable than of other systems.

Expected Output and Outcome of the Invention:

Although the technology in this system is better and more capable than that of previous systems, the invention only reduces air pollution to a certain extent. Additional vacuum pumps and filters are also being utilized in conjunction with ESP to further reduce pollution. Several vacuum pumps are installed in the chimney to extract an increasing amount of contaminated air from the surrounding environment. Later, the air can be distributed throughout the environment, improving both its quantity and quality. After being captured by the ESP, sand and other hard particles are finally disposed of outside in the garbage can. Regardless of what the work is doing by other people, the number and capacity of vacuum pumps and filers will be increased in order to use this system for a greater area and reduce the pollution of air more than the other methods. First, a small region is used to replicate this system.

Suitability of the proposed work in major national initiatives of the Government:

Make in India, Aatam Nirbhar Bharat, STARTUP, Swasth Bharat, Smart Cities

Theme of Proposed Work:

Health, Environment

Introduction:

There is always a source and a destination for pollution. The source of pollution point is the point at which it enters the environment. The recipient is where the pollution ends up, and it could be a human, animal, or environmental component that is contaminated or damaged. Pollution can be identified in a variety of ways. These include finding indicators of harm to aquatic life (e.g., dead fish), detecting pollutants in the water, comparing present water quality to historical levels, and receiving complaints from water users.

Delhi's air quality remained in the 'worst' category, with the AQI being recorded at 500, which made the government announce special measures to tackle the rising pollution. Environment Minister Shri Bhupender Yadav said his department issued a notification to implement the emergency measures effectively. It is to be proposed that the collected data is from the reliable sources on NCR-Delhi that there might be a lack of differences between global warming and the mentality of human beings, which involves a person, a unit, and a manufacturing system, that all of these things, which are finally liable to take sincere intact regarding to make a solution for the excellent health for the earth to protect from the considerable pollution, from the natural air-based and water-based pollution. We know better than the nature has given us the best purity on this earth, but we never realize at any point of stage that people are dying in the number of thousands, even in a single day, and in the quantum of millions in several days.

An AQI level between 0-50 is to be considered as good, 51-100 as satisfactory, 101-200 as moderate, 201-300 as poor, 301-400 as very poor and 401-500 as severe. Because Delhi's high levels of nitrogen oxides and matter particles exceed the allowable limit of ambient air quality standards set by India's Central Pollution Control Board (CPCB), they have long threatened public health.

Schools and government offices were announced to stay shut for one week. It was later extended and Delhi schools were to remain closed for physical classes till further orders while online courses and board exams were to continue, as announced by the Directorate of Education (DoE) because of the prevailing air quality situation Such situations arise in Delhi that's why we want to go towards the development of this device. The importance of this proposed research in this context of its current status.

All the related re to reduce air pollution are to reduce air pollution to a certain extent. Still, in this system, the equipment is of better quality and capacity than other systems' equipment.

In 2015, Z.J. Zhou et al. was investigated Effects of existing energy saving and air pollution control devices on mercury removal in coal-fired power plants. This research investigated the effects of load variation on mercury conversion via selective catalytic reduction (SCR) catalysts at two coal-fired boilers, as well as the impacts of a low-temperature economizer (LTE) on mercury removal via an electrostatic precipitator. The purpose of this research was to taken into consideration the things out in all the eyes with the efficiency and environmental performance of coal-fired power plants, with a special emphasis on emissions of mercury, which are a major environmental issue because of their poisonous nature. When the LTE was activated, the total and mercury elemental removal efficiency increased by 42.87% and 18.85%, respectively, because to the fly ash's enhanced oxidation capacity and adsorption at lower temperatures. The examination of mercury speciation at the inlet and exit of the SCR system was investigated, as well as the impact of load fluctuation and catalyst aging on HgO conversion. Due to fluctuating loads, the ambient temperature, oxygen concentration, and space velocity of gas hourly all altered at the same time. The results showed that load decrease assisted HgO conversion and that the load ratio was critical for HgO conversion by SCR catalysts. The HgO conversion rates were 61.78%, 65.71%, and 72.12% for 100%, 75%, and 60% load ratios, respectively. Furthermore, catalyst aging had a larger effect on Hg0 conversion than NO_X reduction. According to the gray relational analysis, the flue gas temperature is the most important of the three factors [see 1].

In 2016, H Nasir et al. published “Review Air Quality Monitoring: Case Study of India”. In this paper, pollution of air is one of developing nations' most significant and severe environmental and public health concerns. This essay aims to give readers insight into the current state of air quality in different Indian cities, as well as the numerous causes and effects of air pollution. An effort is made to educate people about the particulate matter and multiple gases in the air, emphasizing their environmental impact and outlining possible solutions. Methods: The National Air Quality Index (NAQI) enables comparisons across different cities so that fresh approaches can be developed to reduce the particulate matter amount in the air. Based on historical NAQI data, the concentration of various pollutants and dangerous gases in several Indian cities is evaluated in this article, indicating the locations most at risk from pollution [see 2].

In 2018, K. Okokpujie et al. were proposed “A Smart Air Pollution Monitoring System”. A pollution of air monitoring system is used in this research. The Arduino microcontroller was used in the development of this system. Real-time air quality monitoring and analysis was part of its design, and data was regularly updated online and logged to a distant server. Microsoft Excel was used to analyze the air quality measurements based on PPM (Parts per Million) metrics. The designed system accurately measured the air quality. The results were shown on the hardware's display interface and were accessible on any smart mobile device through the cloud [see 3].

In 2020, R. Bajaj et.al. developed a Low-Cost Air Pollution Monitoring Device Based on Air Quality Index. The novelty in this system relies on a cheap, affordable and quick measuring index for the air quality around us. It uses a portable battery-powered hub based on an 8-bit microcontroller, equipped with several Metal Oxide Semiconductor (MOS) based gas and Particulate matter (PM) sensors. The developed system acquires the sensor responses in real time for accurate monitoring. A mobile application that converts the obtained sensor values to the standard Air Quality Index (AQI) and displays the final result has been developed. This ensures the user-friendliness of our project, keeping a constant check on the air quality around us [see 4].

In 2020, V.V. Tran et al. conducted research on Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality. Every year, millions of people die as a result of indoor air pollution (IAP), which poses a serious health danger. Several pollutants can result in IAP. Finding solutions to enhance and control indoor air quality (IAQ) and identifying their main sources and concentrations are crucial. The main sources of major pollutant emissions, their health impacts, and problems pertaining to IAP-based illnesses, such as sick building syndrome (SBS) and building-related illness (BRI), are critically reviewed and evaluated here. Additionally, recent trends in efforts to resolve and improve IAQ are discussed in this article, along with the tactics and approaches for controlling and reducing pollutant concentrations, each with its own advantages and potentials. The creation of new materials for sensors, IAQ monitoring devices, and smart houses is anticipated to be a viable approach to IAQ management and improvement in the future [see 5].

In 2022, Y Hua et.al studied Global value chain engagement and air pollution: Evidence from Chinese firms. In this study examines the environmental effects of a firm's involvement in the global value chain using a unique firm-level data set that was created by fusing various sizable and representative databases in China from 2000 to 2007. We provide a novel global value chain (GVC) participation measure that accurately describes the importing habits of Chinese firms. Our findings convincingly demonstrate that firms' participation in GVC resulted in lower SO2 emissions by estimating fixed-effects models with a rich set of firms- and industry-level covariates. The identified consequences are more pronounced for domestically owned businesses, businesses with greater pollution levels, and businesses subject to stricter place-based environmental regulations. We further show that the pollution reduction impacts brought about by the firm's GVC engagement are due to lower SO2 intensity, it can be accomplished by reducing the usage of fossil fuels and increasing the adoption of abatement technologies [see 6].

In 2022, F.O. Abulude et al. proposed a real-time air quality index app: The use of an e-wave HDF app for education in monitoring pollutants and meteorological parameters in Nigeria. This paper describes the pollutants as a severe problem, especially in developing nations. Pollutants must be measured in the environment (both inside and outside) to see whether they are under World Health Organization (WHO) standard limits to adder his problem. Expensive equipment was initially required to measure the levels of pollutants (PM2. 5 and PM10,$_2$, CO,SO_2, and O_3). However, the Internet of Things (IoT) and citizen science projects employing inexpensive sensors have saved the day for those with little financial resources. To gather and communicate real-time data on air quality, air sensor networks, such as wireless dispersed networks of sensors, have been created and tested using mobile applications (Jiao et al., 2016). Because most people carry a cell phone, it is a natural choice for monitoring personal exposure. To yet, it hasn't been utilised as a standalone tool for this objective. There are ample of methods for accumulating and sharing information on air quality utilizing mobile devices and pollutant-sensing equipment (Brienza et al., 2015; Nyarku et al., 2018). This was done by either pairing or tethering the sensing device directly with the phone or by connecting it via Bluetooth, enabling real-time data viewing on the phone and subsequent server upload. Nigeria has a dearth of monitoring equipment, thus nothing is done to keep an eye on the air quality, especially in rural areas. As a result, residents in these places won't have access to vital information about the air quality for their health. It is now feasible to assist in risk avoidance and enhance the health and wellbeing of their owners thanks to the accessibility of weather apps and mobile phones, which have a variety of functions. However, they have not been employed to test individual ambient air pollution thoroughly [see 7].

In 2022, S Gulia et.al published the paper titled "Performance evaluation of air pollution control device at traffic intersections in Delhi". In this research a lot of consideration has been paid to urban air-pollution and its effects on people's health. On the other hand, source-specific control is the main focus of policymakers; however, because of the variety and complexity of the sources, it is challenging to see the action and subsequent effects on improved air quality right away. At traffic intersections, many cities worldwide have experienced significant air pollution levels; this is particularly true of all Indian cities. Managing the pollution level at severely polluted sites may be possible through site-specific air pollution reduction. The Wind Augmentation and PurifYing Unit (WAYU) was created by India's CSIR-National Environmental Engineering Research Institute to remove gaseous and particle pollutants from urban hotspots like traffic sites. The authors of the current study tried to assess the effectiveness of two alternative WAYU designs for removing matter particles from contaminated air at various traffic sites in Delhi City, the national capital territory of India. According to the performance assessments, WAYU's current design effectively filters out PM10 and PM2.5 concentrations from the inlet air, which are 34–49% and 19–25%, respectively. From 120,557 operating hours across all sample sites, 34.19 kg of PM were collected from all WAYU devices. The size-segregated particulate matter pollution in the ambient air affects how quickly PM is removed [see 8].

In 2023, S. Pawar et.al studied on AQI: Monitoring and Predicting System. This study aims to use IOT with the cloud to make services faster and faster in real-time. The system primarily aims to access and visualize air quality based on real-time sensor data. At regular intervals, the level of each hazardous pollutant is measured. The Air Quality Index i.e. (AQI) for the measured pollutants is calculated, and public awareness is raised via a web application that shows the air quality index in that specific place. Further, an ML model is developed that can predict future AQI index values based on the data collected, which can help in making precautions arrangements in the case of the worst AQI index concerning public health [see 9].

The goal of all linked research to reduce air pollution is to do so to a certain level (see [10]), although this system's equipment is of higher quality and more capable than other systems.

Importance of the proposed research in the context of current status

All the related research to reduce the pollution of air are to reduce the pollution of air at certain extent but in our system, the equipment are of better quality and better capacity than other systems equipment. The number of filters and vacuum pumps are also increased to reduce pollution with the help of ESP. Several vacuum pumps are installed in chimneys to suck more and more polluted air from the environment. When the polluted air is sucked, it will be thrown onto the number of filters one by one in a layer of filters so that the level of air is more refined and the air quality may be increased, and the air can be spread out in the environment later. The ESP is there to catch the sand and hard particles, and in the end, all the particles are thrown outside in the waste container. This system is simulated first for a small area. Then the capacity and number of vacuum pumps and filers will be increased to be used for big areas and the pollution of air can be reduced more than the other systems, whatever the other people are working on.

Methods & Materials

Our research is introduces a device to control the pollution of air to address air quality degradation in urban and industrial environments. This device integrates advanced technologies such as vacuum pumps, electrostatic precipitators (ESP), air filters, and a chimney system to extract, purify, and release air back into the environment. At its core, the device utilizes vacuum pumps to create a partial vacuum, drawing in polluted air from its surroundings. The polluted air then passes through an electrostatic precipitator, where particulate matter is efficiently removed through corona discharge technology, achieving collection efficiencies exceeding 99%. Subsequently, the purified air is filtered through multiple layers of air filters to remove airborne particles, pollutants, and microorganisms, ensuring high-quality air output. Finally, the chimney system facilitates airflow through the device, enhancing air extraction and purification efficiency.

The air pollution control device operates systematically, involving key components that work in tandem. Initially, vacuum pumps create a partial vacuum within the device, drawing in polluted air from the environment. This polluted air then undergoes purification in the electrostatic precipitator (ESP), where corona discharge technology charges and collects particulate matter on oppositely charged collector plates. The air that is purified then passes through multiple layers of air filters, effectively removing any remaining airborne particles and pollutants. The filtered air is released back into the environment through the chimney system, ensuring improved air quality.

FIG 1 illustrates an air pollution control device designed as an integrated solution for effectively controlling air pollution. At its core, the vacuum pump plays a pivotal role by creating a relative vacuum within a specified volume, enabling the system to extract polluted air from the environment. This vacuum effect is critical for initiating the purification process and ensuring that contaminated air is efficiently transported into the system for treatment. The electrostatic precipitator (ESP) is connected to the vacuum pump, which functions as a critical component for filtering out particulate matter and harmful gases from the incoming air stream. ESP technology utilizes electrostatic forces to attract and capture pollutants, preventing their release into the atmosphere. By incorporating an ESP, the system effectively mitigates the emission of pollutants, contributing to improved air quality. Following the ESP, the air undergoes further purification through air filters. These filters are instrumental in removing airborne particles, microorganisms, and other pollutants that causes health risks to humans and the environment. The air filters ensure that the purified air meets best quality standards before being released into the surrounding atmosphere.

The device includes a chimney component to facilitate efficient air circulation and ventilation. The chimney creates a draught effect, wherein hot air rises naturally, and inducing air flow through the system. This airflow mechanism aids in directing polluted air through the purification process, enhancing the system's overall efficacy in reducing air pollution levels. Figure 1 illustrates an advanced air pollution control infrastructure, highlighting the interconnected components essential for achieving optimal air quality. By integrating vacuum pumps, electrostatic precipitators, air filters, and chimneys, the system demonstrates a comprehensive approach to combating air pollution. This innovative system design effectively captures filters and eliminates pollutants, contributing to environmental sustainability and public health improvement.

In this research the air pollution control device incorporates advanced vacuum pump technology to create a powerful partial vacuum, optimizing air extraction efficiency. The vacuum pump employs positive displacement, momentum transfer, or entrapment techniques to extract polluted air from the surrounding environment. By generating a partial solid vacuum within the device, the vacuum pumps ensure thorough extraction of contaminated air, a crucial initial step in the air purification process. This embodiment highlights the importance of efficient air extraction for effective air pollution control, setting the stage for subsequent purification and filtration stages.

Another body part of the invention focuses on the electrostatic precipitator (ESP) system integrated into the air pollution control device. The ESP utilizes corona discharge technology to charge and collect particulate matter suspended in the polluted air. As the polluted air passes through the ESP, dust particles and other contaminants are attracted to the oppositely charged collector plates, achieving exceptional collection efficiencies exceeding 99%. The ESP system plays a precarious role in air purification, effectively removing harmful particles before the purified air undergoes further filtration and is released back into the environment. An ESP consists of the following components:

- High voltage supply source and control system- High voltage DC supply is given to the Electrodes for the corona discharge.
- Mesh- Mesh is used as both pre-filter and post-filter for collecting dust particles. Pre-filter collects the dust before sending flue gases to the ionization process. Post-filter is used to filter out the dust particles, if any, found after the ionization process.
- Gas Distribution System- The gas distribution system is employed to pass flue gases through the pre-filtration and ionization process properly. The system consists of several perforated plates, which help maintain proper flow distribution of the entering gas stream.
- Hopper- A Hopper collects the dust particles collected by the collecting plate.
- Collecting plate- The collecting plate is a positively charged electrode that collects the dust particles by the attraction principle, which are ionized by the highly negatively charged electrode. It provides the collection surfaces for the charged particulate matter.
- Discharge Electrode- The discharge electrode is a highly negatively charged electrode that ionizes the dust particles those are made to pass through it. The discharge electrodes are divided into fields. Most ESPs have three or four fields in series; however, very large units may have as many as fourteen. Discharge electrodes are energized by a single transformer-rectifier (T-R) set power supply. The energized electrodes create ions that collide with the particles and apply the electrical charge to the particles in the incoming gas stream.
- Hammering or Rapping system- Hammering is done on the collecting plate periodically to collect these dust particles in the hopper. The rapping system removes the collected matter particles from the collection surfaces.

Yet another body part of this research highlights the multi-layered air filtration system integrated within the device. This system comprises pre- and post-filters strategically arranged to refine air quality progressively. The pre-filters capture larger particles and contaminants, while the post-filters target smaller particles and microorganisms. By incorporating multiple layers of air filtration, the device ensures the comprehensive removal of airborne pollutants, contributing to improved air quality and environmental health. The filtration system represents a vital component of the invention, enhancing the overall effectiveness of the air pollution control device.

In a further embodiment of the invention, the chimney system plays a pivotal role in facilitating airflow and optimizing air extraction efficiency. The chimney operates on the principle of hot air rising above cold air, creating a draught that promotes airflow through the purification system. Multiple strategically placed vacuum pumps within the chimney enhance air extraction, ensuring thoroughly removing contaminated air from the environment. The chimney system is a crucial device component, enabling efficient air purification and releasing purified air back into the environment.

These embodiments collectively demonstrate the innovative design and functionality of the air pollution control device, addressing air quality degradation in urban and industrial environments. By integrating advanced vacuum pump technology, electrostatic precipitators, multi-layered air filtration systems, and efficient chimney airflow, the device offers a comprehensive solution for justifying air pollution and improving environmental health. The scalability and adaptability of the invention allow for deployment in diverse settings, from urban centres to industrial facilities, providing a practical and efficient means of combating air pollution and promoting sustainable environmental practices.

The air pollution control device includes an efficient waste disposal mechanism for managing collected dust particles. A waste container integrated into the system facilitates the periodic removal of dust particles from collector plates, enhancing the sustainability of the device by optimizing waste management during the air purification process. Moreover, incorporating advanced filtration materials and technologies ensures the removal of a wide range of pollutants, including airborne particles, microorganisms, and chemical compounds, contributing to improved air quality.

The novel design and integration of vacuum pumps, ESP technology, air filters, and a chimney system represent a comprehensive approach to air pollution control. By combining these advanced components, the device effectively addresses air quality degradation in urban and industrial environments, offering a sustainable solution for moderating the impact of air pollution on public health and the environment. The device's versatility and scalability make it suitable for deployment in diverse settings, from urban centres to industrial facilities. It provides a practical and efficient means of combating air pollution and improving overall air quality.

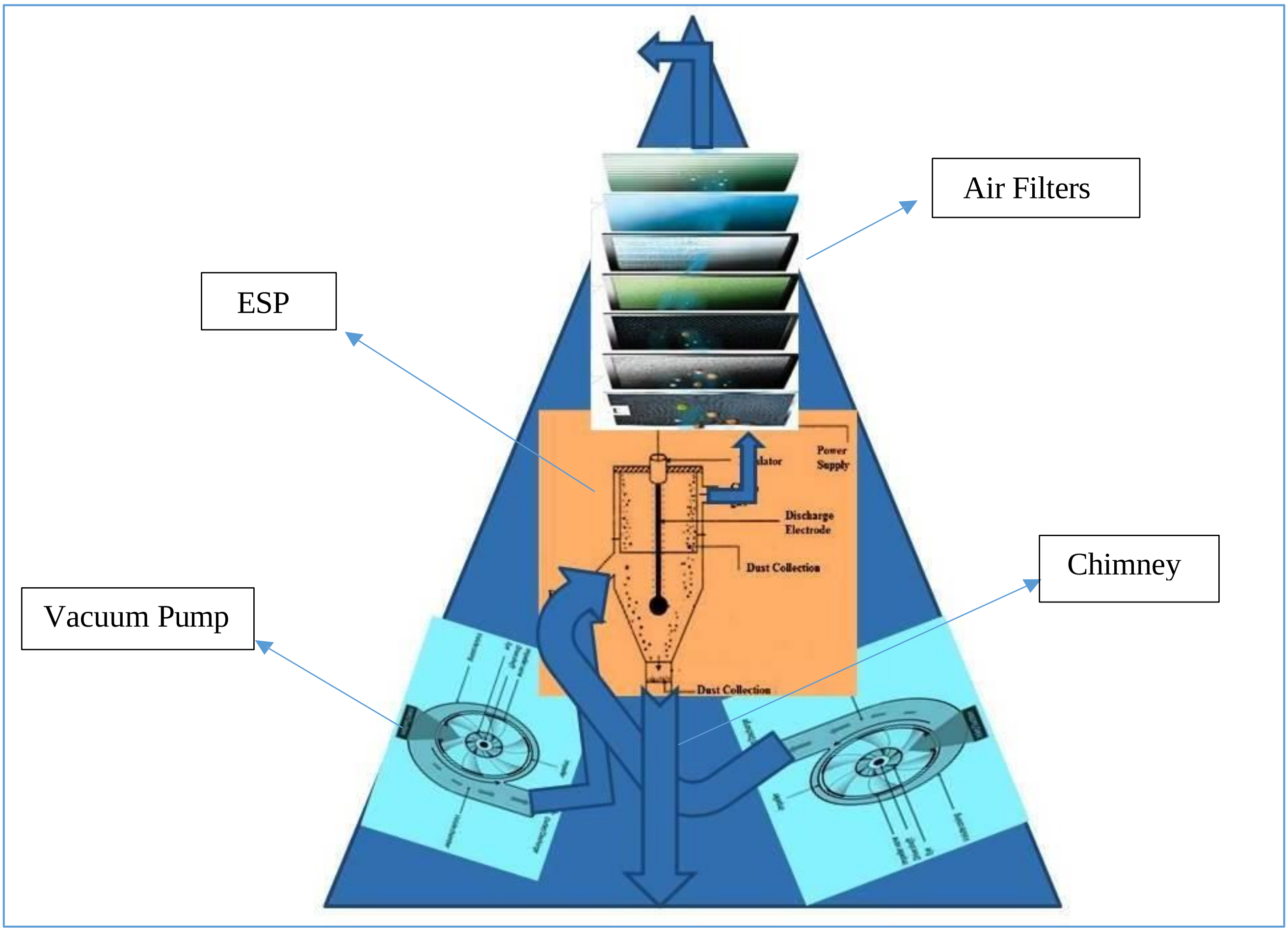

Figure 1: Schematic view of conceptual design of air pollution control device

Conclusion

The Device, wherein the vacuum pump is positioned within the chimney system, maximizes air extraction efficiency, effectively removing contaminated air from the environment and facilitating purification. This research's innovative air pollution control system demonstrates a comprehensive and efficient approach to addressing air quality degradation in urban and industrial environments. Integrating advanced technologies such as vacuum pumps, electrostatic precipitators (ESP), multi-layered air filters, and a chimney system effectively purifies polluted air and enhances environmental sustainability. The high efficiency of the ESP in removing particulate matter and the robust filtration process ensure that the air released back into the environment is significantly cleaner. This scalable solution, adaptable to various settings, mitigates air pollution and promotes public health, making it a vital contribution to contemporary efforts in air quality management.

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