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DESIGN AND EFFICIENCY ANALYSIS OF A MODULAR URBAN AIR PURIFICATION SYSTEM INSPIRED BY TRADITIONAL UZBEK ARCHITECTURE

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Abstract Urban air pollution has become one of the most significant environmental and public health problems in rapidly growing cities. Particulate matter such as PM2.5 and PM10 significantly affects respiratory health and contributes to environmental degradation. Traditional air purification technologies are mainly designed for indoor applications and are not suitable for large-scale outdoor urban environments.

This study proposes the conceptual design and efficiency analysis of a modular urban air purification tower inspired by traditional Uzbek architectural elements. The system integrates multi-stage filtration processes including water-based pre-filtration, mechanical particle filters, and activated carbon adsorption technology. In addition, the structure incorporates solar photovoltaic panels to ensure sustainable energy supply.

The airflow capacity, filtration efficiency, and energy consumption of the proposed system were analyzed using theoretical calculations. Results indicate that a purification tower with a height of 6–9 meters can process approximately 12,000–13,000 cubic meters of air per hour. The modular structure allows flexible installation in urban environments such as parks, road intersections, and industrial areas.

The proposed design demonstrates the feasibility of combining environmental engineering with culturally inspired architecture to improve urban air quality while maintaining aesthetic harmony with the surrounding environment.

Keywords: Urban air purification, PM2.5 filtration, environmental engineering, sustainable urban infrastructure, modular filtration systems.

Introduction Air pollution is one of the most critical environmental challenges affecting modern cities worldwide. According to reports by global environmental organizations, urban air pollution contributes significantly to respiratory diseases, cardiovascular problems, and premature mortality.

The primary sources of urban air pollution include vehicle emissions, industrial activity, construction dust, and fossil fuel combustion. These activities produce harmful pollutants such as nitrogen oxides, sulfur dioxide, carbon monoxide, and particulate matter.

Traditional environmental control strategies mainly focus on reducing emissions at the source. However, in many rapidly developing cities, it is difficult to eliminate pollution sources completely. Therefore, additional technological solutions are required to improve air quality in urban areas.

In recent years, several large-scale air purification towers have been developed and tested in different parts of the world. These systems use advanced filtration technologies to remove airborne pollutants and improve local air quality.

This research proposes a modular air purification tower inspired by traditional Uzbek architecture. The concept combines modern environmental engineering technologies with cultural design elements to create a functional and visually appealing urban infrastructure system.

Literature Review Several studies have investigated large-scale air purification technologies designed for outdoor environments. Smog tower systems implemented in cities

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such as Beijing and Rotterdam demonstrated the ability to reduce particulate concentration within localized areas.

Mechanical filtration technologies are widely used to capture particulate matter from air streams. High-efficiency particulate air (HEPA) filters are capable of removing particles as small as 0.3 microns with high efficiency.

Water-based filtration systems, commonly known as wet scrubbers, are also widely used in industrial environments. These systems remove particulate matter by introducing liquid droplets that capture airborne particles.

Activated carbon filters are effective for removing gaseous pollutants including volatile organic compounds and nitrogen oxides. These filters rely on adsorption processes to trap harmful molecules within porous carbon structures.

Despite the technological advancements in air purification systems, most existing designs focus primarily on functionality and ignore aesthetic integration with urban environments. This research aims to bridge that gap by incorporating architectural elements inspired by traditional Uzbek design into the purification tower structure.

System Design and Architecture Structural Design The proposed purification tower has a height between 6 and 9 meters, which allows effective air circulation and filtration capacity. The structure consists of multiple internal chambers designed for sequential filtration processes.

The outer design incorporates geometric patterns inspired by Uzbek architectural traditions, which allows the structure to integrate aesthetically into urban landscapes.

Filtration Stage The purification system consists of four main filtration stages

Stage 1 – Air Intak Ambient air enters the purification tower through intake openings located at the lower section of the structure. High-capacity axial fans draw polluted air into the filtration chamber.

Stage 2 – Water Pre-Filtration The incoming air passes through a water spray chamber where large dust particles and heavy pollutants are captured through wet scrubbing.

Stage 3 – Mechanical Particle Filtration Air then passes through multi-layer mechanical filters designed to capture fine particulate matter such as PM10 and PM2.5.

Stage 4 – Activated Carbon Filtration The final filtration stage uses activated carbon filters to remove gaseous pollutants and unpleasant odors.

Stage 5 – Clean Air Release Purified air exits through upper vents, improving the air quality in the surrounding environment.

Airflow Calculation The volumetric airflow rate through the system can be estimated using the equation:

$$Q=A\times V$$

Where: Q = Airflow rate (m^3/s A = Air intake area (m^2) V = Air velocity (m/s)

Assuming: A = 1.2 m^2 V = 3 m/s $Q=1.2\times3=3.6m3/s$

Converted to hourly airflow:

$$3.6\times3600=12960m3/h$$

Therefore, a single purification tower can process approximately **13,000 cubic meters of air per hour**.

Filtration Efficiency Analysis Based on filtration technology characteristics, the estimated pollutant removal efficiencies are: PM10 removal efficiency: **85–90%** PM2.5 removal efficiency: **70–80%** Gas pollutant removal efficiency: **60–70%**

These values depend on filter material, airflow velocity, and environmental conditions.

Energy Consumption The purification tower is designed to operate using renewable energy sources, primarily solar photovoltaic panels. Estimated power consumption: Fan system: 600 Water pump: 250 Control system: 50 W

Total power consumption:

$$P=900W$$

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A solar panel system with a capacity of approximately **1 kW** is sufficient to operate the purification tower during daylight hours.

Environmental Impact The installation of modular air purification towers in urban areas may provide several environmental benefits: Reduction of particulate pollution in densely populated areas Improvement of urban air quality Reduction of respiratory health risks Integration of renewable energy technologies

The modular design allows multiple towers to be installed across different locations within a city.

Discussion The proposed purification tower demonstrates a novel approach to urban environmental engineering by combining technological functionality with cultural architectural elements.

Compared with conventional industrial filtration systems, the modular tower design allows flexible deployment across various urban environments including public parks, pedestrian streets, and transportation hubs.

However, practical implementation requires addressing several operational challenges such as filter replacement, water recycling, and maintenance requirements.

Future Work Future research should focus on the following aspects: Computational Fluid Dynamics (CFD) simulation of airflow patterns Optimization of filtration materials Development of prototype purification towers Real-world testing in urban environments

These studies will provide more accurate performance data and help improve the overall system design.

Conclusion

This research presents the conceptual design and efficiency analysis of a modular urban air purification tower inspired by traditional Uzbek architecture.

The proposed system integrates multi-stage filtration technologies and renewable energy sources to improve urban air quality. Analytical calculations indicate that a purification tower with a height of 6–9 meters can process approximately 13,000 cubic meters of air per hour.

The modular structure allows flexible deployment across urban environments while maintaining aesthetic compatibility with local architectural traditions.

Future research including CFD simulations and prototype testing will further validate the performance and feasibility of the proposed system.

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