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Solar-Powered Hybrid Magnetic–Electrostatic Device For Urban Particulate Air Pollution Reduction

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Research Question

1) What is the impact of air pollution on productivity, concentration, and well-being in our daily lives?
2) How does exposure to urban air pollution (PM2.5, PM10, NOx) affect respiratory health and daily physical activity?
3) How can solar-powered hybrid magnetic–electrostatic devices reduce harmful particulate levels in homes or offices?
4) How effective are low-cost air purifiers (electrostatic, photocatalytic, water-based) in reducing pollutants in urban households?

Introduction:

Air pollution has become one of the most critical environmental challenges in urban areas, affecting human health, daily life, and overall well-being. Particulate matter (PM2.5 and PM10), nitrogen oxides (NOx), and other pollutants are released from vehicles, industries, and household activities, leading to respiratory problems, reduced productivity, and decreased quality of life. Addressing this issue requires practical and sustainable solutions that can reduce pollutant levels effectively. This research focuses on exploring both technological and natural interventions, including solar-powered hybrid magnetic–electrostatic devices, low-cost air purifiers, and plant-based air purification methods. The aim is to evaluate the impact of air pollution on daily life and investigate feasible solutions to improve urban air quality.

Literature Review:

As people engage in activities, the number of breaths increases, for every minute healthy humans breathe 12 times, utilizing 21% of oxygen at rest [1]. Bangladesh, one of the fastest-growing economies in the world, is facing a severe air pollution crisis. In 2023, it was ranked the most polluted country globally, with an annual average fine particulate matter (PM2.5) concentration of 79.9 µg/m^3—more than double the national standard of 35 µg/m^3 and 15 times the World Health Organization's (WHO) guideline of 5 µg/m^3 (IQ Air, 2023) [2]. In Bangladesh, major sources of air pollution include brick kilns, vehicular emissions, road dust, and industrial activities, which together contribute heavily to $PM_{2.5}$ levels. Additionally, open waste burning and biomass fuel use in households worsen both outdoor and indoor air quality [3]. The number of motor vehicles is increasing rapidly in Bangladesh, from 1.49 million in 2010 to 4.44 million in 2020, and 5.11 million in February 2022 (BRTA-Number of registered vehicles). Most of these vehicles are reconsidered or old and lack proper maintenance. Congested traffic, bad parking management, contaminated fuels, overloading, and the dust generated

due to friction with the roadways contribute to air pollution [2]. However, we now need to take steps to resolve this issue. Firstly, Air Quality Monitoring and Feedback System will continuously measure PM levels, enabling the device to adjust its operation automatically. Then, A display panel will provide real-time air quality information and system status to users [4]. Hybrid System Integration device will combine both **magnetic and electrostatic filtration** in sequence: magnetic filters first remove ferromagnetic particles, followed by electrostatic precipitators for non-magnetic fine particles. A control system will manage the operation of both units for maximum efficiency. Another way HEPA filters are high-efficiency air filters capable of removing at least 99.97% of airborne particles as small as 0.3 microns, widely used for reducing indoor particulate pollution (U.S. Environmental Protection Agency [EPA], 2025). In Summary, Bangladesh faces critical air pollution, with PM2.5 levels far above WHO standards. This project introduces a low-cost, solar-powered hybrid device combining magnetic, electrostatic, and HEPA filtration to capture harmful particles. A smart monitoring system with real-time feedback ensures maximum efficiency. The solution is scalable, sustainable, and designed to protect public health in polluted urban environments.

Research Methodologies:

This study will employ mixed-method approaches. A comparative survey and environmental monitoring will be conducted. Participants (n = 50–100 households and offices) will be recruited using stratified sampling to ensure even representation across different socioeconomic groups, building types, and exposure levels. Each site will undergo air quality measurements for PM2.5, PM10, and NOx, and residents will complete a survey rating their perceived indoor air quality, respiratory health, productivity, and comfort on a 1–7 Likert scale. The study will include participants from high-exposure areas (near traffic or industrial zones) and low-exposure areas (residential interiors), allowing comparison of air quality improvements across different urban settings. Along with the survey, a solar-powered hybrid magnetic–electrostatic device will be installed at each site, and its effectiveness in reducing particulate matter will be measured over a defined period. This will be followed by semi-structured interviews with a subsample of participants (n = 20–30) to explore experiences, perceived health benefits, challenges in device use, and attitudes toward sustainable air pollution solutions. Rigorous data analysis will then be conducted, using descriptive and inferential statistics for quantitative data and thematic coding for qualitative data, to evaluate the device's performance and assess differences in perceptions and outcomes across various demographic and environmental contexts.

Project Practicalities: The project is planned over approximately 8 weeks, including design and planning (1–2 weeks), field testing and data collection (5-6 weeks), and data

analysis and reporting (1–2 weeks). The study will adhere strictly to ethical guidelines regarding participant privacy and data security.

Conclusion Air pollution continues to pose a serious threat to urban life, demanding solutions that are both effective and sustainable. The findings of this research highlight that technological innovations, such as solar-powered hybrid magnetic–electrostatic devices and low-cost air purifiers, along with natural interventions like plant-based air purification, can significantly improve air quality. Together, these approaches provide a feasible and scalable pathway to reducing pollutants and protecting human health. By integrating science, technology, and nature, this study offers practical strategies to build healthier and more resilient urban environments.

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