

Sustainable Ink Production from Vehicular Emissions Using Smart Collection Technology

Prataprao Patil¹, Ameya Bharam², Lokesh Chavan³,
Lalit Choudhary⁴, Dheeraj Bansode⁵

¹ Lecturer, Prataprao Patil, Department of Civil Engineering, Zeal Polytechnic, Narhe, Pune-41

^{2,3,4,5} Student, Ameya Bharam, Department of Civil Engineering, Zeal Polytechnic, Narhe, Pune-41

Abstract

The escalating issue of vehicular pollution poses a significant threat to environmental sustainability and human well-being. This paper introduces an innovative solution aimed at mitigating pollution generated by vehicles through a Smoke Absorber system strategically positioned along roadways. Equipped with IR Sensor modules, the absorber initiates operation upon detecting approaching vehicles, capturing emissions and directing them through carbon filters. These filters trap pollutants while allowing clean air to pass through, eventually converting the captured waste into ink. This approach represents a paradigm shift in the intersection of transportation infrastructure and environmental conservation.

Keywords:

Pollution Control, IR Sensor, Carbon Filtration, Resource Recovery, Sustainability

1. Introduction

In the relentless battle against pollution, innovative solutions are indispensable. This project addresses the rampant issue of vehicular pollution by ingeniously integrating a mitigation system into the very fabric of road infrastructure. The core objective is to harness emissions expelled by vehicles and transform them into a resource for positive environmental impact.

At the heart of our innovation lies the Smoke Absorber. By employing intelligent sensor technology, the system remains dormant until a vehicle's presence activates it, ensuring that energy resources are utilized sparingly and effectively. The captured pollutants are eventually converted into ink, symbolizing a commitment to a circular economy.

2. Methodology

The development of the SVEC system followed a structured, multi-phase methodology:

2.1 Research and Analysis

A comprehensive literature review was conducted to understand the state of the art in vehicular emission mitigation and carbon capture technologies. Vehicular emission data, traffic density patterns, and air quality parameters were analysed to identify optimal deployment conditions and system requirements.

2.2 Conceptualization and Design

Conceptual designs for a road-integrated pollution capture system were developed through iterative brainstorming in collaboration with environmental engineering and sensor technology experts. Detailed schematics and circuit blueprints were produced for the Smoke Absorber unit, incorporating IR sensor modules, relay circuits, DC motors, and multi-stage carbon filter arrays.

2.3 Prototype Development

A functional prototype was assembled using the following components:

- IR sensor modules (transmitter-receiver pairs) for vehicle detection
- A relay module for signal-based motor activation
- DC motorised fans for suction generation
- Activated carbon filter layers arranged in series
- A sealed collection chamber for soot retention

Individual components were tested for compatibility and performance prior to integration. The assembled prototype was calibrated to ensure reliable vehicle detection and adequate suction force for emission capture.

2.4 Testing and Optimisation

Controlled tests were performed to evaluate the prototype's performance under simulated vehicular emission conditions. Sensor sensitivity thresholds, motor rotational speeds, and filter configurations were fine-tuned to maximise pollutant capture efficiency while minimising energy consumption.

2.5 Integration with Road Infrastructure

Installation guidelines were developed in consultation with civil engineering principles, specifying optimal unit placement along roadsides to maximise exposure to vehicle exhaust streams without obstructing traffic. Prototype units were installed at controlled test sites for real-world validation.

2.6 Performance Evaluation

Installed units were monitored over an extended evaluation period. Particulate capture rates, system uptime, and energy consumption metrics were recorded. Periodic maintenance cycles were also documented to establish operational requirements.

2.7 Documentation and Dissemination

All methodology, design specifications, performance data, and maintenance protocols were systematically documented. Findings were prepared for dissemination to academic, governmental, and environmental stakeholder communities.

3. Working Principle

The Smart Vehicular Emission Collector operates through the following sequential stages:

3.1 Vehicle Detection and Activation

IR sensor modules positioned along the roadside continuously scan for approaching vehicles. Upon detecting an interruption in the IR beam caused by a vehicle, the sensor transmits a signal to a microcontroller-based relay unit. The relay activates the DC motorised Smoke Absorber, initiating suction.

3.2 Emission Collection

The activated Smoke Absorber generates a directed airflow that draws in exhaust emissions expelled by the passing vehicle. Particulate matter, including fine soot and carbon particles, are entrained within the airstream and directed into the sealed collection chamber.

3.3 Filtration

The pollutant-laden airstream is channelled through a series of activated carbon filter layers. These filters trap PM, carbon soot, and other particulate pollutants via adsorption and mechanical interception, allowing only purified air to be exhausted back into the environment.

3.4 Energy Management

The system employs a dormancy protocol in the absence of vehicular activity. The IR-based activation mechanism ensures that the motorised components are energised only during vehicle detection events, significantly reducing overall power consumption and extending component lifespan.

3.5 Resource Transformation

Accumulated carbon soot retained within the filter chambers is periodically harvested and processed. Through a controlled carbon-to-ink conversion process involving mixing the soot with binding agents and solvents, a usable carbon-based ink is produced. This ink is suitable for printing and writing applications, demonstrating the system's resource recovery capability.

3.6 Intermittent Operation

The SVEC system operates intermittently, synchronised with vehicular activity. This operational pattern ensures high utilisation efficiency and prevents unnecessary wear on mechanical components during low-traffic periods.

4. Advantages and Limitations

Advantages

The system effectively reduces air pollution and improves overall air quality in urban environments. By converting waste into a valuable resource, it promotes sustainability and circular economy principles. Additionally, the seamless integration into existing infrastructure provides a scalable solution for pollution control.

Limitations

Implementation may require a significant initial investment in sensor technology and filtration systems. Regular maintenance is necessary to ensure the proper functioning of sensors and motors. Furthermore, the system's effectiveness is dependent on vehicle activity and may be limited in remote areas with low traffic.

5. Conclusion

The development of a system that converts vehicular emissions into ink represents a significant step forward in addressing environmental challenges. Through the integration of sensor systems and carbon filtration, this system offers a sustainable solution for reducing urban air pollution. While challenges such as investment costs and maintenance requirements exist, addressing these will be crucial for long-term viability.

References

1. Chen, X., Yang, L., Zhang, J., et al. (2018). Health risk assessment of vehicular particulate pollution in urban environments: a case study of two cities in China. *Environmental Pollution*, 238, 253-262.
2. Johnson, K. C., Samaras, C., & Van Der Zwaan, B. (2018). Future cost-competitive electricity systems and their impact on US CO₂ emissions. *Nature Climate Change*, 8 (10), 848-854.
3. Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. *Journal of Cleaner Production*, 175, 544-552.
4. Li, Z., Wang, S., Fu, H., et al. (2019). Review on mobile sensor nodes for real-time air quality monitoring. *Sensors*, 19(3), 528.
5. Liu, B., Chen, J., Wang, Y., et al. (2020). A techno-economic evaluation of carbon capture and utilization technologies: A case study of China. *Applied Energy*, 265, 114788.
6. Liu, J., Wu, Q., Liu, G., et al. (2021). A comprehensive review on the atmospheric pollution of heavy metals in China: From 63 sources and concentrations to impacts. *Science of the Total Environment*, 768, 144686.
7. Peng, Z., Zhang, Y., & Jin, Q. (2021). Recent advances in electrochemical sensors for in-situ detection of air pollutants. *Trends in Analytical Chemistry*, 134, 116150.
8. Wang, S., Qiao, Y., Jin, H., et al. (2019). A review on techno-economic analysis of CO₂ direct air capture systems. *Greenhouse Gases: Science and Technology*, (6), 1034-1051.
9. Yan, C., Liu, Y., Wang, X., et al. (2021). A review on the global status and prospects of carbon capture and utilization from industrial processes. *Journal of Cleaner Production*, 292, 126030.
10. Yao, M., Zhang, Y., & Zhang, Q. (2020). Review of catalytic technologies for VOCs removal from industrial flue gases. *Fuel Processing Technology*, 206, 106452.
11. Yuan, Z., Wu, Y., Hu, S., et al. (2020). Circular economy policies and practices in China: A review. *Journal of Cleaner Production*, 258, 120712.
12. Zhang, C., Zhong, L., Li, X., et al. (2019). A comprehensive review on physical, chemical and biological technologies for removing contaminants in roadsidewater treatment systems. *Science of the Total Environment*, 695, 133800.
13. Zhang, H., Yan, L., Liu, J., et al. (2022). Recent advances in catalytic hydrogenation of CO₂ for value-added chemicals production. *Journal of Energy Chemistry*, 65, 377-397.