International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 10 | Oct - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

A Review Paper on Air Pollution and Control Technologies in Mechanical Engineering Field

1) Author : **Kedar Redekar (Faculty)**

2) Author : (Student)

I. **Vishvjeet S. Kadam (ME)**

II. **Niketan S. Kalaskar (CSE)**

III. **Harshad S. Swami (ME)**

IV. **Kunal S. Gite (CSE)**

Institution : D.Y. Patil Technical campus talsande, Kolhapur

Abstract - Air pollution is a major environmental problem caused by industrial activities, automobile emissions, fossil fuel combustion, and manufacturing processes. Mechanical engineering plays an important role in reducing air pollution through the development of efficient engines, filtration systems, exhaust treatment devices, and computational analysis. This review paper examines different air pollution control technologies, including diesel particulate filters, baghouse filters, eco-friendly adsorbent materials, and Computational Fluid Dynamics (CFD). Published research indicates that metallic particulate filters can reduce diesel particle emissions, while activated carbon, silica gel, and zeolites have potential for exhaust treatment. CFD is also useful for improving airflow distribution and filtration performance in industrial equipment. The review compares the working principles, benefits, and limitations of these technologies. It concludes that combining improved engine design with efficient pollution-control equipment can help reduce emissions and improve environmental quality. Keywords: Air pollution, Mechanical Engineering, Diesel Engine, Particulate Matter, Baghouse Filter, CFD, Exhaust Emission Control.

***Key Words*:** Air pollution, Mechanical Engineering, Diesel Engine, Particulate Matter, Baghouse Filter, CFD, Exhaust Emission Control.

1. INTRODUCTION

Air pollution refers to the presence of harmful gases, particles, and other contaminants in the atmosphere. Major sources include motor vehicles, industrial boilers, thermal power plants, manufacturing industries, and fossil fuel combustion. Common air pollutants include particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), and unburned hydrocarbons (HC). These pollutants can affect human health, ecosystems, buildings, and industrial equipment. Mechanical engineering contributes to pollution control through engine design, combustion optimization, exhaust treatment, industrial filtration, and fluid-flow analysis. Diesel engines are widely used in transportation and industry because of their efficiency and high torque, but their exhaust can contain harmful particles and gases. Wai et al. investigated a metallic partial-flow particulate filter for a diesel engine and reported a reduction in particle emissions under the tested conditions. Lima and Huebner studied airflow distribution in a baghouse filter using CFD. These studies demonstrate the importance of both experimental testing and numerical simulation in pollution-control engineering.

2. Objectives

The main objectives of this review are:

1. To identify the major sources of air pollution related to mechanical engineering.
2. To review technologies used to control automobile and industrial emissions.
3. To study the performance of diesel particulate filters and eco-friendly filter materials.
4. To examine the application of CFD in industrial filtration systems.
5. To identify the limitations of existing technologies and suggest future research directions.

3. Research Methodology

This review is based on published journal articles related to air pollution control in mechanical engineering. The selected studies cover diesel exhaust filters, industrial baghouse filters, alternative filter materials, and airflow optimization.

The research papers were examined according to the following factors:

- Pollution source and type of pollutant.
- Working principle of the control technology.
- Experimental or numerical method used.
- Reported performance.
- Advantages, limitations, and possible applications.

This is a literature-based review, not a new experimental investigation. The results discussed below are taken from the individual studies and should not be interpreted as results obtained from the present author's experiments.

4. Sources of Air Pollution in Mechanical Engineering

4.1 Automobile Emissions

Internal combustion engines release pollutants due to fuel combustion. Diesel engines can produce particulate matter, nitrogen oxides, carbon monoxide, and hydrocarbons. The quantity of emissions depends on engine design, fuel quality, operating conditions, and maintenance.

4.2 Industrial Boilers and Furnaces

Industrial boilers and furnaces burn fuels to generate heat and steam. Depending on the fuel and combustion conditions, their exhaust may contain particulate matter, sulfur oxides, nitrogen oxides, and carbon monoxide.

4.3 Manufacturing Industries

Processes such as casting, welding, grinding, cement production, and material handling may generate dust, fumes, and fine particles. Dust collection equipment is therefore essential in many industrial plants.

4.4 Fossil Fuel Combustion

Coal, diesel, and other fossil fuels release pollutants during combustion. Proper combustion control, suitable fuel selection, and exhaust treatment can help reduce emissions.

5. Air Pollution Control Technologies

5.1 Diesel Particulate Filter

A diesel particulate filter (DPF) is used to capture soot and other particles from diesel engine exhaust. Exhaust gases pass through a porous filtering structure that traps particulate matter while allowing gases to pass through.

Wai et al. (2023) investigated a metallic partial-flow particulate filter on a 3-litre, four-cylinder diesel engine. Their study reported that particle emissions were reduced by approximately 50% under the tested operating conditions. Theresearchers also found that the filter did not significantly affect the engine's in-cylinder combustion characteristics or brake thermal efficiency.

Advantages:
- Reduces particulate emissions.
- Can be integrated into an exhaust system.
- Helps control soot from diesel engines

Limitations:

- Requires maintenance and monitoring.
- Collected soot must be managed through suitable regeneration or cleaning.
- Performance depends on engine load, exhaust conditions, and filter design.

5.2 Baghouse Filter

A baghouse filter is an industrial air-pollution control device that removes dust from gas streams. Dust-laden air passes through fabric filter bags, where particles are retained and cleaner gas exits the system.

Lima and Huebner (2019) investigated airflow distribution in an existing baghouse filter. They used field measurements and CFD simulations to examine flow velocity and pressure distribution. Their study addressed non-uniform airflow, which can contribute to uneven filter loading and premature damage to filter bags.

The research highlights the importance of proper inlet design, uniform airflow, pressure-drop monitoring, and suitable filter cleaning.

Advantages:-

- Effective for collecting industrial dust.
- Suitable for many large-scale industrial applications.
- Collected dust can sometimes be recovered for reuse Limitations:
- Filter bags require periodic cleaning or replacement.
- Pressure drop increases energy consumption.
- High temperature and chemically aggressive gases may require special filter materials.

5.3 Eco-Friendly Adsorbent Materials

Adsorption is a process in which pollutants attach to the surface of a solid material. Activated carbon, silica gel, and zeolites have properties that make them useful for investigating the removal of certain exhaust pollutants.

Patil, Navale, and Talib (2017) studied adsorbent materials in a stationary compression-ignition engine exhaust system. They investigated activated carbon, silica gel, and zeolites for controlling hydrocarbons, carbon monoxide, carbon dioxide, and particulate matter. The authors reported promising pollutant-control results for the materials tested. However, the reported percentages apply to their particular experimental setup and should not be generalized to

all engines or operating conditions.

Advantages:

- Offers potential for low-cost pollution-control systems.
- Uses materials with useful adsorption properties.
- May complement other exhaust treatment technologies.

Limitations:
- Adsorption capacity is finite.
- Materials may require regeneration or replacement.
- Performance depends on temperature, humidity, gas composition, and filter design.

5.4 Open-Channel Particulate Filter

An open-channel filter uses a structured metal-screen arrangement to reduce particle emissions from engine exhaust. Unlike conventional wall-flow filters, its open passages can reduce the risk of blockage while still capturing some particles.

Heikkilä et al. (2009) studied an open-channel filter on a modern heavy-duty diesel engine. The study reported a 78% reduction in particle mass over the European Steady Cycle. Particle-number reduction varied with particle size and engine load. This research demonstrates that filter structure and particle-capture mechanisms influence emission-control performance.

Advantages:

- Can reduce soot and particle emissions.
- Open passages may help limit blockage.
- Can be evaluated under different engine operating conditions. Limitations:
- Performance varies with particle size and engine load.
- It does not eliminate every pollutant.
- Results from one engine and test cycle may not apply to all vehicles.

5.5 Computational Fluid Dynamics in Pollution Control

Computational Fluid Dynamics (CFD) is a numerical method used to analyze fluid flow, pressure, velocity, and heat transfer. In pollution-control engineering, CFD can help engineers understand how gas flows through filters, scrubbers, ducts, and exhaust systems.
Lima and Huebner (2019) used CFD to investigate the flow field inside a baghouse filter. Their work demonstrates how simulation can identify areas of uneven flow and help engineers evaluate design modifications.

A typical CFD analysis involves:

1. Creating the geometry of the pollution-control device.
2. Generating a computational mesh.
3. Defining fluid properties and boundary conditions.
4. Selecting appropriate physical models and solver settings.
5. Solving the governing equations.
6. Examining velocity, pressure, and flow distribution.
7. Comparing predictions with experimental measurements.

Advantages:

- Helps evaluate design alternatives before manufacturing.
- Provides detailed information about internal airflow.
- Can reduce the need for repeated physical prototypes. Limitations:
- Results depend on model assumptions and mesh quality.
- Accurate boundary conditions and experimental validation are important.
- Complex multiphase flows and particle interactions can increase computational cost.

6. Comparative Review of Selected Research

Research study| Technology| Main finding
Wai et al. (2023)| Metallic partial-flow DPF| Approximately 50% reduction in particle emissions under tested conditions.
Lima and Huebner (2019)| CFD-based baghouse analysis| Examined non-uniform airflow and pressure distribution to support design improvements.
Patil et al. (2017)| Activated carbon, silica gel, and zeolites| Reported potential for exhaust-pollutant control in a stationary engine experiment.
Heikkilä et al. (2009)| Open-channel metal filter| Reported 78% particle-mass reduction over the tested engine cycle.
Khanna et al. (2025)| Review of diesel-emission strategies| Reviewed engine, fuel, and exhaust-treatment approaches for reducing emissions.

The studies show that different technologies target different problems. Particulate filters mainly address solid particles, adsorbents can capture selected compounds, and CFD helps improve the design and operation of pollution-control equipment. No single technology should be assumed to remove all pollutants effectively.

7. Discussion

The reviewed studies demonstrate that mechanical engineering offers several approaches to reducing air pollution. First, engine-exhaust filtration can reduce particulate emissions.

However, particulate filters do not automatically remove gaseous pollutants such as NOx and CO. Additional technologies may be necessary.

Second, industrial baghouse filters can collect dust effectively, but their performance depends on airflow distribution, pressure drop, cleaning arrangements, and filter material. Uneven flow may reduce equipment life and increase maintenance costs.

Third, adsorbent materials show potential for selected exhaust pollutants. Nevertheless, their performance must be confirmed under realistic operating conditions, including changes in exhaust temperature and pollutant concentration.

Finally, CFD can support design optimization by revealing flow patterns that cannot easily be observed experimentally. Its predictions should be validated with measured data before being used to make final engineering decisions.

The strongest overall approach is to combine source reduction, suitable filtration, gas-treatment technologies, and regular performance monitoring.

8. Research Gaps and Future Scope

The following areas require further investigation:

1. Development of durable, low-cost filter materials.

2. Improvement of particulate filters to reduce pressure drop while maintaining particle-capture efficiency.
3. CFD optimization of baghouse filters, scrubbers, and exhaust systems.
4. Experimental evaluation of adsorbents under different temperatures and gas compositions.
5. Integration of particle filters with technologies for controlling NOx, CO, and hydrocarbons.
6. Long-term assessment of maintenance cost, energy consumption, and filter life.
7. Validation of laboratory results under real industrial and vehicle operating conditions.

Future studies should report clear test conditions, pollutant concentrations before and after treatment, measurement uncertainty, and energy requirements. This would make it easier to compare technologies fairly.

9. Conclusion

Air pollution control is an important application of mechanical engineering. The reviewed research shows that diesel particulate filters, open-channel filters, adsorbent materials, and industrial baghouse filters can help reduce particular pollutants under suitable conditions.

CFD provides an additional engineering tool for improving airflow distribution and pollution-control equipment design. However, the performance of each technology depends on its operating conditions, material properties, maintenance requirements, and pollutant type.

Therefore, effective air-pollution management requires a combination of efficient combustion, appropriate exhaust treatment, industrial filtration, numerical simulation, and experimental validation. Further research should focus on improving efficiency, reducing operating costs, and developing sustainable pollution-control systems.

References:

1. Wai, P. A., et al. (2023). “Experimental Investigation of Metallic Partial-Flow Particulate Filter on a Diesel Engine's Combustion Pressure and Particle Emission.” Case Studies in Thermal https://doi.org/10.1016/j.csite.2023.103188

2. Lima, W. F., and Huebner, R. (2019). “Optimization of Air Distribution in a Baghouse Filter Using Computational Fluid Dynamics.” Engineering, Technology & Applied Science Research, 9(4), 4452–4456. https://doi.org/10.48084/etasr.2732

3. Patil, V., Navale, L. G., and Talib, M. I. (2017). “Diesel Engine Exhaust Emission Control Using Eco-Friendly Materials.” International Review of Mechanical Engineering, https://doi.org/10.15866/ireme.v11i10.12876

4. Heikkilä, J., et al. (2009). “Effect of Open Channel Filter on Particle Emissions of Modern Diesel Engine.” Journal of the Air & Waste Management Association, 59(10), 1148–1154. https://doi.org/10.3155/1047-3289.59.10.1148

5. Khanna, S., Dewangan, A. K., Yadav, A. K., and Ahmad, A. (2025). “A Progressive Review on Strategies to Reduce Exhaust Emissions from Diesel Engine: Current Trends and Future Options.” Environmental Progress & Sustainable Energy, 44(5), e70012. https://doi.org/10.1002/ep.70012