УДК 504.05/.06+504.75.05

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EFFICIENCY OF CLEANING PAH EMISSIONS TECHNOLOGIES FROM BIOMASS THERMAL POWER PLANTS

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Анотація
У статті розглядається порівняння ефективності трьох технологій очищення викидів теплоелектростанцій від поліциклічних ароматичних вуглеводнів (ПАВ). Застосовані технології включають електрофільтрацію, каталітичне окислення та плазмову очистку. Проведено аналіз ефективності кожної технології, а також їх впливу на зниження викидів ПАВ. Визначено ключові переваги та недоліки кожного методу, що дозволяє надати рекомендації щодо використання найбільш підходящих технологій у залежності від умов експлуатації ТЕС.
Ключові слова: ПАВ, очищення викидів, теплоелектростанції, електрофільтрація, каталітичне окислення, плазмова очистка

Abstract
This article compares the effectiveness of three technologies for cleaning emissions from thermal power plants of polycyclic aromatic hydrocarbons (PAHs). The technologies assessed include electrostatic filtration, catalytic oxidation, and plasma cleaning. An analysis of the efficiency of each technology and its impact on reducing PAH emissions is conducted. Key advantages and disadvantages of each method are identified, providing recommendations for the use of the most suitable technologies depending on TPP operational conditions.
Keywords: PAH, pollution, thermal power plants, electrostatic filtration, catalytic oxidation, plasma cleaning

Introduction

Thermal Power Plants (TPPs) are significant contributors to environmental pollution, with emissions containing hazardous pollutants, including Polycyclic Aromatic Hydrocarbons (PAHs). PAHs are known for their carcinogenic and mutagenic properties, making the reduction of these emissions critical for environmental health and air quality. To mitigate these impacts, various technologies have been developed to clean emissions from TPPs, each with its distinct mechanism and efficiency in removing PAHs. This study aims to compare the effectiveness of three prominent technologies - electrostatic filtration, catalytic oxidation, and plasma cleaning-in terms of their ability to reduce PAH concentrations in TPP emissions.

Results of the study

The comparative analysis focuses on three emission control technologies:

1. Electrostatic filtration (EF) is widely used for removing particulate matter from industrial emissions. It functions by creating an electrostatic field in which particles, including PAHs attached to dust, are electrically charged [1]. These charged particles are then attracted to oppositely charged collection plates, where they are removed from the gas stream (refer to Fig.1).

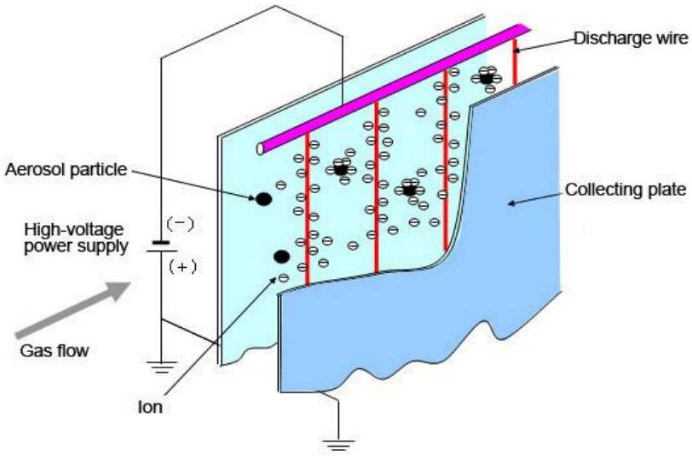

Fig. 1. Principle of electrostatic [2]

Key characteristics:

- works on the principle of electrostatic attraction.
- highly effective at removing solid particulate matter (PM) but less efficient for gaseous pollutants such as PAHs. Efficiency for PAH removal ranges from 40-60%.
- low operational and maintenance costs, highly effective in capturing fine particles.
- limited removal efficiency for gaseous PAHs, additional systems may be needed for complete PAH removal.

2. Catalytic oxidation (CO) [3] is one of the most effective methods for treating organic pollutants in gas streams. In this process, the exhaust gases pass through a catalytic converter, where PAHs and other hydrocarbons are oxidized into carbon dioxide, water and/or other safety materials (refer to Fig.2).

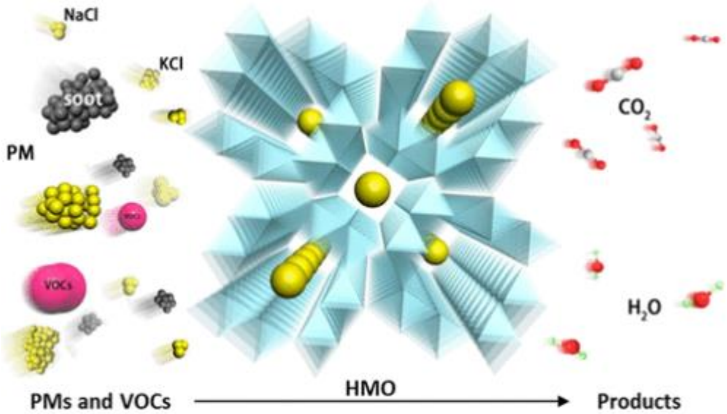

Fig. 2. Catalytic oxidation using hollandite manganese oxide catalyst as an example [4]

Key characteristics:

- involves the use of a catalyst (typically a metal or metal oxide) to accelerate the oxidation of PAHs at lower temperatures than conventional combustion.
- high PAH removal efficiency, typically exceeding 90%.
- very efficient in breaking down PAHs, also reduces other hydrocarbons and CO emissions.
- high operational and installation costs, requires periodic catalyst replacement due to fouling and degradation.

3. Plasma cleaning (PC) [5] employs a high-energy electrical field to ionize gas molecules, creating reactive species such as free radicals that can break down PAHs into less harmful compounds. This advanced technology has the ability to treat a wide range of organic pollutants (refer to Fig.3).

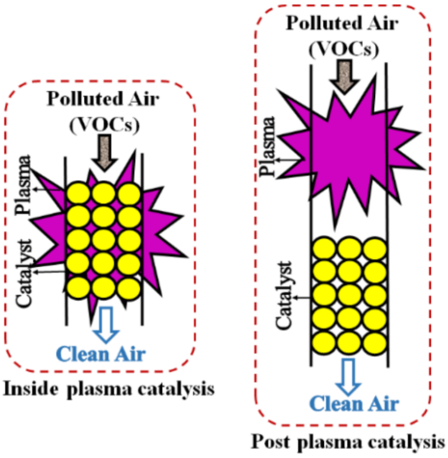

Fig. 3. Types of plasma-catalysis process [6]

Key characteristics:

- uses a non-thermal plasma, generating highly reactive species to destroy PAHs in the gas phase.
- moderate-to-high PAH removal efficiency, ranging between 70-85%, depending on the operating conditions.
- capable of treating both particulates and gaseous pollutants, fast reaction rates, applicable to multiple pollutants.
- high energy consumption, complex operation, and expensive maintenance due to the need for precise control of the plasma state.

Table 1 summarized the comparison between the three technologies based on several key parameters:

Tab. 1. Comparison of technologies for reducing emissions from biomass TPPs

Parameter	Electrostatic Filtration (EF)	Catalytic Oxidation (CO)	Plasma Cleaning (PC)
PAH Removal Efficiency	40-60%	>90%	70-85%
Operational Costs	Low	High	Moderate
Maintenance	Low	High (catalyst replacement)	Moderate to High
Energy Consumption	Low	Moderate	High
Additional Pollutant Removal	Effective for particulates	Effective for CO and HC	Effective for multiple pollutants
Complexity of Operation	Simple	Moderate	High
Applicability	Suitable for large-scale PM removal	Suitable for advanced PAH treatment	Applicable for wide range of pollutants
Scalability	High	Moderate	Moderate

The comparison highlights that while each technology has its strengths, the choice of technology depends largely on the specific needs and constraints of the power plant in question. EF is most suitable for power plants with high particulate matter emissions and low financial resources for advanced treatment. However, additional treatment systems would be required to remove gaseous PAHs effectively. CO stands out as the most effective technology for the reduction of PAH emissions, but it comes with significant cost implications. It is highly suitable for plants in regions with stringent environmental regulations where PAH removal is a priority, and the cost of catalyst replacement can be justified. PC technology represents a balance between efficiency and versatility. It can treat a broader range of pollutants but requires substantial energy and precise operation, making it suitable for facilities that need a flexible and comprehensive solution for emission control but can afford the higher operational complexity.

Conclusion

Catalytic oxidation offers the highest efficiency for PAH removal, making it the top choice for meeting stringent emission reduction standards. However, its high costs may restrict its use in smaller power plants. Electrostatic filtration, while more affordable, has limited effectiveness in PAH removal and is best utilized in combination with other technologies. Plasma cleaning, with its capability to handle multiple pollutants, presents a versatile and promising option, particularly for facilities requiring a broader solution, though its high energy demands remain a drawback.

Future research should explore hybrid systems that combine these technologies to maximize overall efficiency while minimizing costs and energy consumption. Additionally, further studies on the long-term environmental impact and practical challenges in real-world operations are crucial for optimizing emission control in TPPs.

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