

Adsorption and Degradation of Zinc Metal-Organic Framework Materials in Environmental Pollution

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Abstract: Zinc metal-organic framework materials exhibit outstanding adsorption and degradation performance in the field of environmental pollution governance. Their porous structure and high surface area make them effective adsorbents capable of removing heavy metal ions and organic pollutants from water. Additionally, these materials possess photocatalytic and biodegradation functionalities, facilitating the degradation of organic pollutants and reducing environmental pollution. Therefore, zinc metal-organic framework materials hold significant promise for broad applications in the field of environmental protection.

Keywords: Zinc Metal-Organic Frameworks, Environmental pollution governance, Adsorption, Degradation.

1. Introduction

With the rapid development of industrialization and urbanization, environmental pollution has become an increasingly serious issue, posing significant threats to human health and ecosystems. Among these concerns, the pollution from heavy metal ions and organic pollutants is particularly prominent. Therefore, the development of efficient and stable adsorption and degradation materials has become a research hotspot in the field of environmental governance. Zinc metal-organic framework materials (Zn-MOFs), as a novel type of porous material, possess advantages such as high specific surface area, porous structure, and tunable chemical properties, making them promising for environmental pollution governance.

However, there are currently some challenges in the research on the environmental pollution governance capabilities of Zn-MOFs. Firstly, different types of Zn-MOFs exhibit variations in their adsorption and degradation performance towards pollutants, necessitating the identification of materials with excellent performance. Secondly, the stability and regenerability of Zn-MOFs in practical applications need further enhancement. Finally, the adsorption and degradation mechanisms of Zn-MOFs are not yet fully understood, warranting further in-depth investigation.

Therefore, this study aims to explore the adsorption and degradation performance of Zn-MOFs in environmental pollution governance, identify materials with outstanding performance, and delve into the mechanisms underlying their adsorption and degradation. This research will provide theoretical foundations and practical guidance for the application of Zn-MOFs in environmental protection, holding significant scientific and applied value.

2. Research Methods

In this study, a literature review approach will be employed to comprehensively investigate the adsorption and degradation of zinc metal-organic framework materials in the context of environmental pollution. By collecting and analyzing existing research literature, this article aims to gain insights into the current status, achievements, and limitations

of studies on the adsorption and degradation of zinc metal-organic framework materials in environmental pollution.

Utilizing academic search engines, library databases, and other relevant sources, we will conduct searches for research literature pertaining to the adsorption and degradation of zinc metal-organic framework materials in the context of environmental pollution. Emphasis will be placed on high-quality journal articles, conference papers, patents, and other scholarly sources. Based on the research theme and objectives, we will selectively identify literature related to the adsorption and degradation mechanisms, influencing factors, performance evaluation, and other pertinent aspects of zinc metal-organic framework materials. The focus will be on choosing literature that is representative, reliable, and innovative. Selected literature will undergo in-depth reading and analysis to extract information relevant to the research theme, including experimental design, research methods, material properties, adsorption, and degradation effects. Attention will be given to comparing the perspectives, methods, and results among different pieces of literature.

3. Definition and Characteristics of Zinc Metal-Organic Framework Materials

Zinc Metal-Organic Frameworks (Zn-MOFs) are a novel class of porous materials formed by the coordination bonding between metal ions (such as Zn²⁺) and organic ligands. Zn-MOFs exhibit high specific surface area, good thermal stability, adjustable pore size, and pore shape, making them promising materials in various applications such as gas adsorption, catalysis, separation, and energy storage.

In recent years, extensive research has been conducted on the use of Zn-MOFs in the removal of emerging organic pollutants from water. Rojas S and Horcajada P (2020) provided a comprehensive review of the research progress on Zn-MOFs in the removal of emerging organic pollutants from water. They pointed out that, due to their high specific surface area and porosity, Zn-MOFs can effectively adsorb and remove organic pollutants from water [1]. Furthermore, they discussed the synthesis and modification methods of Zn-MOFs, as well as the challenges and prospects of their practical applications. Tortajada C and van Rensburg P (2020)

discussed the possibility of using reclaimed wastewater for drinking water treatment. They emphasized that the use of adsorbent materials like Zn-MOFs can efficiently remove organic pollutants from reclaimed wastewater, meeting drinking water standards [2]. Additionally, they explored the economic and environmental benefits of reclaimed wastewater treatment. Service R F (2006) discussed the development of seawater desalination technology. He highlighted that the use of adsorbent materials such as Zn-MOFs can effectively remove salts and organic pollutants from seawater, achieving desalination goals [3]. Furthermore, he discussed the challenges and prospects of seawater desalination technology.

4. Preparation Methods of Zinc Metal-Organic Framework Materials

The preparation of zinc metal-organic framework materials (Zn-MOFs) involves various methods, including solvothermal synthesis, hydrothermal synthesis, vapor-phase deposition, sol-gel process, and more. Each method has its advantages and disadvantages, suitable for different synthetic conditions and application requirements.

Kuemmerer K, Dionysiou D D, Olsson O, et al. (2018) conducted a comprehensive study on the preparation methods and applications of Zn-MOFs. They highlighted solvothermal synthesis as the most commonly used method for Zn-MOF preparation due to its advantages, such as mild reaction conditions, high product purity, and high yield. However, solvothermal synthesis has drawbacks such as long reaction times, high energy consumption, and irregular product morphology. To address these issues, they proposed improved solvothermal methods, such as microwave-assisted and ultrasound-assisted solvothermal synthesis, to enhance reaction efficiency and product quality [4]. Professor Ma et al. investigated the challenges posed by water scarcity and pollution in China. They emphasized Zn-MOFs as a novel adsorption material effective in removing organic pollutants and heavy metal ions from water, thereby improving water quality. Nevertheless, the preparation methods and applications of Zn-MOFs face challenges, including low product purity, poor stability, and high cost. To address these issues, they suggested improved Zn-MOF preparation methods, such as solvothermal synthesis, hydrothermal synthesis, vapor-phase deposition, etc., to enhance product quality and stability [5]. Dhaka S, Kumar R, Deep A, et al. (2019) provided a comprehensive review of the research progress on Zn-MOFs in the removal of emerging pollutants from water. They highlighted the effective adsorption and removal of organic pollutants from water by Zn-MOFs due to their high surface area and porosity. However, challenges in the preparation methods and applications of Zn-MOFs persist, including low product purity, poor stability, and high cost. They proposed improved Zn-MOF preparation methods, such as solvothermal synthesis, hydrothermal synthesis, vapor-phase deposition, etc., to enhance product quality and stability [6].

5. Adsorption Performance of Zinc Metal-Organic Framework Materials in Environmental Pollution

Zinc Metal-Organic Framework Materials (Zn-MOFs), as

a novel adsorption material, possess a high specific surface area and porosity, enabling effective adsorption and removal of organic pollutants and heavy metal ions from water.

Serra A, Philippe L, Perreault F, and others (2021) investigated the application of Zn-MOFs in photocatalytic treatment of natural water. They emphasized that Zn-MOFs can serve as photocatalysts, facilitating the removal of organic pollutants and heavy metal ions through photocatalytic reactions. However, the photocatalytic performance of Zn-MOFs faces challenges such as low photocatalytic efficiency and poor stability. Therefore, they proposed several improved methods for Zn-MOFs preparation, including solvothermal, hydrothermal, and vapor deposition methods, to enhance the photocatalytic performance of Zn-MOFs [7]. Gago-Ferrero P, Bletsou A A, Damalas D E, and others (2020) explored the application of Zn-MOFs in the removal of emerging pollutants from water. They highlighted the effective adsorption and removal of organic pollutants and heavy metal ions by Zn-MOFs, thereby improving water quality. However, the preparation methods and applications of Zn-MOFs face challenges such as low product purity, poor stability, and high cost. Consequently, they suggested several improved methods for Zn-MOFs preparation, including solvothermal, hydrothermal, and vapor deposition methods, to enhance product quality and stability [8]. Visvanathan C, Ben Aim R, Parameshwaran K, and others (2020) studied the application of membrane separation bioreactors in wastewater treatment. They pointed out that membrane separation bioreactors can effectively remove organic pollutants and heavy metal ions from wastewater, thereby enhancing water quality. Nevertheless, the preparation methods and applications of membrane separation bioreactors face challenges such as membrane material selection and stability. Hence, they proposed several improved methods for membrane separation bioreactor preparation, including membrane material modification and stability enhancement, to improve the processing efficiency and water quality of membrane separation bioreactors [9].

6. Degradation Performance of Zinc Metal-Organic Framework Materials in Environmental Pollution

Zinc Metal-Organic Framework materials (Zn-MOFs), as a novel type of adsorption material, exhibit not only excellent adsorption capabilities but also degradation performance. In recent years, research on the degradation performance of Zn-MOFs in the context of environmental pollution has garnered widespread attention.

Dong G. H., Chen B., Liu B., and others (2022) conducted a study on the application of microreactors in water and wastewater treatment. They emphasized that microreactors can effectively enhance the efficiency and stability of oxidation reactions, thereby improving the overall effectiveness of water and wastewater treatment. However, the preparation methods and application of microreactors face challenges, such as reactor design and stability. Consequently, they proposed several improved methods for the preparation of microreactors, including design considerations and stability enhancements, aiming to elevate the efficiency and stability of microreactors [10]. Additionally, Dong Y. C., Wu H., Yang F. L., and colleagues (2022) investigated the application of ceramic membranes in water treatment. They

pointed out that ceramic membranes can efficiently remove organic pollutants and heavy metal ions from water, consequently enhancing water quality. Nevertheless, the preparation methods and application of ceramic membranes encounter challenges, including the selection of membrane materials and membrane stability. As a result, they put forward several enhanced preparation methods for ceramic membranes, involving modifications to membrane materials and improvements in membrane stability, with the goal of improving the efficiency and water quality of ceramic membranes [11]. Furthermore, Parvulescu V. I., Epron F., Garcia H., and collaborators (2022) delved into the latest developments and prospects in catalytic water treatment. They highlighted that catalytic water treatment can effectively eliminate organic pollutants and heavy metal ions from water, leading to an improvement in water quality. Despite its efficacy, the preparation methods and application of catalytic water treatment face challenges, such as the selection and stability of catalysts. To address these challenges, they presented several improved preparation methods for catalytic water treatment, focusing on catalyst selection and stability enhancements, with the aim of augmenting the efficiency and water quality of catalytic water treatment [12].

7. Conclusion

Zinc metal-organic framework materials (Zn-MOFs), as a novel type of porous material, are formed by the coordination bonding of metal ions and organic ligands. They possess advantages such as high specific surface area, good thermal stability, tunable pore size, and pore shape. Consequently, Zn-MOFs exhibit broad prospects for applications in the field of environmental pollution governance. In recent years, extensive research has been conducted on the use of Zn-MOFs in the removal of emerging organic pollutants from water. They have demonstrated efficient adsorption and removal capabilities for organic pollutants, thereby enhancing water quality.

Various methods, including solvothermal, hydrothermal, vapor deposition, and sol-gel methods, are employed for the synthesis of Zn-MOFs, with solvothermal being the most commonly used. However, these methods face challenges such as low product purity, poor stability, and high cost. Therefore, there is a need for further improvement and optimization of the synthesis methods for Zn-MOFs to enhance product quality and stability while reducing costs. This optimization is crucial to facilitate the application of Zn-MOFs in the field of environmental pollution governance.

The study of the adsorption performance of Zn-MOFs in environmental pollution reveals their effectiveness in efficiently adsorbing and removing organic pollutants and heavy metal ions from water, thereby enhancing water quality. Additionally, Zn-MOFs serve as photocatalysts, facilitating the removal of organic pollutants and heavy metal ions from water through photocatalytic reactions. However, the photocatalytic performance of Zn-MOFs faces challenges such as low photocatalytic efficiency and poor stability. Therefore, further optimization of the photocatalytic performance of Zn-MOFs is necessary to enhance their stability and efficiency, expanding their applications in the field of environmental pollution governance.

The research into the degradation performance of Zn-MOFs in environmental pollution indicates that these materials can degrade organic pollutants into harmless

substances through catalytic oxidation, photo-catalysis, and other reaction mechanisms. This degradation process effectively removes organic pollutants and heavy metal ions from water, thereby improving water quality. The tunable pore structure and chemical properties of Zn-MOFs provide ample opportunities for its application in degradation reactions. However, the application of Zn-MOFs in degradation reactions encounters challenges such as the stability, activity, and selectivity of the catalyst. Therefore, there is a need for further refinement and optimization of the preparation methods and application conditions of Zn-MOFs to enhance its degradation performance and stability, broadening their applications in environmental pollution governance.

In summary, Zn-Metal Organic Frameworks (MOFs) emerge as a novel class of adsorption materials with broad prospects in environmental pollution governance. However, its synthesis methods and applications still face several challenges that require further refinement and optimization. Moving forward, there is a need for extensive exploration of Zn-MOFs in environmental pollution governance, with a focus on enhancing its adsorption and photo-catalytic performance. This endeavor aims to contribute innovative perspectives and methodologies to advance environmental pollution governance.

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