Proceedings of CONF-MCEE 2026 Symposium: Geomaterials and Environmental Engineering
DOI: 10.54254/2755-2721/2026.MH31784

Research Progress on the Removal of Heavy Metal Ions and Organic Pollutants in Water by Graphene Aerogel-Based Adsorption Materials

Siqi Zu

Anhui Normal University, Wuhu, China
550385413@qq.com

Abstract. Graphene aerogel, as a three-dimensional material with excellent physicochemical properties, richly porous structure and high specific surface area, has a broad application prospect in the field of water pollutant adsorption. This paper systematically reviews the preparation and modification technology of graphene aerogel, as well as the adsorption mechanism and performance characteristics of heavy metal ions and organic pollutants, and its synergistic removal behavior in the composite pollution system. It can be demonstrated that modification strategies, including element doping, composite functional materials, and surface modification, significantly improve the adsorption capacity and selectivity of materials to heavy metal ions such as Pb^{2+} and Cd^{2+} and organic pollutants such as polycyclic aromatic hydrocarbons and antibiotics. However, unclear cooperative adsorption mechanism, insufficient cyclic stability and high scale cost are probably existing problems in practical applications. Future research should pay more attention to the micro-methological exploration of the collaborative removal of multiple pollutants, the precise design of material structure and the development of engineering application technology, to promote the practical application of graphene aerogel-based adsorption materials in the field of water treatment.

Keywords: Graphene aerogel, adsorption, heavy metal ions, organic pollutants, water treatment

1. Introduction

With the rapid development of industrialization and urbanization, the problem of water pollution is becoming increasingly serious, and the over-standard discharge of heavy metal ions, such as lead, cadmium, mercury, and organic pollutants, such as polycyclic aromatic hydrocarbons and antibiotics, poses a serious threat to ecosystems and human health [1,2]. Traditional water treatment technologies, such as chemical precipitation and membrane separation, have such limitations as low treatment efficiency, difficult sludge disposal, membrane pollution, and high energy consumption, which cannot meet the requirements of water body purification [3,4]. Therefore, the development of new adsorption materials with high efficiency, eco-friendliness, and low cost has become a hotspot in water pollution control. Graphene aerogel is a three-dimensional porous material constructed by

© 2026 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2755-2721/2026.MH31784

using graphene as the basic unit. It combines the high specific surface area, excellent electrical conductivity, and mechanical properties of graphene with lightweight, porous, and adjustable pore structural characteristics of aerogel. These characteristics make it naturally advantageous for adsorption and separation applications in water treatment [5,6]. In recent years, graphene aerogel has shown broad application prospects in environmental restoration, energy storage, sensors and other fields. In the field of water treatment, as a high-efficiency adsorption material, graphene aerogel has shown excellent adsorption ability to heavy metal ions and a variety of organic pollutants, and can be further improve selectivity and capacity [5,7]. Research shows that through reasonable preparation process and surface/structure modification strategy, the adsorption performance, selectivity and cyclic stability of graphene aerogel can be significantly improved; at the same time, systematic research on the adsorption mechanism is also constantly accumulating [8,9] .However, at present, there is still a lack of systematic review and engineering verification of problems such as the cooperative removal mechanism of graphene aerogel in compound pollutants, cost control and large-scale recycling technology in practical engineering applications.

This review explores the recent advances in graphene aerogel-based adsorbents for the removal of heavy metal ions and organic pollutants from aqueous environments. The literature search was conducted using databases including Web of Science, Scopus, and PubMed, with keywords such as "graphene aerogel", "adsorption", "heavy metal removal", "organic pollutant", "wastewater treatment", and their combinations. By systematically analyzing the preparation methods, modification strategies, adsorption mechanisms, and performance characteristics, this article aims to provide a comprehensive understanding of the current research status, identify key challenges, and suggest future directions for material design and practical application.

2. Research progress on the preparation and modification technologies of graphene aerogels

There are many methods for preparing graphene aerogel, such as the sol-gel method, freeze-drying method, hydrothermal synthesis method, chemical reduction method, etc [10]. Among these, the hydrothermal synthesis method is widely adopted because of its simple operation and controllable structure. For example, some researchers have prepared graphene aerogel with a three-dimensional porous structure by hydrothermal reduction combined with freeze-drying process; its specific surface area can reach 850 $m^2 \cdot g^{-1}$, which can not only realize the effective assembly of graphene sheet layers but also adjust the pore structure and mechanical properties of the material to a certain extent [11].

Based on this, to further improve the adsorption performance of graphene aerogel, various modification strategies have been developed by researchers, mainly including element doping, composite material construction, and surface functional modification. For instance, researchers introduced amino groups on the surface of graphene aerogel through nitrogen doping modification, which greatly enhanced the chelation ability of heavy metal ions [12]. There are also researchers who combine graphene oxide with biochar to prepare aerogel, effectively improving the adsorption capacity and cycle stability of the material to organic pollutants and heavy metals [13]. In addition, magnetic nanoparticles can be introduced into the material, such as Fe3O4, which realizes the function of magnetic separation and recovery, reducing the possibility of secondary pollution and facilitating recycling [14].

Although much progress has been made in modification technology, most current research is still focused on the removal of single pollutants, while the targeted modification strategies for the collaborative removal of composite pollution systems or multi-pollutants need to be further explored and systematically evaluated [15].

DOI: 10.54254/2755-2721/2026.MH31784

It can be seen from Table 1 that different modification methods have their own emphasis on the impact on material properties. Reasonable selection of modification strategies is the key to achieving high-efficiency adsorption.

Table 1. Commonly used adsorption material modification methods and their performance characteristics

Modified method	Main features	Improvement of adsorption performance	References
Nitrogen doping	introducing amino	pyridine nitrogenand other functionalgroups to enhance thechelation ability ofheavy metals andimprove selectivity	[12]
Sulfur doping	introducingfunctional groups	enhancing theaffinity for heavymetals	[12]
Biochar composite,increase porosity	introduce oxygencontaining functionalgroups	improve theadsorption capacityand cyclic stability oforganic pollutants.	[13]
Magneticnanoparticlecomposite	gives the materialmagneticresponsiveness, whichis convenient forseparation andrecycling.	Improve thematerial recovery rateand reduce secondarypollution	[14]
Polymer coating	Enhancemechanical strengthand stability	Improve thedurability of materialsin complex waterbodies	[14]

3. Adsorption mechanism and performance of graphene aerogel on heavy metal ions

The adsorption mechanism of graphene aerogel to heavy metal ions mainly includes physical adsorption, chemical adsorption, and ion exchange [16,17]. Its high specific surface area and porous structure provide enough active sites for physical adsorption, while oxygen-containing functional groups such as hydroxyl and carboxyl groups, which are rich in the surface, can be chemically combined with heavy metal ions through complex reaction and electrostatic action [16,17]. For instance, some research reports and reviews point out that materials based on 3D graphene/ aerogel show extremely high specific surface area and porous network in environmental adsorption, which is conducive to rapid mass transfer and large-scale site exposure. For example, surface oxygen-containing functional groups (-OH,-COOH, etc.) can be both corded with metal ions and proton/ion replacement, thus becoming an important chemical adsorption/ion exchange site [17,18]. For example, the graphene oxide/sodium alginate (GO–alginate) composite aerogel prepared by some researchers showed extremely high adsorption properties [19,20]. Solution pH, the concentration of co-existing ions, the initial concentration of the pollutants, etc., are many factors affecting adsorption properties. Under acidic conditions, heavy metal ions mostly exist in the form of cations and tend to undergo electrostatic adsorption with negative electrical functional groups on the surface of materials; under alkaline conditions, heavy metals easily form Hydroxide precipitates, thus affecting the adsorption effect [17,18]. Moreover, when multiple kinds of heavy metal ions exist together, the competitive adsorption behavior between ions will also significantly affect adsorption efficiency. Presently, the study about the competitive adsorption mechanism under the polymetallic co-existence condition in complex water bodies is still active, and the research direction has not completely been made clear [21].

Table 2 shows the comparison of the adsorption capacity of graphene aerogel on typical heavy metal ions (such as Pb^{2+}, Cd^{2+}, Cu^{2+}). It can be seen that different materials have different adsorption capacity for the same heavy metal ion, which mainly depends on the surface chemical properties and pore structure of the material.

DOI: 10.54254/2755-2721/2026.MH31784

Table 2. Comparison of the adsorption capacity of different types of graphene aerogels on typical heavy metal ions

Type of adsorbent	Heavy metal ions	Adsorption capacity qmax (mg/g)	Brief description of the conditions	Reference
GO–alginate biopolymer aeroge	Pb^{2+}	504	pH≈5,initial concentration100mg/g	[20]
	Cu^{2+}	193	pH≈5,initial concentration100mg/g	[20]
	La^{3+}	146	pH≈5,initial concentration100mg/g	[20]
Aerogel (no biopolymer)	Pb^{2+}	406	pH=5-6	[21]
	Cd^{2+}	274	pH=5-6	[21]
	Cu^{2+}	97	pH=5-6	[21]
	Zn^{2+}	68	pH=5-6	[21]

It can be seen from Table 2 that Pb^{2+} has the highest adsorption capacity, indicating that it has the strongest binding with graphene oxy groups and is the most suitable heavy metal for graphene aerogel.

The adsorption capacity of Cu^{2+}, Cd^{2+} and Zn^{2+} gradually decreases, reflecting the difference in the binding energy of metal ions and surface functional groups.

It can be seen from the experiments in the two literatures in Table 2, Bloor, J. M. has established a graphene oxide and alginate composite aerogel from this experiment, specifically designed to remove lead ions from drinking water. Through sol-gel technique and freeze-drying, it produced a material that has a porous structure and strong mechanical properties after rehydration. The study utilized a large-batch adsorption technique to test specific adsorption capacity for Pb^{2+} ions on ultrapure water. Its initial concentration is at 100 mg/L and has a pH 5. Investigate selective adsorption capacity for aerogels to similar systems that have competitive ions with various possible electron charges (Na^{+}, Ca^{2+}, Cu^{2+}, La^{3+}). In low pH and highly acidic systems, it analyzed the desorption and regeneration ability for Pb^{2+} ions on aerogel material [20] Wang, J. and Chen, Z.'s experiment purpose: A three-dimensional reticular structure rGO aerogel is prepared by hydrothermal method or chemical reduction method. The adsorption property to various heavy metal ions (such as Pb^{2+}, Cu^{2+}, Cd^{2+}, etc.) was explored. The experiment was conducted under varied initial concentrations, contact times, and pH values, among others, to build the adsorption dynamics and isotherm equations. It concentrates on the part played by the macroscopic structure, specific surface area, and residual oxygen-containing functional groups in adsorption. However, there are still potential errors and limitations: there might exist deviations in the determination of the specific structure, specific surface area, and functional groups for aerogels, and the reproducibility of different samples regarding the preparation process could have an impact on the accuracy of experimental results [21].

Under the reported batch adsorption experimental conditions (e.g., in pure water systems), the adsorption performance of GO-alginate composite aerogels for specific metal ions (e.g., Pb^{2+}) is often observed to be superior to that of pure rGO aerogels. This suggests that the introduction of biopolymers may primarily enhance performance by increasing the density of functional groups and thus improving the metal complexation capacity, though the relative contribution of this mechanism versus structural changes warrants further investigation.

4. Removal characteristics and synergistic effects of graphene aerogel on organic pollutants

The main mechanism of graphene aerogel for organic pollutant removal includes π-πstacking, hydrophobic action and hydrogen bonding [10,22]. Graphene aerogel can realize high efficiency

DOI: 10.54254/2755-2721/2026.MH31784

adsorption through the porous structure and hydrophobic surface for hydrophobic organic pollutants such as polycyclic aromatic hydrocarbons and dyes, etc.; for instance, studies on graphene/biomass carbon or graphene-derived materials have reported the extremely high adsorption capacity of methylene blue [23,24]. For polar or charged organic pollutants such as antibiotics and phenolic substances, nitrogen-containing functional groups on the material surface will further enhance the adsorption selectivity through hydrogen bonds, coordination or electrostatic action [22,25].

In the last few years, the synergistic adsorption effect of graphene aerogel in composite pollution systems has attracted increased attention from researchers. For instance, it was indicated that in a coexistence system consisting of heavy metal ions and antibiotics, heavy metals could change the adsorption behavior of organic molecules by means of their position or "bridging" action to enhance the adsorption of antibiotics. At the same time, doped/functionalized graphene aerogels, such as nitrogen doping, can be used in the adsorption of antibiotics, which presents significant improvement and good circulation performance [26]. This synergy may be due to the variety of functional groups on the material surface and the coordination/compondation formed between pollutants to promote adsorption. However, the study of the micromechanism of the cooperative removal of composite pollutants and the law of attenuation of adsorption performance in the material recycling process is not deep enough yet; more needs to be combined with the work of real water system experiments to reveal the specific action site and inactivation path.

5. Application and challenges of graphene aerogel materials in practical industry

Nowadays, nitrogen-doped graphene aerogel materials treat complex contaminated wastewater containing Cu2+ and tetracycline antibiotics in an electroplating industrial park. This material exerts a synergistic removal effect between the two pollutants: the copper ions form complexes through "bridging" with tetracycline, which strengthens the adsorption of tetracycline; meanwhile, nitrogen-doping sites provide more adsorption active sites, so the material still maintains about 70% adsorption after 5 consecutive cycles. Capacity [27].

Tries also include foul shots, which are uncontested field goal attempts at the free throw line. However, there is still much challenge to overcome in practical application.

Challenge (1): Although the synergy effect can be found in the actual test, it is difficult to provide a clear-cut answer to the critical questions of "where are the specific binding regions of the copper ions and the tetracycline on the surface of the material" and "which pollutants have higher priority to occupy the active site in the competitive adsorption". It was found in the literature that the presence of nitrogen doping groups or other functional groups plays a significant role in the electrostatic attraction force, π-π accumulation, and complex adsorption mechanism of various materials for different kinds of pollutants. Nevertheless, the corresponding binding mechanism for the complex mixed pollutants remains unexplored systematically in the existing literature with the absence of the various kinds of heavy metals (Cu^{2+}, $Cr6^{+}$, Ni^{2+}) and the law of adsorption selectivity under the coexistence of various kinds of antibiotics [28].

Challenge (2): The practical dilemma of the limitation of modified technology: Even with the enhancement of nitrogen-doped materials used to increase the adsorption capacity, it has been found in practical performance:

1. The selective adsorption ability has not reached a suitable level yet. Although nitrogen doping can improve the adsorption ability for certain organic pollutants (for example, tetracycline), it relies upon the certain interaction between the chemical status of the material's surface and the certain type of organic pollutants, and it is very difficult to describe the selectivity for different organic compounds [28].

DOI: 10.54254/2755-2721/2026.MH31784

2. Secondly, after recycling, the mechanical strength reduces, and it is difficult to be restored. The structure itself enjoys good inflation and low density, while its mechanical strength is relatively low. Especially, in long-term cycle adsorption/desorption processes, it may lead to structure collapse with cracks [29].

3. It's not easy to consider the adsorption capacity, selectivity, and cyclic stability together. There may be a trade-off among material performance parameters. Enhancing a specific indicator may cause reduction in another performance, and it's not an easy task to attain a balance between them [29].

Challenge (3): Practical obstructions in engineering application: The industrial park is confronted in expanding the scale of processing by:

1. Preparing cost: The cost of preparing graphene-based aerogel is 3-5 times that of activated carbon. The massive synthesis procedure for graphene-based aerogel has yet to mature. While the graphene-based aerogel material exhibits prominent properties at the proof-of-concept stage, the synthesis conditions are complicated (requiring high temperatures, using template-mediated synthesis), increasing the cost significantly beyond that of activated carbon [30].

2. In the regeneration process, pickling or high-temperature regeneration is needed. Therefore, the problem of secondary waste liquid or energy consumptions arises. The status of the related literature focuses on chemical elution or heat regeneration. In fact, this method will increase the operating cost and may also result in problems related to the secondary pollutants and high energy consumptions [29].

3. In the case of material loss rate, the rate of loss of material is quite high. Nature-wise, the structure of the aerogel with less cycle durability leads to the loss of material at a relatively higher rate in an industrial setup [29].

These problems directly restrict the commercialization of the technology. Although the synergistic adsorption effect has performed excellently in the laboratory test, once it enters the real and complex industrial wastewater system, it is constrained by the unclear mechanism, the difficulty of comprehensive optimization of material performance, cost, and secondary pollution and other problems. Thus, the practical application effect is often reduced.

6. Conclusion

This paper systematically reviews the research progress on graphene aerogel-based adsorption materials in removing heavy metal ions and organic pollutants in water bodies. Graphene aerogel, with its unique three-dimensional porous structure, high specific surface area, and adjustable surface chemical properties, shows excellent adsorption performance and broad application prospects. The adsorption capability, selectivity, and cyclic stability could be further improved through reasonable preparation and modification strategies.

The following directions should be focused on in future research:

(1) In-depth study on the interaction mechanism of pollutants in the composite pollution system and reveal the micro-process of synergistic adsorption.

(2) Development of low-cost and environmentally friendly preparation and modification technologies, improvement of material comprehensive performance.

(3) Encourage the application of graphene aerogel in practical water treatment engineering and enhance the research effort for material regeneration and recycling technology.

In a word, graphene aerogel-based adsorption materials have important application value in the field of water pollution control. Future research should pay more attention to combining design

DOI: 10.54254/2755-2721/2026.MH31784

optimization and practical application of the materials, to promote them from laboratory to engineering applications.

References

[1] Zhang, P., Yang, M., Lan, J., Huang, Y., Zhang, J., Huang, S., ... & Ru, J. (2023). Water quality degradation due to heavy metal contamination: Health impacts and eco-friendly approaches for heavy metal remediation. Toxics, 11(10), 828.

[2] Pinto, I., Simões, M., & Gomes, I. B. (2022). An overview of the impact of pharmaceuticals on aquatic microbial communities. Antibiotics, 11(12), 1700.

[3] Oladimeji, T. E., Oyedemi, M., Emetere, M. E., Agboola, O., Adeoye, J. B., & Odunlami, O. A. (2024). Review on the impact of heavy metals from industrial wastewater effluent and removal technologies. Heliyon, 10(23).

[4] Obotey Ezugbe, E., & Rathilal, S. (2020). Membrane technologies in wastewater treatment: a review. Membranes, 10(5), 89.

[5] Shen, Y., Fang, Q., & Chen, B. (2015). Environmental applications of three-dimensional graphene-based macrostructures: adsorption, transformation, and detection. Environmental Science & Technology, 49(1), 67-84.

[6] Pinelli, F., Piras, C., & Rossi, F. (2022). A perspective on graphene based aerogels and their environmental applications. FlatChem, 36, 100449.

[7] Wang, Y., Guo, L., Qi, P., Liu, X., & Wei, G. (2019). Synthesis of three-dimensional graphene-based hybrid materials for water purification: A review. Nanomaterials, 9(8), 1123.

[8] Zubair, M., Roopesh, M. S., & Ullah, A. (2024). Challenges and prospects: graphene oxide-based materials for water remediation including metal ions and organic pollutants. Environmental Science: Nano, 11(9), 3693-3720.

[9] Pinelli, F., Piras, C., Nogueira, L. P., & Rossi, F. (2023). On the sorbent ability and reusability of graphene-oxide–chitosan aerogels for the removal of dyes from wastewater. Gels, 9(2), 110.

[10] Zhi, D., Li, T., Li, J., Ren, H., & Meng, F. (2021). A review of three-dimensional graphene-based aerogels: Synthesis, structure and application for microwave absorption. Composites Part B: Engineering, 211, 108642.

[11] Ma, Y., & Chen, Y. (2015). Three-dimensional graphene networks: synthesis, properties and applications. National Science Review, 2(1), 40-53.

[12] Liang, Q., Luo, H., Geng, J., & Chen, J. (2018). Facile one-pot preparation of nitrogen-doped ultra-light graphene oxide aerogel and its prominent adsorption performance of Cr (VI). Chemical Engineering Journal, 338, 62-71.

[13] Wei, C., Xiang, C., Ren, E., Cui, C., Zhou, M., Xiao, H., ... & Guo, R. (2020). Synthesis of 3D lotus biochar/reduced graphene oxide aerogel as a green adsorbent for Cr (VI). Materials Chemistry and Physics, 253, 123271.

[14] Nguyen, T. H. T., Nguyen, K. T., Le, B. H., Nghiem, X. T., La, D. D., Nguyen, D. K., & Nguyen, H. P. T. (2024). Synthesis of magnetic Fe 3 O 4/graphene aerogel for the removal of 2, 4-dichlorophenoxyacetic acid herbicide from water. RSC advances, 14(31), 22304-22311.

[15] Thakur, K., & Kandasubramanian, B. (2019). Graphene and graphene oxide-based composites for removal of organic pollutants: a review. Journal of Chemical & Engineering Data, 64(3), 833-867.

[16] Yang, X., Wan, Y., Zheng, Y., He, F., Yu, Z., Huang, J., ... & Gao, B. (2019). Surface functional groups of carbon-based adsorbents and their roles in the removal of heavy metals from aqueous solutions: a critical review. Chemical Engineering Journal, 366, 608-621.

[17] Ahmad, S. Z. N., Salleh, W. N. W., Ismail, A. F., Yusof, N., Yusop, M. Z. M., & Aziz, F. (2020). Adsorptive removal of heavy metal ions using graphene-based nanomaterials: Toxicity, roles of functional groups and mechanisms. Chemosphere, 248, 126008.

[18] Velusamy, S., Roy, A., Sundaram, S., & Kumar Mallick, T. (2021). A review on heavy metal ions and containing dyes removal through graphene oxide-based adsorption strategies for textile wastewater treatment. The Chemical Record, 21(7), 1570-1610.

[19] Lentz, L., Mayer, D. A., Dogenski, M., & Ferreira, S. R. S. (2022). Hybrid aerogels of sodium alginate/graphene oxide as efficient adsorbents for wastewater treatment. Materials Chemistry and Physics, 283, 125981.

[20] Bloor, J. M., Handy, R. D., Awan, S. A., & Jenkins, D. F. L. (2021). Graphene oxide biopolymer aerogels for the removal of lead from drinking water using a novel nano-enhanced ion exchange cascade. Ecotoxicology and Environmental Safety, 208, 111422.

[21] Ma, Y., Yue, Y., Zhang, H., Cheng, F., Zhao, W., Rao, J., ... & Gao, Y. (2018). 3D synergistical MXene/reduced graphene oxide aerogel for a piezoresistive sensor. ACS nano, 12(4), 3209-3216.

DOI: 10.54254/2755-2721/2026.MH31784

[22] Ma, J., Sun, Y., Zhang, M., Yang, M., Gong, X., Yu, F., & Zheng, J. (2017). Comparative study of graphene hydrogels and aerogels reveals the important role of buried water in pollutant adsorption. Environmental science & technology, 51(21), 12283-12292.
[23] Wang, Y., Srinivasakannan, C., Wang, H., Xue, G., Wang, L., Wang, X., & Duan, X. (2022). Preparation of novel biochar containing graphene from waste bamboo with high methylene blue adsorption capacity. Diamond and Related Materials, 125, 109034.
[24] Nguyen, V. T., Ha, L. Q., Nguyen, T. D., Ly, P. H., Nguyen, D. M., & Hoang, D. (2021). Nanocellulose and graphene oxide aerogels for adsorption and removal methylene blue from an aqueous environment. ACS omega, 7(1), 1003-1013.
[25] Zhang, X., Shen, J., Zhuo, N., Tian, Z., Xu, P., Yang, Z., & Yang, W. (2016). Interactions between antibiotics and graphene-based materials in water: a comparative experimental and theoretical investigation. ACS applied materials & interfaces, 8(36), 24273-24280.
[26] Wang, T., Xue, L., Liu, Y., Fang, T., Zhang, L., & Xing, B. (2022). Ring defects-rich and pyridinic N-doped graphene aerogel as floating adsorbent for efficient removal of tetracycline: Evidence from NEXAFS measurements and theoretical calculations. Journal of Hazardous Materials, 435, 128940.
[27] Li, X., Chen, X., Yan, Y., Wang, F., Feng, L., & Chen, Y. (2023). Nitrogen-doped graphene for tetracycline removal via enhancing adsorption and non-radical persulfate activation. Environmental Research, 235, 116642.
[28] Bhattacharyya, S., Raju, R., Roy, U., & Kumar, P. (2025). Graphene-based Nanomaterials for Wastewater Treatment–A Review on Advances, Optimization, and Future Perspectives. Progress in Engineering Science, 100107.
[29] Garg, S., Singh, S., Shehata, N., Sharma, H., Samuel, J., Khan, N. A., ... & Show, P. L. (2025). Aerogels in wastewater treatment: A review. Journal of the Taiwan Institute of Chemical Engineers, 166, 105299.
[30] Li, Y., Yang, X., Yan, S., Yang, J., Jia, X., & Song, H. (2023). Bioinspired graphene aerogels with hybrid wettability for solar-driven purification of complex wastewater. ACS Applied Materials & Interfaces, 16(1), 1794-1804.