Meteorological and Environmental Research 2024, 15(4): 52 - 53, 57

Research Progress and Prospects of Traceability Methods of Organic Matter in Lake Sediment

Jing LIU[1], **Zhuolin LI**[2], **Yousong MA**[1*]

1. Hebei Provincial Academy of Ecological Environmental Science, Shijiazhuang 050037, China; 2. Tianjin Tianbin Tongsheng Environmental Technology Co., Ltd., Tianjin 300000, China

Abstract Organic matter in sediment is an important carrier of energy and material circulation in ecosystems, and also provides an important place for the accumulation of nutrient salts. The study of its composition, structure and characteristics is of great importance for the study of the geochemical cycle of sediment in water environment. Identifying the source of organic matter in sediment and mastering its temporal and spatial distribution characteristics are important ways to reveal the migration and transformation law of pollutants, which is conducive to controlling nutrient load from the source and providing strong technical support for the fine management of water environment.

Key words Sediment; Organic matter; Traceability

DOI 10.19547/j.issn2152 - 3940.2024.04.014

Sediment, which is an important carrier to study the characteristics of lake environmental evolution and an important way to explore the information of lake history, provides space for the exchange of matter and energy in a lake, and is the connection point of important links in the ecosystem. A large number of studies have shown that internal and external pollution are the main factors affecting lake water quality, but internal pollution has become an important factor affecting lake water quality under the premise of effective control of external pollution. A large amount of carbon, nitrogen, phosphorus and other elements are gathered in sediments. As more active chemical elements, they play a certain role in various biochemistry and geochemistry, and also affect the migration and transformation of pollutants. Under the influence of different temperature, meteorological, hydrodynamic and biological factors, the pollutants in the sediment are released into the upper water body again through diffusion, convection, suspension and other ways, causing the internal factors of lake water pollution.

Organic matter in sediment comes from complex sources, and has different forms, structures, humification degrees, and different impacts on the environment. At present, China has achieved relatively remarkable results in water pollution control, but some rivers and lakes still have problems of COD exceeding the standard and water eutrophication. In view of the current problems such as large spatial differences in sediment, difficult identification of pollution sources, and incomplete treatment. In this paper, in order to achieve legal, accurate and scientific pollution control, the traceability method of organic matter in sediment will be studied to provide technical support for the fine management of water environment[1-2].

1 Sources of organic matter in sediment

Endogenous decomposition and exogenous input are the main sources of organic matter in sediment. Endogenous decomposition mainly refers to the decomposition of residues by animals, plants, plankton and microorganisms. Exogenous input mainly refers to the organic matter carried by external water supply, which is greatly affected by temperature and precipitation.

2 Methods for tracing organic matter in sediment

2.1 Stable isotope technology Stable isotopes refer to a series of nuclides with stable nuclear structure, with or without radioactive decay and extremely long half-life, and exist stably in the process of migration and reaction, which greatly reduces the problem of easy falling off caused by the use of external tracers. It is simple to operate, and the results are accurate, so it is widely used in geochemistry, sedimentology, biology, ecology and other fields. Lakes are important carbon sinks in river basins, where a large amount of organic matter are stored, providing an ideal carrier for the study of the source and change of organic matter by using stable isotope tracer of carbon and nitrogen. During the diagenetic process of organic matter in sediment, microbial degradation results in the change of its original molecular composition and the loss of a large amount of organic matter, but the effect on $\delta^{13}C$ is small, accounting for less than 2‰ of the total change of organic carbon isotope. Therefore, $\delta^{13}C$ in sediment preserves important features of organic matter and has been widely used in the study of lake sediment.

The sources of organic matter in lake sediment are complex, and many scholars have explored the different sources of organic matter by combining carbon and nitrogen isotopes with C/N ratio. In general, the C/N of terrestrial higher plants, soil organic mat-

---

Received: July 3, 2024 Accepted: August 16, 2024

* Corresponding author.

ter, aquatic organisms, phytoplankton, and algae is above 15, 10 – 13, 2.8 – 3.4, 6 – 13, and 5 – 14[3].

The above methods can only qualitatively assess the sources of organic matter in sediment, and different mathematical models, such as multivariate mixed model and Bayesian mixed model, are combined to assess the contribution rate of different sources.

2.2 Biomarker method Biomarkers are compounds with certain characteristics of biological sources, which can be preserved well in sediment even if the environment changes. They are originally applied to the traceability of marine sediment, and have been widely used in the estuary and inland environments in recent years. The sources are analyzed by establishing the relationship between different land use types and organic matter in sediment. Commonly used biomarkers include protein, carbohydrate, lipid and lignin, among which lipid biomarkers are the most widely used.

n-alkanes are stable in structure, and their degradation rate is one quarter of that of organic matter in sediment. They are one of the most common lipid biomarkers in land plants, plankton and aquatic plants. The maximum carbon number (Cmax) is used to characterize organic matter from different sources. Short-chain n-alkanes ($<C_{20}$) are mainly synthesized by bacteria, plankton and algae, in which C_{15}, C_{17} and C_{19} n-alkanes are the most abundant, and C_{17} n-alkanes mainly represent algae and photosynthetic bacteria. Middle-chain n-alkanes ($C_{20}-C_{25}$) are usually dominated by submerged and floating macroplants, in which C_{21}, C_{23} and C_{25} n-alkanes are the most abundant. Long-chain n-alkanes ($C_{25}-C_{35}$) are mainly terrestrial carbon sources, and they are generally dominated by odd homologous species, in which C_{27}, C_{29} and C_{31} are abundant. C_{27} and C_{29} n-alkanes are mainly synthesized by deciduous trees/shrubs, while C_{31} and C_{33} n-alkanes are mainly synthesized by herbaceous plants. Liu Chenyu analyzed the content of n-alkanes and composition characteristics of sediment in four different habitats (river, lake, fish pond, lotus pond) of Baiyang Lake, and analyzed the sources and evolution of organic matter in the sediment based on principal component analysis-multiple linear regression (PCA-MLR) model. The organic matter of sediment in the fish pond and lotus pond was mainly from algae and lower aquatic organisms, while the organic matter of river sediment was mainly from higher terrestrial plants. In the sediment of open lakes, the proportion of different organic matter sources was 33.0% for lower aquatic organisms, 26.2% for higher aquatic plants and 40.8% for higher terrestrial plants. In addition, fatty acids, sterols, alkanols and other lipid markers can also be used to characterize the sources of organic matter in sediment. Biomarker method is simpler and consumes less time than isotope analysis, but it requires special instruments for extraction and determination. In addition, many biomarkers exist at trace levels that may affect the accuracy of identification[4].

2.3 Spectrotechnical method Pore water in sediment is an important medium for material exchange between sediment and overlying water. The composition and spectral characteristics of colored dissolved organic matter (CDOM) in the pore water can be analyzed by three-dimensional fluorescence spectroscopy and ultraviolet and visible spectroscopy, so as to further identify the source of organic matter in sediment.

Three-dimensional fluorescence spectrum data is a typical two-dimensional matrix data, with tens of thousands of spectral points in each spectrum, which can provide rich information, but similar components are prone to overlapping fluorescence peaks. It is needed to select a suitable feature extraction method to compute the data, identify and separate the overlapping fluorescence peaks, and calculate the relative content of each component. Common methods include parallel factor analysis, fluorescence region integration, self-organizing neural network and so on. Based on the trilinear decomposition theory, the parallel factor analysis method cluster spectral data by the alternating least squares principle to realize the separation of spectral matrix. By fluorescence regional integration, spectra can be divides into 5 regions, of which each region represents different types of organic matter, and different types of CDOM are quantified and characterized by calculating the standard volume and percentage of specific regions. Self-organized neural network, a kind of unsupervised neural network algorithm, can use input feature vector for reasonable distinction, and use the self-organized network weight to characterize the characteristics and content of each component. Ultraviolet and visible technology is used as a supplement to three-dimensional fluorescence spectroscopy to characterize CDOM components, and commonly used indices include a254, spectral slope ratio S_r, E_2/E_3, *etc*[5].

3 Outlook

(1) The structure and source of organic matter in sediment are complex, and the components that can be identified at present are very limited, but there are still many components to be identified. The method introduced in this paper can only analyze its composition qualitatively or semi-quantitatively, and it is difficult to extract and identify a single component accurately. In order to obtain a more accurate analysis, it is necessary to separate organic matter by chemical analysis methods, and obtain high-resolution molecular information by combining Fourier infrared spectroscopy, Fourier transform ion cyclotron resonance mass spectrometry, nuclear magnetic resonance and other means to obtain more detailed chemical structure, so as to more accurately reveal the sources and chemical composition of organic matter.

(2) The sources of exogenous pollution are extensive, and sewage treatment plants, industrial enterprises, agricultural and rural sources, *etc.* will have an impact on lake sediment. In combination with factors such as bedrock properties, soil types and hydrological conditions, by means of isotopic tracer, ultraviolet, fluorescence spectrum and mass spectrometry, it is needed to establish exogenous databases, list suspected pollutants, and manage the obtained information in a unified manner, so as to reduce unnecessary duplication of work and provide reliable basic data for the tracing of lake sediment and technical support for the management department for accurate and scientific pollution control.

(To page 57)

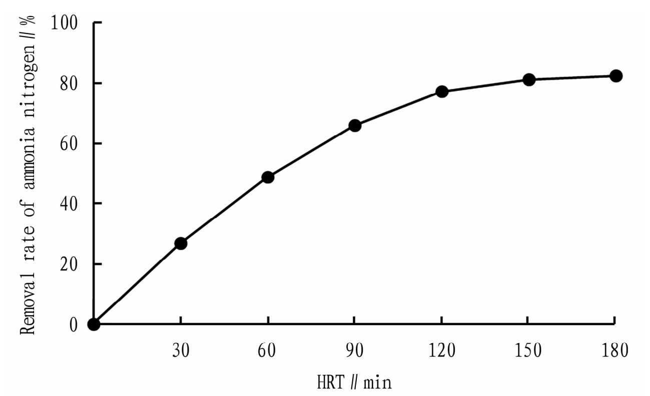

Fig. 7 Removal rate of ammonia nitrogen under the optimal condition

2.8 Removal rate of total phosphorus under the optimal condition When the pH of the wastewater was 7, the PMS dosage was 0.15 mmol/L, the MBs intake volume was 15 ml/min, the current intensity was 15 A, and the iron – carbon mass ratio was 1 : 1, the changes in total phosphorus removal rate were shown in Fig. 8. From Fig. 8, it can be seen that when the HRT was 30 min, the total phosphorus removal rate in the wastewater was 25.68%. However, with the increase of HRT, the removal rate of total phosphorus showed a significant upward trend. When HRT was extended to 120 min, the removal rate of total phosphorus increased significantly to 73.58%, indicating the importance of HRT in improving the efficiency of total phosphorus removal.

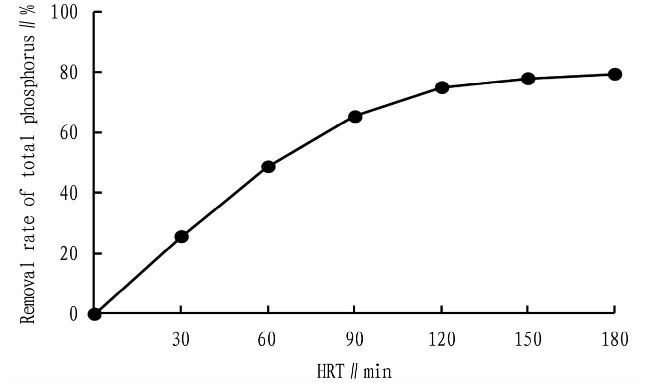

Fig. 8 Removal rate of total phosphorus under the optimal condition

2.9 Economic analysis According to the experiment, the treatment of rural domestic sewage by the micro-electrolysis + micro-nano bubbles coupled with peroxymonosulfate can achieve water quality standards. According to the experimental estimation, the main operating costs included the power consumption of the sewage lift pump, micro-nano bubble generator, and micro-electrolysis DC charger, which was approximately 0.6 kW · H/m^3. Calculated by 0.5 yuan/(kW · h) of electricity price, the electricity fee was 0.3 yuan/m^3. The dosage of reagent PMS was 0.1 kg/m^3. Calculated at 8 yuan/kg, the chemical cost was 0.8 yuan/m^3. Loss rate of micro-electrolysis packing was 25 g/m^3. Calculated at 2 yuan/kg, the consumables cost was 0.05 yuan/m^3. Therefore, the comprehensive operating cost was 1.15 yuan/m^3.

3 Conclusions

(1) When HRT was 120 min, the PMS dosage was 0.15 mmol/L, pH = 7, MBs intake volume was 15 ml/min, the current intensity was 15 A, and the iron – carbon mass ratio was 1 : 1, the removal rates of COD, ammonia nitrogen, and total phosphorus can reach 85.79%, 76.57%, and 73.58%, respectively.

(2) Without adjusting the pH value of the sewage, the micro-electrolysis + micro-nano bubbles coupled with peroxymonosulfate can achieve non-biochemical synchronous decarbonization, denitrification, and phosphorus removal of rural domestic sewage. The concentrations of COD, ammonia nitrogen, and total phosphorus in the effluent met the requirements of the first-level standard of the *Discharge Standard of Water Pollutants for Rural Domestic Sewage Treatment Facilities* (DB45T2413 – 2021), and the comprehensive operating cost was about 1.15 yuan/m^3.

References

[1] Proposal of the Central Committee of the Communist Party of China on formulating the 14th five-year plan for national economic and social development and the long-range objectives for 2035[N]. People's Daily, 2020.

[2] TU YH, HAO SL, WU T. Study on the treatment effect of rural decentralized domestic sewage treatment terminal[J]. Shandong Chemical Industry, 2021, 50(12): 256 – 258.

[3] TANG B, XU MZ, XU ZR, *et al.* Study of comparative analysis and applicability on treatment process of rural domestic sewage in Zhejiang Province[J]. Hubei Agricultural Sciences, 2016, 55(14): 3597 – 3600.

[4] MENG JX. Two-phase anaerobic pre-treatment process of wastewater from trimethylpropane plant[D]. Handan: Hebei University of Engineering, 2020.

[5] ZHANG DB, ZHANG H, ZHOU JY. Treatment of leachate from garbage by electric Fenton method[C]//Collection of Excellent Papers on Environmental Protection in China (2005) (II). 2005.

(From page 53)

References

[1] YANG R, LI L. Applications of stable carbon, nitrogen, and oxygen isotope techniques in aquatic environment and ecology[J]. Research of Environmental Sciences, 2022, 35(1): 191 – 201.

[2] WANG WJ, HOU XW, LIU JY, *et al.* Application and research progress of traditional stable isotope technology in environmental science [J]. Environmental Chemistry, 2021, 40(12): 3640 – 3650.

[3] CHEN X, LI Y, WAN YF, *et al.* Tracing the sources of sedimentary organic matter in Nanyue small water CHEN shed based on ^{13}C, ^{15}N and C/N[J]. Chinese Journal of Applied Ecology, 2021, 32(6): 1998 – 2006.

[4] LIU Q, PANG Y, XIANG S, *et al.* Distribution characteristics and source analysis of organic matter in surface sediments of Luoma Lake [J]. Chinese Journal of Environmental Science, 2019, 41(10): 4850 – 4856.

[5] LUO YQ, WAN ZW, YAN CX, *et al.* Spectral characteristics of dissolved organic matter in sediments from Poyang Lake[J]. Environmental Science, 2022, 43(2): 847 – 858.