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Study on the Photodegradation of Dissolved Organic Matter in Urban Water Bodies in Nanjing

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Abstract: *This paper reviews the DOM pollution of water resources in China, and complements the organic matter degradation characteristics of urban water bodies in Nanjing. In this study, the photodegradation experiment and UV-visible spectroscopy measurement of three types of water are conducted, analyzed and discussed around the degradation of DOC and aromatic substances, and the DOM degradation characteristics of different cities are studied. It can be identified in this study that urban water bodies near human living areas and non-circulation have higher DOM content and are less susceptible to decomposition, which is related to human needs and transformation of the environment and human daily activities.*

Keywords: *Dissolved organic matter; Light degradation; Urban water body; UV-visible spectra; Xuanwu Lake*

1. Introduction

1.1. Background of the study

1.1.1. Research findings on the prevention and control of water pollution in China

Given the layout and development of industrial activities along rivers and tributaries since the founding of the people's Republic of China [1], together with the unbridled consumption of fertilizers and uncontrolled discharge of sewage and water in some relatively backward areas, as well as the overpopulation of China, which has put increasing pressure on water pollution[2], China has become increasingly concerned about environmental pollution and water conservation [3].

1.1.2. Introduction to DOM

Dissolved Organic Matter (DOM), a group of organic mixtures of complex components, is of widespread origin and of complex structure, and is used to describe all organic compounds dissolved in water, usually as a heterogeneous mixture of hydrocarbons dissolved in water, acid or alkaline that can pass through a 0.45 μm filter membrane. It can be found in water ecosystems such as lakes, rivers and oceans and is an essential and active organic component of the water ecosystem. In addition, DOM links life-form and inorganic carbon and participates in the natural carbon cycle in water, and therefore has a major contribution to the water ecosystem. The structural characteristics of DOM in watersheds are highly dependent on its origin, climate and geographic location [4], and are influenced water conditions within the watershed [5,6].

1.1.3. Impact of water pollution on the DOM balance in water ecosystems

Water pollution is a critical issue in China. It is mainly organoleptic, organic, inorganic (often metals), toxic, eutrophic and oily water pollution that can have a significant impact on the material and energy flow in water. DOM is an active part of the river ecosystem, acting as a carrier of organic inorganic xenobiotics, and its composition influences the geochemical processes in the water environment to a certain extent [7]. Due to its xenobiotic-carrying capacity, DOM is an effective and carrier for many pollutants in the water environment, especially organic pollutants, and can be used as an agent or inhibitor of pollutants through physical, chemical or biological reactions [8]. Pollutant discharges can lead to high DOM concentrations and contribute to the growth of bacterial algae,

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aggravating the contamination of water [9, 10]. Even though some DOM can inhibit the environmental effects of pollutants, continued discharges and subsequent increases in DOM itself can negatively affect the water environment. If pollutants are promoted by sorption with DOM, the interaction between the two can create a vicious cycle that is environmentally sustainable.

1.1.4. Exploring the value of DOM research

In the water ecosystem, excessive emissions of DOM can adversely affect the ecosystem through photolysis [11], material use [12] and transport of pollutants. The study of the environmental and ecological effects of DOM has therefore contributed to the progress of environmental protection in China and worldwide. Furthermore, as water pollution is a growing challenge, the study of DOM is of increasing interest because it is a reactive mixture that can photodegrade itself and has an important influence on the photochemical processes of other pollutants in the water environment [13].

1.2. Literature Review

1.2.1. Analysis of the composition structure and sources of DOM in water in a specific region

The study of the nature and sources of DOM is the most developed in the current research on DOM in water. Such studies examine the optical properties of water and examine the differences in the photoreactivity and physical response of different sources of DOM [14], commonly using three-dimensional fluorescence spectroscopy - flat factor (EEM-PARAFAC) and UV-Vis absorption spectroscopy [15]. This research is carried out nationally and globally, as altitude affects the production and cycling of nutrients in lakes, and consequently the structure and properties of DOM [16]. Such studies are mostly focused on changes at the water interface and the impact of exogenous pollutants from human activities on water DOM. Current data show that pollution from human activities affects DOM in water, as towns and industries contribute land-based sources of DOM and nutrients to rivers [17]. It has also been found that the different sources of DOM in water, especially in rivers, are influenced by the season [18], the nature of the DOM [19] and the geological use [20, 21].

1.2.2. Environmental impacts of DOM

Studies on the solubility of organic matter in water have found that DOM can alter the solubility of certain pollutants in water, thereby increasing their material availability. The quantitative relationship between DOM and common contaminants in water is often used in equilibrium dialysis [22].

1.2.3. Main research methods

Most of the previous studies have involved filtration and freeze-drying techniques, however, the complex composition of DOM requires a variety of techniques to determine and process it, which is to say, a combination of techniques will be the future trend in DOM research. Typically, infrared spectroscopy, nuclear magnetic resonance, mass spectrometry, fluorescence analysis and various fluorescence spectroscopy techniques, such as fluorescence excitation spectroscopy, fluorescence emission spectroscopy, simultaneous fluorescence spectroscopy and three-dimensional fluorescence spectroscopy, are the main techniques available [23].

1.2.4. Research Vacancy

While much research has been undertaken on DOM, this paper focuses on the photodegradation characteristics of DOM in different water bodies in Nanjing. This is a topic that is missing from mainstream research. Likewise, specific inter-water characteristics and material gaps need to be added and the exogenous impacts of urban water are not to be underestimated so that research should be further elaborated.

1.3. Objectives of this Study

The results of this paper provide new insights into the photodegradation characteristics of different typical water bodies in Nanjing. In this study, the photodegradation of DOM in water was analysed by UV-visible absorption spectroscopy in three types of water bodies in Nanjing, namely, Xuanwuhu Lake, Zhenzhu River and the pond of the Nanjing Branch of Chinese Academy of Sciences. The results of this pilot study predicted that the aromatic content of water would vary from heavier to lighter in the small ponds of the Nanjing Branch of Chinese Academy of Sciences, the Xuanwuhu Lake and the Zhenzhu River, as the results for different water bodies would vary depending on the organic matter and water temperature conditions. The results of this study will contribute to the understanding of the

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characteristics of different water bodies in Nanjing and to the process of biochemical research.

2. Methodology and materials

2.1. Experimental materials

In this experiment, we used XPA-1 rotary photochemical reactor (Nanjing Xujiang Mechanical and Electrical Factory), 300 W mercury lamp, UV-Vis spectrophotometer (Shimadzu, UV-5100), filter,and stainless steel water collector for experimental operation.

2.2. Experimental method

Water samples were collected from Zhenzhu River (32°3′35″N, 118°47′34″E), Xuanwuhu Lake (32°3′41″N, 118°48′28″E) and the pond of the Nanjing Branch of Chinese Academy of Sciences (32°3′39″N, 118°48′1″E) in January 2023. The water samples were transported to the lab within 5 h for cold storage and filtered using a 0.45 μm membrane with a filter extractor. The samples were then irradiated with a 300 W mercury lamp using an XPA-1 rotating photochemical reactor (Nanjing Xujiang Mechanical and Electrical Factory) to simulate UV light for photodegradation experiments. The samples were collected at 0 h, 0.5 h, 1 h, 2 h, 4 h, 8 h, 12 h and 24 h, respectively, and the UV-visible spectra of the above samples were immediately determined using a UV-Vis spectrophotometer (Shimadzu, UV-5100).

3. Results and Discussion

3.1. SUVA254-1 - Absorbance per unit organic carbon content

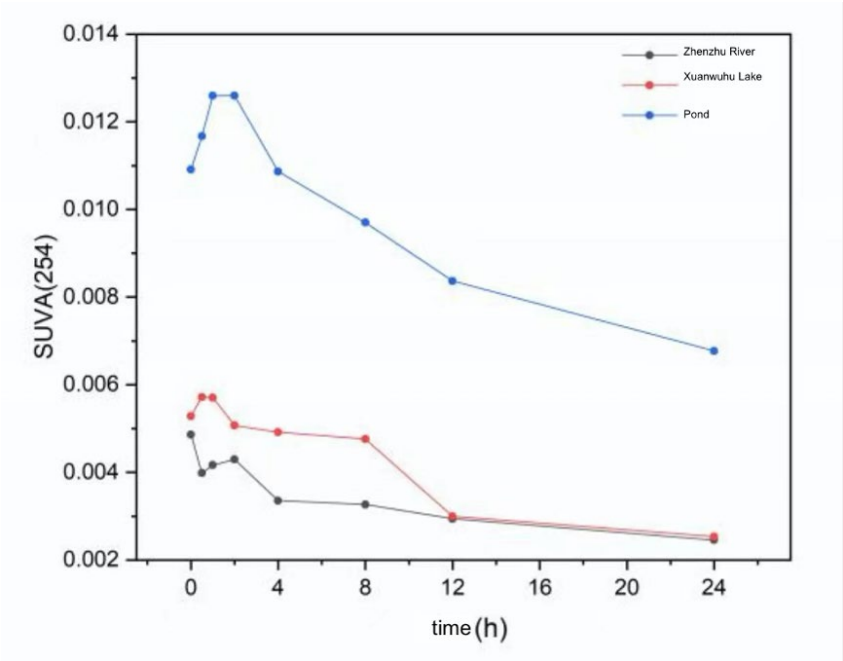

Figure 1: SUVA254 of the urban water bodies in Nanjing.

As figure 1, when comparing the overall data linearity of SUVA254 in Figure SUVA254-1, the mean and initial values of SUVA254 in the pond are much higher than those in the Zhenzhu River and the Xuanwuhu Lake, so it can be concluded that the pond contains more aromatic material per unit than the Xuanwuhu Lake and the Zhenzhu River. The slope of the pond is steeper than that of the Zhenzhu River, as it represents the amount of naturally occurring humus-like fractions of organic matter and aromatic compounds with C=C and C=O double bonds in the water, and the degradation efficiency of the pond is higher than that of the other two waters during the 12-24 h degradation time, so there is still more aromatic matter in the pond than in the other two waters. This supports the view that the pond is high in aromatic substances.

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It can be seen from the comparison of the graphs that the aromatic substances are gradually decreasing. Since the ratio of aromatics to DOC for the three water sources rises during the 0-2 hour photodegradation process, this proves that the non-aromatics in the water samples are degraded faster than the aromatics and the aromatic content rises and therefore the curve rises. The curve then decreases as the non-aromatics are largely degraded and the aromatics continue to degrade.

As the pond is a closed, immobile water area, situated in close proximity to mythological sites and densely populated by trees, a large number of exogenous influences such as leaf litter were found during the sampling, which increased the concentration of DOM in the water and provided nutrients for the growth of phytoplankton and bacteria in the water [24], indirectly increasing the endogenous production of DOM [25].

3.2. UV254 and degradation rates

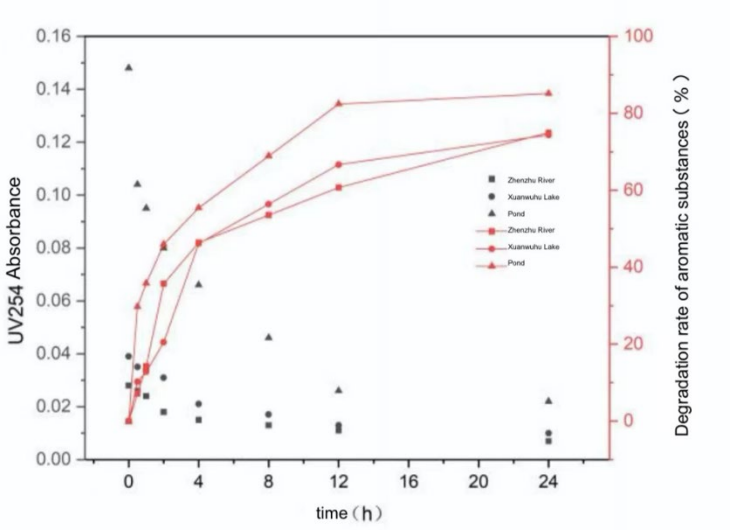

Figure 2: UV254 and dissolve rate of the urban water bodies in Nanjing.

With figure 2, it can be found that the concentration of aromatic substances in the pond is higher than in the two natural water areas of the Zhenzhu River and Xuanwuhu Lake, as shown by the variation of the UV254 absorbance values against UV254 and degradation rates. The degradation rates are then observed and it can be concluded that the degradation rate of aromatic substances in the pond has already reached % within 24 hours, while the degradation rate of aromatic substances in the Zhenzhu River and Xuanwuhu Lake is close to 80% within 24 hours. The short initiation period and the rapid degradation rate are reflected in the two natural waters, where the degradation rate and initiation period is slightly longer than in the pond. As a result, the main organic compounds in these three waters are phenols, o-phenols and benzoic acid, which have an initiation period of less than 15 hours and a complete degradation time of about 40 hours. [26].

3.3. UV254 degradation kinetics

With figure 3 and 4, it can be seen from the graph that the initiation points for the Xuanwuhu Lake and the pond are the same. However, at the second stage, the absorbance of the organic carbon content of the pond is higher than that of the Xuanwuhu Lake, probably because the non-organic carbon fraction of the Xuanwuhu Lake is degrading first, while the non-organic carbon content of the pond is lower, so the absorbance of the organic carbon content of the pond is higher than that of the Xuanwuhu Lake. It is possible that, at a later stage, most of the non-organic carbon fraction of the Xuanwuhu Lake has been degraded and the organic carbon fraction has started to degrade. The absorbance of the organic carbon content of the Xuanwuhu Lake is therefore greater than that of the pond. As a whole, it can be concluded that the absorbance of the organic carbon content is greater in the Zhenzhu River than in the Xuanwuhu Lake and greater than in the pond.

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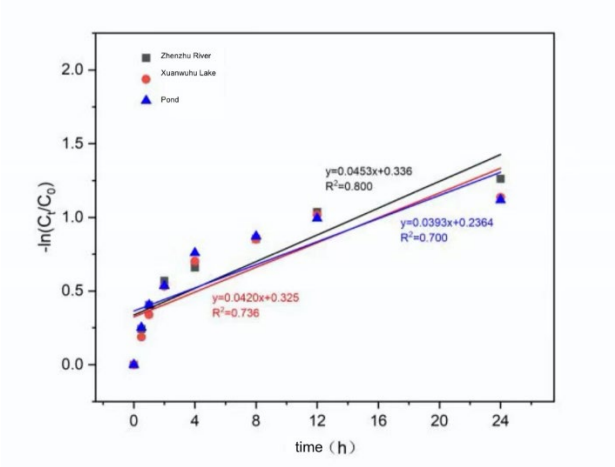

Figure 3: DOC content of the urban water bodies in Nanjing.

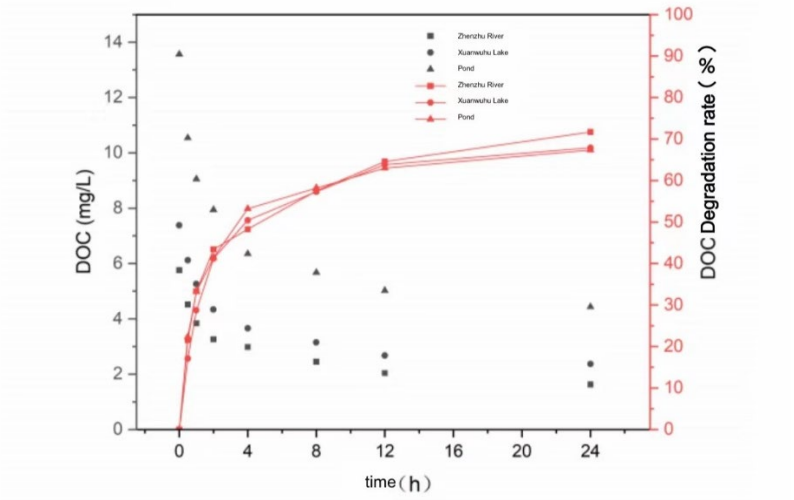

Figure 4: Reacting rate of the urban water bodies in Nanjing.

This is probably the result of it being a closed, immobile water area, close to a human habitat, densely populated with trees, and because of the large number of fallen leaves during the winter in Nanjing when we took our samples. The pond has the lowest absorbance of organic carbon because DOM is mainly derived from soil runoff and the release of decaying dead leaves. The lower absorbance of Xuanwuhu Lake than the Zhenzhu River may be due to the abundance of water plants and animals in Xuanwuhu Lake and the increased activity of micro-organisms in the water due to the pollution produced by the surrounding industries, agriculture and residential activities [27]. Higher concentrations of organic carbon can be observed in the Xuanwuhu Lake than in the ponds possibly due to its larger surface area and the fact that it is less confined and immobile than the pond. The Zhenzhu River has the highest organic carbon content absorbance, probably due to less influence from human activities and less leaf litter.

3.4. DOC and degradation rates and degradation kinetics

As can be seen from Figure 5, the DOC content of the pond is greater than that of the Xuanwuhu Lake and the Zhenzhu River throughout the reaction, which indicates that the degradation rates of the three water bodies are more or less the same. The degradation rate in the small pond slows down significantly after 4 h, which can be inferred to be the result of the reduction of aromatic substances in the pond, and it can be assumed that there is something in the small pond that promotes the degradation of aromatic substances.

The degradation rate of the Zhenzhu River is generally higher than that of the Xuanwuhu Lake and the half-life of the DOC substances in each water body can be calculated using the k-value, that is, the DOM is more stable in the pond, followed by the Xuanwuhu Lake, and the DOM is the most active in the Zhenzhu River.

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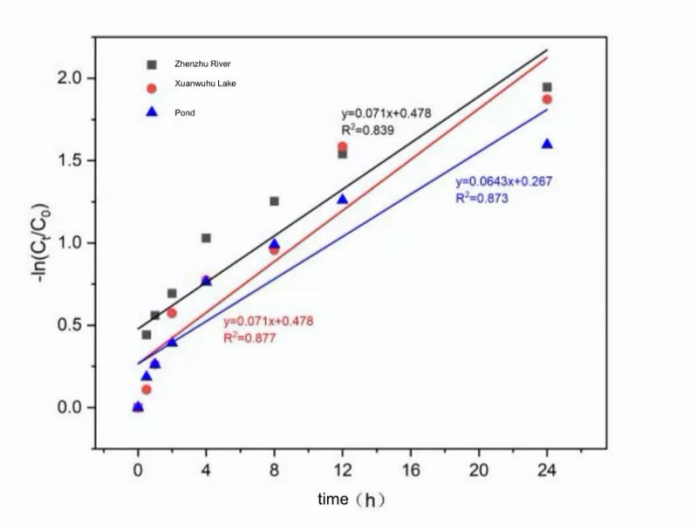

Figure 5: UV254 and degradation kinetics of the urban water bodies in Nanjing.

4. Conclusion

In this study, a comparison of three water sources, namely the Xuanwuhu Lake, the Zhenzhu River and the pond of the Nanjing Branch of Chinese Academy of Sciences is conducted to complement the studies on urban water in China. The study demonstrates that the DOC and aromatic content of all three water bodies are significantly degraded by UV light. The pond exhibits a higher DOC concentration and aromatic content than the Xuanwuhu Lake and the Zhenzhu River, and this is a result of the influence of human and other exogenous DOM on the water. The pond are much more proximate to areas of human activity, where materials such as leaf litter carry exogenous DOM and increase the nutrient level of the water, which promotes the production of endogenous DOM. This indicates that the DOM in Xuanwuhu Lake and the Zhenzhu River is unstable and easily degraded, and therefore cannot persist in the water column for long periods of time, and the rate of recycling is high. This also confirms that the DOM content of these two water bodies is smaller than that of the pond.

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