ISSN 2616-5872 Vol.8, Issue 1: 130-137, DOI: 10.25236/AJEE.2026.080117

Comparison of dissolved organic matter in different environmental water bodies

Sophia Jiayun Cui[1,a,#], Xinyue Jiang[2,b,#]

[1]*Dulwich College Beijing, Beijing, China*
[2]*High School Affiliated to Renmin University of China, Beijing, China*
[a]*sophia.cui28@stu.dulwich.org,* [b]*Erinlovegood0506@sina.com*
[#]*The above authors made the same contribution to this article and are the co-first authors.*

Abstract: *Dissolved organic matter (DOM) constitutes the largest organic carbon (OC) pool in aquatic environments, and its behavior exemplifies a key role in greenhouse gas emissions and the carbon-climate feedback. However, studies on understanding the process of DOM degradation in different natural waters remain relatively scattered. In this study, the UV-induced photodegradation properties of DOM from different origins (i.e., pond, river, and lake) were investigated through a photochemical degradation experiment under simulated irradiation conditions. Later, the changes in absorbance rate at 254 nm (UV_{254}) and total organic carbon (TOC) were measured to evaluate the degradation process and its removal efficiency across different water bodies. Results showed that, in the presence of UV_{254}, degradation, irrespective of DOM origin, followed a similar trend over the period of light exposure, as absorbance in all water bodies gradually decreased. Compared to the various water bodies, lake water had a higher overall removal efficacy, whereas pond and river water were relatively lower. The addition of TiO_2 as a catalyst enhanced the removal efficiency in all samples, with pond water showing the most noticeable enhancement. In addition, over prolonged light exposure, the removal efficiency gradually approached that of lake water, indicating that photocatalysis can promote DOM degradation effectively. The study conducted parallel experiments to ensure the reliability of the degradation patterns of DOM from different origins under light and photocatalytic conditions, to understand further the transformation of photochemical and organic matter in water, and to extend it to pollution control in water bodies.*

Keywords: *Dissolved organic matter, Photodegradation, Natural water bodies, Titanium dioxide, Total organic carbon*

1. Introduction

1.1 Background

At present, China is one of the countries with relatively severe water pollution. Dissolved organic matter (DOM) is ubiquitous in natural water bodies and is mainly composed of humid substances, polysaccharides, proteins, esters, nucleic acids, and other components. Dissolved organic matter can undergo adsorption, complexation, and redox reactions with heavy metals and organic pollutants. Therefore, organic matter degradation is the core process by which aquatic ecosystems achieve self-purification.

To date, most studies focus on photodegradation of DOM from a single origin [5]. However, ponds, lakes, and rivers of these different types of water bodies may differ in their hydrodynamic conditions, light availability, temperature, microbial communities and external input intensities. Therefore, they shape distinctly different organic matter degradation patterns and capacities [4]. For instance, DOM reactivity increases under the influence of a greater wind-wave disturbance, while the variety of DOM sources (e.g., soil leaching in contrast to deep sea humidification) can also impact its reactivity [4].

Dissolved organic matter (DOM) constitutes the largest organic carbon (OC) pool in aquatic ecosystems. Its decomposition critically influences greenhouse gas emissions and carbon–climate feedback [1]. The mechanisms and pathways behind DOM degradation in aquatic ecosystems are still largely unknown when compared to terrestrial soil environments [2].

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1.2 Literature review

Within aquatic ecosystems, terrestrial human-rich DOM sources and autochthonous inputs are 2 major origins that contribute to DOM [2]. In terrestrial environments, DOM is a complex of organic matter from soils, plant decomposition products, and aromatic compounds generated when water browning is transported into rivers, lakes, ponds, and other aquatic environments [2]. Furthermore, anthropogenic activities such as agricultural runoffs can cause substantial quantities of organic matter to be internally produced through phytoplankton and algae blooms during the process of eutrophication. In research contexts aimed at increasing inputs of autochthonous labile dissolved organic matter (DOM) and terrestrial DOM, algal blooms and land-use changes that drive water browning fall outside the scope of global environmental change. [3]. Moreover, associated with industrial development, anthropogenic activities such as wasteful water discharges and agricultural occupation have raised the level of organic matter inputs into aquatic systems, which contributes to enhancing the level of DOM degradation potential [1]. With the increasing understanding of carbon cycling in aquatic ecosystems, increasing attention has been paid to DOM degradation processes and their regulatory mechanisms. As existing studies have mainly focused on case studies of single types of aquatic systems or on the characterization of DOM sources and compositions, the comparisons of DOM degradation behaviors among different natural aquatic environments remain limited. Under controlled and comparable conditions, systematic parallel investigations of DOM degradation kinetics and underlying mechanisms among ponds, lakes, and rivers of these three natural aquatic systems representing a continuous hydrodynamic gradient remain relatively insufficient.

This study will explore and contrast the degradation process of DOM and its controlling mechanisms among different types of aquatic systems under standardized and controlled experimental conditions. As the study was conducted in the summer season, it has shown that factors including level of precipitation and temperature contribute to the determination of the DOM molecule's composition [2]. Summer seasons in Nanjing have a higher precipitation rate and temperature; in contrast, collecting samples in areas with high rainfall and rising temperatures increases the production of nitrogenous compounds, as terrestrial DOM is most abundant and shows a higher percentage change in trend. As the climate becomes wetter, terrestrial DOM will become more common in lakes. Three major objectives in this investigation are:

1) To measure and compare the efficacy of DOM degradation in various aquatic systems, particularly in lakes, rivers, and ponds. Under identical experimental conditions, the degradation constant rates will be determined using 1st-order kinetic models, which exposes variation in DOM degradation capacity among different water bodies.
2) To apply UV-Vis absorption spectroscopy to compare the trend of DOM components across various aquatic environments and monitor changes dynamically in DOM chemical composition—optical properties throughout the degradation process.
3) To integrate environmental features of various aquatic systems (such as hydrodynamic conditions, water quality parameters, and ecological characteristics), it is possible to determine the primary factors influencing the rates and compositional changes of DOM degradation and to clarify further the regulatory mechanisms of environmental conditions on the DOM degradation process.

2. Materials and Methods

2.1 Experimental equipment and lab supplies

A list of the equipment and materials used in this experiment is provided below. (Table 1)

Table 1 Experimental equipment and lab supplies information

Name of Apparatus	Model Number & Manufacturing Company
Diaphragm vacuum pump	GM-0.33A (Tianjin Jinteng Experiment Equipment Co., Ltd.)
Aluminum Clamp	
Granted Funnel	300mL
Membrane Filter (PES)	0.22um
Universal Vacuum Hose Connection	
Glass Flask	1000mL
UV-Vis Spectrophotometer	UV-2700 (Shimadzu Company)

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Lab vacuum filtration distillation apparatus	1000mL
Quartz tube	50mL
Photochemical Reactors	Phchem III (Beijing NEBT Technology Co., Ltd)
Photochemical slot	Phchem III (Beijing NEBT Technology Co., Ltd)
Syringe	10mL (Changzhou Yuekang Medical Appliance Co., Ltd.)
Ultrasonic Cleaner	KQ-700DE (KUNSHAN Ultrasonic Instruments Co., LTD)
E-balance	FA204EN (Changzhou XINGYUN Electronic Equipment Co., Ltd.)
Reagent Bottle	200mL

2.2 Sample collection and pretreatment

This study collected water samples from three different origins (pond, lake, river) over the summer season in Nanjing, China (Table 2). Water samples were primarily stored in PET plastic bottles when collected from aquatic environments. The lab vacuum filtration distillation apparatus connected to the diaphragm vacuum pump was utilized to filter the impurities using a membrane filter (PES) at 0.22 μm to exclude microorganisms. To prevent contamination during sampling, glass syringes and bottles containing the water source were rinsed 3-5 times prior to collection. When filtering the sample, the filter membrane and filter were rinsed with the primary water to reduce the frequency of replacing the filter membrane. Ideally, one filter membrane should be used to complete the filtration for each type of water source. If more filtering and water sample collection were required, the filter membranes would be changed, and the preceding steps would be repeated.

Table 2 The sampling location distribution and sampling index of the pond, river, and lake in Nanjing

Date and Time	Sampling Location	Sampling Index
2026-8-6 11:00 am	Ornamental pond beside Building 22, NIGLAS	DOM TOC
2026-8-6 11:20 am	Sanhe Lake	
2026-8-6 12:00 am	Yunliang River	

2.3 Photodegradation experiment

The photodegradation experiment was carried out using a photochemical reactor. The three water body samples were adjusted to lower initial DOC concentrations to minimize concentration-related heterogeneity in photodegradation. Because the light source system in the photochemical reactor facilitates DOM photodegradation, adjusting the wavelength and light intensity enables control of illumination parameters. It simulates irradiation conditions representative of aquatic ecosystems.

Furthermore, to ensure that the reactions for each tested samples received consistent light exposure, the collected water sample were placed in the photochemical reactor's turntable prior to data measured through UV & TOC spectrometer. The circulating cooling water system within the photochemical reactor maintains the reaction temperature at a predetermined level (25 ±0.5℃). Time gradients (e.g., 5, 10, 15, 30, 60, 120, 1260, and 1440 minutes) for light exposure were set for each experiment onwards. As eight irradiation duration were applied, dark control treatments were also included to distinguish the contributions of photodegradation from those of microbial degradation and other non-photochemical processes. Upon the completion of the reaction, samples were promptly removed for subsequent absorbance measurements.

2.4 Analytical method

After the degradation experiment, a UV-Vis spectrophotometer was used to measure the absorbance of water samples from each treatment group, and changes in absorbance values were used to indirectly reflect the changes in organic matter content in the water. An appropriate volume of the reacted water sample was placed in a quartz cuvette, and the absorbance was measured at specific wavelengths. Each sample was measured three times, and the average value was taken to ensure data accuracy and reproducibility. Additionally, full-wavelength scanning could be combined to obtain the UV-Vis absorption spectra of water samples before and after degradation, allowing analysis of changes in organic matter molecular structure during the degradation process and providing spectroscopic evidence for a deeper understanding of the photodegradation mechanism of organic matter.

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The UV–Vis spectra with a wavelength interval of 200–800 nm were scanned by a spectrophotometer (UV-2700, Shimadzu, Japan). The absorbance coefficients ($a\lambda$, in m^{-1}) corrected for scattering at 700 nm were calculated as follows:

$$a(\lambda) = 2.303A\lambda\ /r - 2.303A700\ /r\ \times\lambda/700$$

The degradation process was evaluated with the pseudo-first-order kinetic model, which can be expressed as follows:

$$[C]_t = [C]_0\ \times e^{-kt}$$

The kinetic constants were obtained through DOC, A254, and PARAFAC-derived components for DOM in water bodies in response to photodegradation.

3. Results and discussion

Two parallel experiments were conducted, and consistent trends were observed in both sets of data, demonstrating good reproducibility and reliability.

3.1 UV_{254} Absorbance Variation in Different Water Bodies

The UV_{254} absorbance of all samples decreased progressively as irradiation time increased, indicating the continuous degradation of chromophoric dissolved organic matter (DOM). Water sample from pond among the samples consistently exhibited highest absorbance, following by river water, as lake water shown the lowest value. This suggests water from pond contains a higher level of DOM which may be relevant to its relatively stagnant conditions and limited water exchange favoring the accumulation of organic matter. Meanwhile, the low DOM concentration river water and lake water both can characterized by higher flow velocity and suspended sediment content.

As shown in Fig. 1., for UV_{254} light the absorbance of the three types of water all decreases over time, this reflects that the pollutants eventually break down under light exposure. The absorbance of the river water remains higher than that of the lake water, but the pond water continues to have the maximum absorbance. This demonstrates that ponds have the highest absorbance levels at 254 nm, followed by rivers and lakes, due to their stagnant water flow and lack of environmental disturbances.

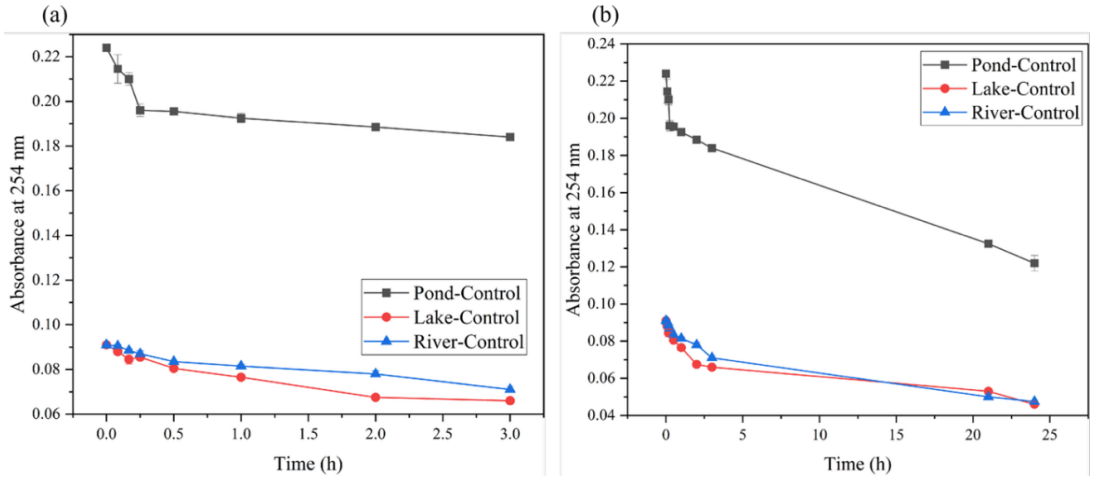


Fig. 1. Temporal variation of absorbance in different water bodies: (a) changes from 0–3 h; (b) changes over 24 h.

3.2 DOM Degradation Efficiency in Different Water Bodies

Table 3 DOM photodegradation efficacy

Sampling	k ($\times10^{-3}$)(min^{-1})	R^2	24h removal
Pond	0.0214	0.9476	45.54
River	0.0255	0.9533	47.80
Lake	0.0231	0.8560	49.45

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The kinetic parameters for DOM photodegradation are summarized in Table 3.

Fig. 2 illustrates that during the 24-hour irradiation period, the degradation efficiency of DOM in pond, lake, and river water rose in both experimental groups. The initial stage showed a quick increase, which was followed by a slower expansion in later phases. Lake water had the highest final degradation efficiency after 24 hours, but the three water bodies' degradation efficiencies were almost the same at 0 minutes.

The removal efficiency of all samples in Fig. 2 (a) increased quickly between 0 and 1 hour, then progressively slowed down and tended to stabilize between 1 and 3 hours.

Lake water continuously showed the highest degradation efficiency in Fig. 2 (b), which showed a sharp increase over the course of 0–2 hours. Between 2 and 22 hours, all three samples exhibited a gradual increase, with the disparities among the water bodies becoming increasingly evident over time. In general, under brief irradiation settings, the efficacy of removal was ranked as follows: Lake > River >Pond

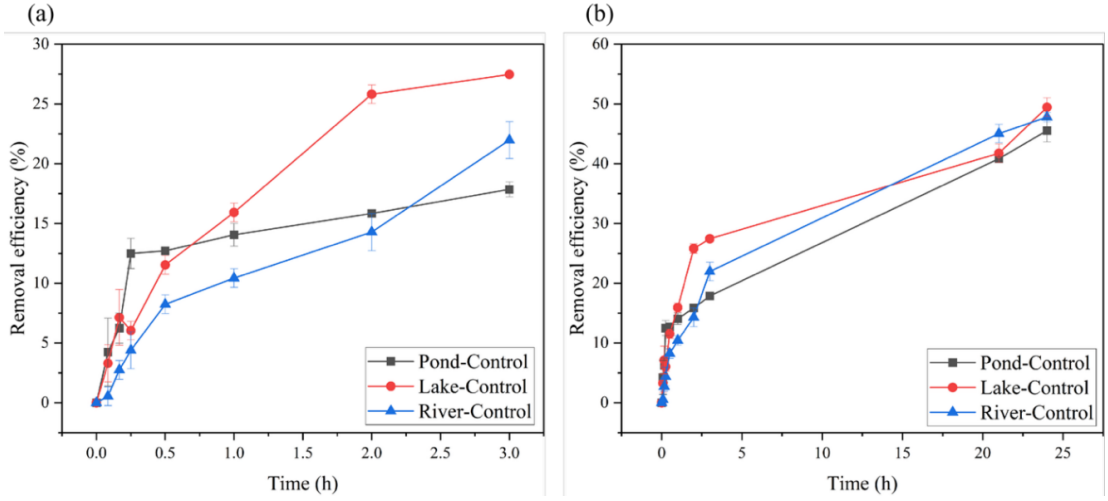


Fig. 2. Temporal variation of DOM degradation efficiency in different water bodies: (a) 0–3 h; (b) 0–24 h.

3.3 TOC Removal Efficiency

Table 4 TOC photodegradation efficacy

Sampling	k ($\times 10^{-3}$)(min^{-1})	R^2	24h removal
Pond	0.0392	0.9803	65.41
River	0.0248	0.9485	47.45
Lake	0.0274	0.9781	49.53

The TOC removal efficiencies and corresponding kinetic constants are listed in Table 4.

The degradation behaviors of TOC and DOM displayed both parallels and major variances. Fig. 3 depicts the time evolution of TOC removal effectiveness in the three analyzed water bodies under irradiation. The TOC removal effectiveness, as shown, rose progressively with irradiation duration for all samples, following a classic pattern of a steep increase during the initial stage and a subsequent steady slowdown.

In Fig. 3 (a), lake water displayed a higher degradation efficiency in contrast to both pond and river water during the early period of the experiment. In contrast, the difference between pond and river water remained relatively insignificant. The removal efficiency shown in Fig. 3 (b) of lake water grew most rapidly within the first 0–5 h, exceeding that of the other two water bodies during this period. However, after 5 h, the degradation efficiency of pond water grew more noticeably and eventually reached that of lake water. At 24 h, pond water displayed the highest final removal efficiency, while lake water remained higher than river water. The observed disparities between DOM and TOC degradation tendencies can be attributed to their differing representational features. Changes in DOM are more closely related to the photochemical modification of chromophoric and aromatic components that absorb UV light, whereas TOC indicates the overall loss of organic carbon. Therefore, the combined use of these two indicators provides complementary insights into the photodegradation processes of organic matter in different water

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bodies.

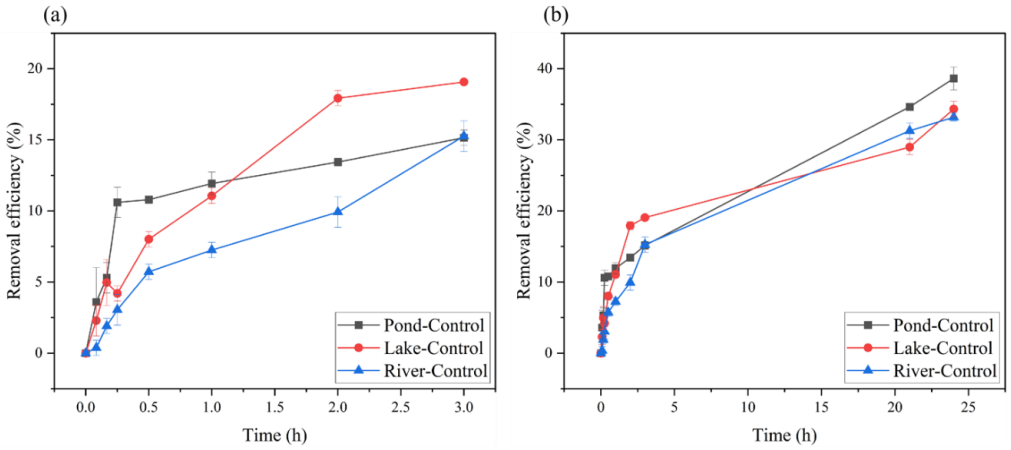


Fig. 3. Temporal variation of TOC degradation efficiency in different water bodies: (a) 0–3h; (b) 0–25h.

3.4 Photocatalytic Degradation of DOM and TOC in Different Water Bodies under a TiO_2 Colloidal System

To further study the differences in pollutant degradation efficiency across the three water bodies under varied conditions, TiO_2 colloids were introduced into the system. As demonstrated in Fig. 4, in both experimental sets, the degradation efficiency of all samples rose progressively over time. In Fig. 4 (a), a rapid increase in degradation efficiency was seen for all samples during 0–0.5 h, with pond water consistently demonstrating the highest efficiency. From 0.5 to 3 h, the growing trend decreased, although pond water retained the highest degradation efficiency, followed by river water and lake water.

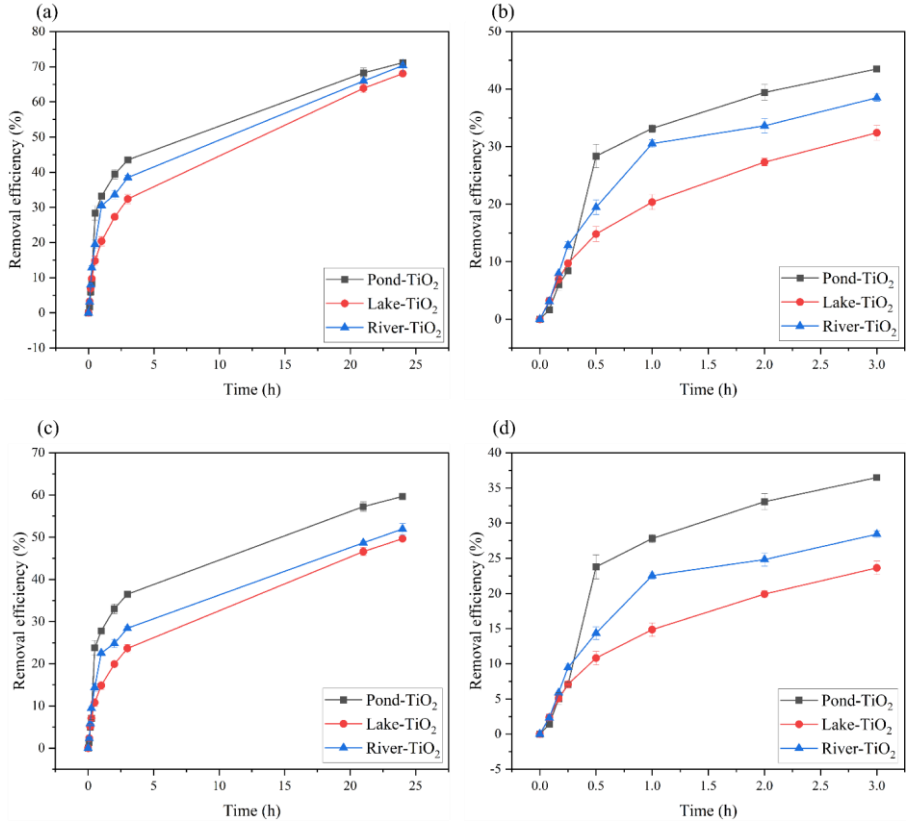


Fig. 4. Temporal variation of DOM and TOC degradation efficiency in different water bodies under a TiO_2 colloidal system: (a) 0–24 h; (b) 0–3 h; (c) replicate experiment (0–24 h); (d) replicate experiment (0–3 h).

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In Fig. 4 (b), all three water bodies showed a rapid growth during 0–3 h, with pond water remaining dominant. During 3–24 h, the growth rate gradually decreased, and pond and river water samples tended to converge the degradation efficiency as water from lake remained lower in contrast.

Overall, the variation in levels of removal efficiency in the addition of TiO_2 improved the DOM removal effectiveness of pond water compared to the control condition, enabling pond water to surpass the photodegradation efficiency previously observed for lake water, making it the most efficient among the three systems. This indicates that TiO_2 substantially promotes the photochemical alteration of DOM components in pond water.

3.5 Possible Reasons for Differences in DOM Photodegradation among various Water Bodies

The enhancement in DOM removal efficiency observed in pond water can be attributed to the photochemical transformation of DOM components. It is proposed that this improvement results from the generation of reactive species (e.g., hydroxyl radicals) under UV irradiation, which accelerate the degradation of organic matter. Under identical experimental conditions, clear differences in pollutant degradation behavior were observed among pond, lake, and river water, indicating variations in the composition and characteristics of UV-absorbing organic components. These variations were evaluated based on absorbance at 254 nm, which reflects changes in chromophoric DOM fractions. The results showed that pond water exhibited significantly higher absorbance at this wavelength, suggesting a greater abundance of UV-absorbing DOM components. This phenomenon can be attributed to differences in hydrodynamic conditions and external organic matter inputs among the water bodies. Pond systems typically exhibit low water mobility and limited exchange capacity, which facilitate the accumulation of organic matter and result in a higher proportion of UV-absorbing DOM. In contrast, lake and river water showed comparable overall pollutant levels, although slightly higher values were observed in river water, likely due to higher flow velocity promoting the transport of suspended sediments and associated organic matter. The collected samples were primarily derived from surface water, where sediment content is relatively high, contributing to elevated measured organic matter concentrations. Conversely, lakes generally exhibit lower hydrodynamic intensity, allowing sediments and associated organic matter to settle, resulting in lower contaminant levels in surface water samples. In addition to differences in absorbance, the photodegradation efficiencies of the three water bodies also varied, which may be attributed to differences in DOM composition and hydrological conditions. River water is typically characterized by a higher proportion of terrestrially derived aromatic DOM, shorter hydraulic residence times, and limited light exposure, all of which collectively influence DOM composition and photodegradation behavior. Overall, the interplay between DOM composition, hydrodynamic conditions, and light availability governs the observed differences in photodegradation among the three water bodies.

Lake water has a mixture of terrestrial and autochthonous DOM, with extended residence durations that may lead to the depletion of photoreactive components. In contrast, pond water is often dominated by autochthonous algal-derived DOM, with shallow depth and sufficient light availability, albeit its aromaticity is relatively higher. These factors collectively influence the photodegradation processes of DOM.

4. Conclusion

DOM with different origins and natural water bodies exhibited differences in degradation efficiency. As in most circumstances, water from lakes generally showed the highest degradation efficiency since DOM from lake water is mainly composed of endogenous small molecules that are easily degradable, with the proportion of biodegradable components being greater than in other water bodies. The presence of TiO_2 added to the water samples significantly raised the removal efficiency for degradation, especially for ponds. In addition, results from DOM and TOC displayed similar overall trends: a rapid initial change followed by a slower phase. However, there were differences in relative efficiency among water bodies, with UV_{254} mainly reflecting the degradation of chromophoric and aromatic structures. At the same time, TOC represents the removal of total organic carbon. Thereby, the differences between these two indicators suggest that different DOM components exhibit varied photochemical reactivity. These results highlight the importance of DOM composition and environmental conditions in determining photodegradation behavior.

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