Analyzing photodegradation of dissolved organic matter in different water bodies: river, lake, and pond

Weiyang Lu

Abstract:
DOM is an important part of water ecosystems worldwide and provides a specific footprint to water bodies. A photochemical reactor and UV/Vis-spectrophotometer were used to treat and characterize water samples from Lake Xuanwu, Qinhuai River, and a pond. Comparing the absorbance, DOC concentration, and $SUVA_{254}$ values of the water samples shows that UV radiation could degrade aromatics contents in water, and the process is most pronounced in the pond water samples compared to the other two. The results of this study could provide a reference to other studies regarding the hydrosphere in Nanjing and be helpful to future projects in the protection of the Xuanwu Lake and Qinhuai River in Nanjing.
Keywords: DOM; Photodegradation; Aromatics; UV radiation

1 Introduction

Dissolved organic matter (DOM) is a key component of water ecosystems and biogeochemical cycles. All organic matter with a particle size smaller than 0.45 μm could be considered as DOM. It comprises many organic molecules derived from plant matter and algae. DOM could be degraded through biological and photochemical processes like sunlight or bacteria. Photodegradation occurs when radiation on organic molecules creates highly reactive free radicals, deleting large dissolved organic matter into smaller molecules, carbon dioxide, and water. Illumination time, wavelength, and radiation intensity affect the degradation process.

Water pollution is a significant cause of illnesses and harms social well-being. Every year in China, 60,000 people die from drinking polluted water[1]. Pollutants are causing the water source to be "teeming with bacteria," according to Tang Kewang, a hydrologist at the Chinese Institute of Water Resources and Hydropower Research in Beijing. Water quality is especially poor in the eastern plains with a high population[2]. With the widespread use of plastic and failure to dispose of it properly, many enterthe water source and releasereleaseDOM through photochemical and mechanical processes[3]. High levels of dissolved organic matter can significantly reduce water transparency in rivers and lakes and diminish the recreational value of water bodies.

Photodegradation of DOM has received great attention in recent years.

Collin et al.[4] Studied the partial photo-oxidation of DOM in arctic ocean water and revealed that the magnitude of partial photo-oxidation in surface sun-lit waters is greater than previously hypothesized. Hu et al.[5] reported that the enhancement of DOC biodegradation by sunlight is not related to the low molecular weight of aliphatic in thermokarst lakes. However, it is due to the photo-produced aromatics, suggesting the importance of aromatics in monitoring light's effect on DOM biodegradation. Sans et al.[6] investigated the photodegradation of alkyl, chloroalkyl, and nine types of organophosphorus flame retardants (OPFR) in river water. The results revealed that with a long irradiation time, OPFR could be effectively removed, with river water enhancing the process. Frost et al.[7] characterized DOM in urban ponds and characterized humic-like components, which are microbial-like and terrestrial-derived. The relatively transparent non-humic DOM has characteristics similar to those in open water systems like lakes, rivers, and wetlands. Though 1.7 days under solar radiation, humid-like components decreased, and protein-like constituents increased.

Although there have been studies on the photodegradation of DOM in waters around the world[8], there is a need for comparison in the photodegradation processes of DOM in water bodies of Nanjing. In this study, the effect of photodegradation on DOM in different water sources of Nanjing is analyzed. The photodegradation procedure is conducted on three samples to observe their effect. UV/Vis-spectrophotometer characterizes the degradation products reacting at different intervals. The absorbance value can indirectly reflect the dissolved organic matter content in water. Their differences can be studied by characterizing water samples from different water sources. Studying the photodegradation process of DOM in these typical rivers, lakes, and ponds is of great significance

for deepening the understanding of the cycle of DOM in different water bodies. It can also provide theoretical guidance and reference for water purification of rivers and lakes in Nanjing city. Results show that photodegradation is the most effective on water samples taken from the pond.

2 Sample collection and Pretreatment

The lake and river water samples were collected in July 2023 from Lake Xuanwuhu and Qinhuaihe rivers accordingly. Water was also taken from a pond. The samples were pretreated by vacuum filtration with a filter membrane of 0.45 μm.

3 Experimental procedures

A quartz tube loaded The samples into the photochemical reactor (XPA-7, Xujiang Machine Factory, China). It operated on a 500W mercury lamp, and the reactor temperature was maintained at 25 degrees by water and air cooling. After different time intervals-10 min, 20 min, 30 min, 1hr, 2 hr, 3 hr, and four hr-smaller testing samples were taken from the tubes and scanned with a UV/vis-spectrophotometer for characterization.

4 Results and Discussion

During the photodegradation process, the absorbance at 254 nm in lakes, rivers, and ponds gradually decreases with the increase of degradation time (Figure 1), indicating that the absorbance substances in all three types of water bodies have been effectively degraded.

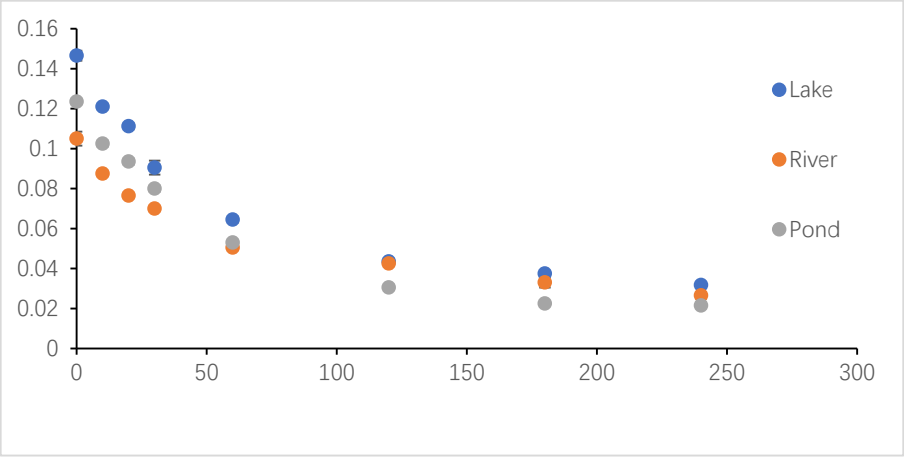

Figure 1 Change in absorbance over time.

After photodegradation, the $SUVA_{254}$ value of dissolved organic matter in each sample is lower than that of the initial (Figure 2), which indicates that the photodegradation process can effectively reduce the aromaticity of dissolved organic matter in lakes, rivers, and ponds.

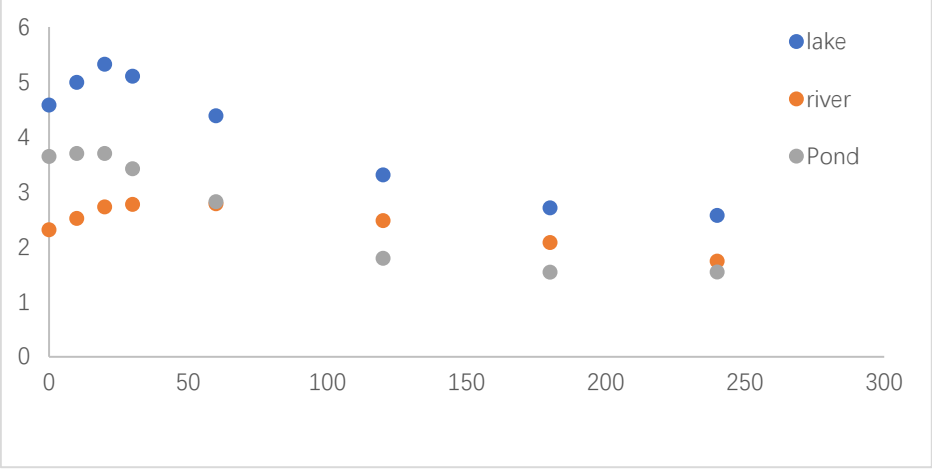

Figure 2 Change in $SUVA_{254}$ over time.

From the DOM content, at the beginning, the DOM in the lake was the highest, while the DOM in the river was the lowest (Figure 3). After 240 minutes of irradiation, the dissolved organic matter content in the river exceeded that in the pond. The changes in the small pond were the most significant; its efficiency is the highest, reaching 82.6%, while that of the river is the lowest, reaching only 74.8%. Additionally, the degradation rates of the three types of water bodies tended to stabilize after 120 minutes of irradiation.

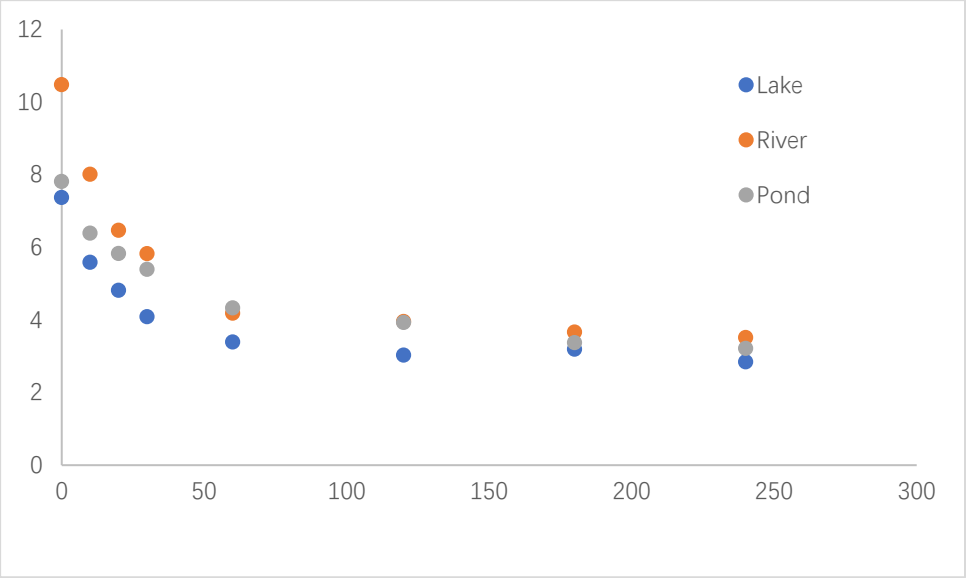

Figure 3 Change in DOC concentration over time.

Furthermore, (Figure 4) indicates that the k value of pond water degradation is at 0.0248, which is the greatest; that of the river sample is shown to be the lowest, where k is at 0.013.

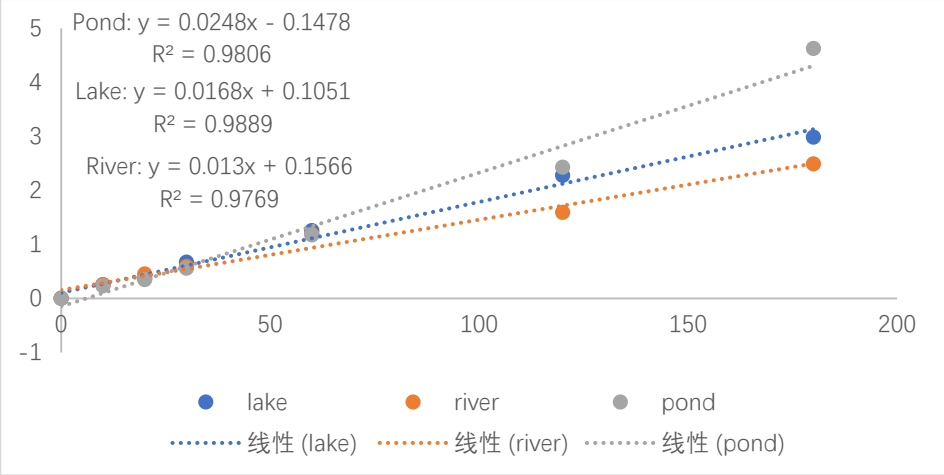

Figure 2 Kinetics of the degradation process.

5 Conclusions

This study compared the photodegradation process of DOM in different water sources from Nanjing. Using a photochemical reactor and UV/Vis-spectrophotometer, the water samples could be analyzed, and the degradation process could be tracked. Data and calculations have maintained the water samples' absorbance, DOC concentration, and $SUVA_{254}$ values. It is concluded that UV radiation could effectively reduce the aromatic contents in water. Also, photodegradation was found to be most effective in the pond water sample compared to Lake Xuanwu and Qinhuai River samples. This study could further investigate the sampling of other rivers and lakes in Nanjing. Also, other analytical methods could also be used to characterize the DOM species before and after

degradation, specifically.

The study provides insight into the composition and degradation of DOM in different water bodies in Nanjing. This references further studies in Nanjing or relevant water bodies and could help guide future conservation projects. In the study of the degradation of DOM, more studies could provide better ideas to help draft guidelines for protecting water ecosystems from damage and pollution. It also provides solutions to environmental restoration on these water bodies.

References

[1] Tao, T., Xin, K. Public health: A sustainable plan for China's drinking water. Nature 511, 527–528 (2014). https://doi.org/10.1038/511527a

[2] Jane Qiu, China to Spend Billions Cleaning Up Groundwater. Science334,745-745(2011).DOI: 10.1126/science.334.6057.745

[3] Sheridan, E.A., Fonvielle, J.A., Cottingham, S. et al. Plastic pollution fosters more microbial growth in lakes than natural organic matter. Nat Commun 13, 4175 (2022). https://doi.org/10.1038/s41467-022-31691-9

[4] Hu, J., Kang, L., Li, Z. et al. Photo-produced aromatic compounds stimulate microbial degradation of dissolved organic carbon in thermokarst lakes. Nat Commun 14, 3681 (2023). Environ. Sci.: Processes Impacts, 2020, 22, 1214. https://doi.org/10.1038/s41467-023-39432-2.

[5] Joyce Cristale, Renato F. Dantas, Antonella De Luca, Carmen Sans, Santiago Esplugas, Silvia Lacorte, Role of oxygen and DOM in sunlight-induced photodegradation of organophosphorous flame retardants in river water, Journal of Hazardous Materials, Volume 323, Part A,2017, Pages 242-249, ISSN 0304-3894, https://doi.org/10.1016/j.jhazmat.2016.05.019.

[6] McEnroe NA, Williams CJ, Xenopoulos MA, Porcal P, Frost PC (2013) Distinct Optical Chemistry of Dissolved Organic Matter in Urban Pond Ecosystems. PLOS ONE 8(11): e80334.

[7] Zhongyu Guo, Dilini Kodikara, Luthfia Shofi Albi, Yuta Hatano, Guo Chen, Chihiro Yoshimura, Jieqiong Wang, Photodegradation of organic micropollutants in aquatic environment: Importance, factors and processes, Water Research, Volume 231, 2023, 118236, ISSN 0043-1354, https://doi.org/10.1016/j.watres.2022.118236.