

Study on the Photocatalytic Activity of Graphene Oxide in Removal of Xylene Solution

P. Gharbani^{1,2,*} and A. Mehrizad^{2,3}

¹Department of Chemistry, Ahar Branch, Islamic Azad University, Ahar, Iran

² Industrial Nanotechnology Research Center, Tabriz Branch, Islamic Azad University, Tabriz, Iran

³Department of Chemistry, Tabriz Branch, Islamic Azad University, Tabriz, Iran

*Corresponding author, Email: parvingharbani@yahoo.com
parvin.gharbani@iau.ac.ir

DOI: 10.71498/ijbbe.2024.1196386

ABSTRACT

Received: Jan. 13, 2025, Revised: Feb. 4, 2025, Accepted: Feb. 18, 2025, Available Online: Mar. 18, 2025

Exposure to xylene can occur through inhalation, ingestion, or contact with the eyes or skin, and can have adverse effects on human health. In this study, graphene oxide was utilized for the photocatalytic removal of xylene from aqueous solutions. The impact of various factors, such as irradiation time, initial pH, and adsorbent dosage, on the removal of xylene was investigated. The findings indicated that the equilibrium of the photocatalytic removal process was reached in 50 minutes, and then decreased. Additionally, the maximum removal of xylene was observed at a pH of 6. It was found that increasing Graphene oxide dosage is due to a decrease in Xylene removal. Notably, the results showed that 0.01g of graphene oxide could eliminate 78.87% of xylene at an initial concentration of 500 mg/L and a pH of 6 under UV irradiation.

KEYWORDS

Xylene; Photocatalyst; Graphene oxide; UV irradiation

I. INTRODUCTION

The advancement of civilization and the industrialization of societies leads to water pollution, which is considered a serious threat to living organisms. The oil, gas, and petrochemical industries play a crucial role in serving humanity today. Given the vast scale and high volume of the oil industry, wastewater from these industries poses one of the most significant global challenges, particularly in oil-rich countries like Iran. Xylene (Fig. 1), a

dangerous and persistent aromatic hydrocarbon commonly found in the effluents of chemical and refinery industries, has a high potential to contaminate surface and groundwater. It can seep into the environment through leaking storage tanks and petroleum products, such as gasoline and diesel fuel, posing harm to humans, animals, and others. Xylene is suspected to cause central nervous system disorders and is classified as a Group E carcinogen. As a result, the maximum allowable level of xylene contamination in

drinking water has been set at around 10,000 µg/L. Due to its detrimental health effects; xylene is considered a high-risk compound for living organisms' health. Therefore, the removal of xylene from surface and underground water sources is essential.

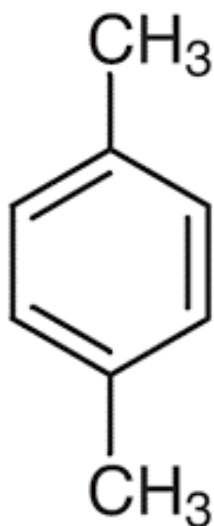


Fig. 1. The structure of Xylene.

Numerous physical methods (such as filtration, adsorption, coagulation, and sedimentation) and chemical techniques (such as biological methods and advanced oxidation processes) have been utilized to eliminate pollutants [9]. Advanced oxidation processes entail the use of chemical agents like hydrogen peroxide, ozone, transition metals, and metal oxides. Moreover, an energy source such as ultraviolet or visible light radiation, electric current, gamma rays, and ultrasonics is necessary. These processes are founded on the generation of free radicals, particularly hydroxyl radicals, which transform pollutants into biologically degradable and less harmful compounds [10,11]. Frequently, advanced oxidation processes incorporate ozone coupled with hydrogen peroxide and ultraviolet (UV) radiation [12,13]. Graphene is a two-dimensional carbon allotrope, with graphene oxide serving as its principal derivative. The graphene oxide comprises oxygenated functional groups like hydroxyl, epoxy, carbonyl, and carboxyl on sp³ carbon atoms, visible on layered graphene sheets, exhibiting properties distinct from those of pristine graphene [14,15]. One intriguing characteristic of photocatalytic materials is

their photoluminescence capability. With graphene oxide, instead of the usual fluorescence deriving from band edge transitions, there exists the possibility of local exciton recombination in electronic states displaying different configurations[16]. This distinct attribute facilitates rapid electron transfer, diminished recombination, and improved light scattering, ultimately enhancing the catalyst's efficiency[17]. It is crucial to acknowledge that graphene oxide operates as a P-type semiconductor[18]. Consequently, when exposed to irradiation, holes gravitate towards the graphene oxide layer, while electrons are propelled towards the surface, generating a cathodic photocurrent[19]. These electrons are subsequently seized by water particles adhered to the electrode surface, leading to the generation of hydrogen post-reaction[20]. The outcomes observed under ultraviolet light are closely tied to the conduct of oxygen groups and their fluctuations in content. Particularly, the optical band gap of graphene oxide is approximately 3.06 electron volts[21]. In this study, we aim to explore the photocatalytic degradation of xylene under UV light using graphene oxide. Additionally, we seek to evaluate the impact of pH, adsorbent dosage, xylene concentration, and contact time on the process.

II. PHOTOCATALYTIC EXPERIMENTS

All experiments were conducted inside a box housing a 300 W halogen lamp serving as a UV light source within a crystallizer placed on a magnetic stirrer. The xylene solution, prepared with the desired concentrations, underwent adsorption measurement using a UV-Vis spectrophotometer. Graphene oxide was introduced into the solution and stirred, followed by a series of photocatalytic processes where samples were extracted every 5 minutes. Subsequently, the samples were filtered, and their absorbance at 282 nm was analyzed using a UV-Vis spectrophotometer (UV mini-1240 Shimadzu). The study investigated the impact of pH parameters, irradiation time, graphene oxide dosage, and xylene concentration. The percentage of xylene removal was then calculated using the equation [20].

$$\% \text{Removal} = \frac{C_0 - C_t}{C_0} * 100 \quad (1)$$

Here, C_0 and C_t are the Xylene concentrations before and after photocatalytic removal, respectively.

III. RESULTS AND DISCUSSION

The photocatalytic process depends on key parameters including irradiation time, the amount of photocatalyst, and the pH of the solution.

A. Effect of irradiation time

To study the effect of irradiation time, a solution of 500 mg/L of xylene was prepared and 0.01 g of graphene oxide was added to it. The solution was then stirred for 50 minutes using a magnetic stirrer under UV irradiation. Sampling was conducted at various time intervals to assess xylene removal, with results displayed in Fig. 1. The data indicates that an increase in irradiation time up to 30 minutes resulted in enhanced xylene removal, after which the removal rate plateaued. This is attributed to the increased interaction between xylene and graphene oxide with longer irradiation time, leading to improved xylene removal efficiency. As a result, all subsequent experiments were performed at a constant time of 30 minutes.

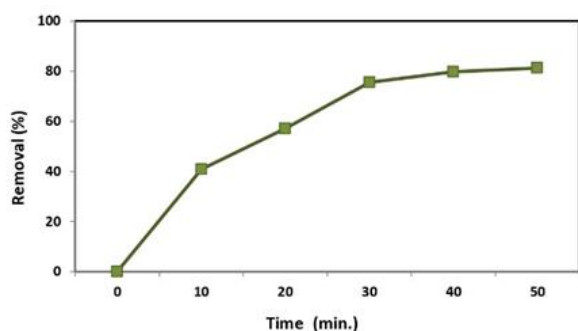


Fig 1. The effect of irradiation time

pH=6.8, [GO]=0.01 g/100mL

B. Dosage of Graphene Oxide

To investigate the impact of graphene oxide dosage on the photocatalytic removal of xylene, varying amounts of graphene oxide were examined. Fig. 2 illustrates that as the dosage of graphene oxide is increased from 0.01 to 0.05 g/100mL, the percentage of xylene removal decreases. This decline can be attributed to the reduction in light penetration as the concentration of particles becomes too high, leading to aggregation and a decrease in available surface area for light absorption, thereby hindering photocatalytic degradation [22]. Furthermore, an increase in the photocatalyst concentration results in heightened turbidity of the solution and non-uniform distribution of light intensity, consequently leading to a decrease in removal percentage with increasing photocatalyst concentration.

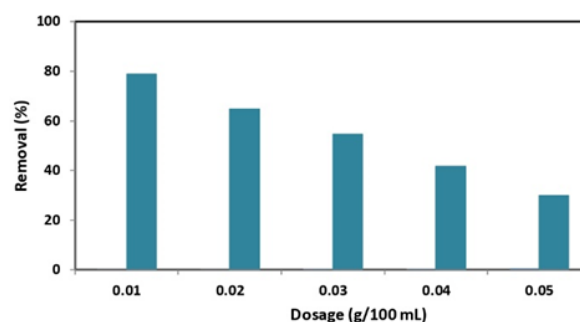


Fig. 2. Dosage of graphene oxide

Irridiation time= 50 min.; pH=6.8

C. Effect of pH

The pH of a solution is a critical factor in the photocatalytic process as it greatly influences the adsorption of pollutants on the photocatalyst's surface [23]. As shown in Fig. 3, xylene degradation is maximized at pH 6. The zeta potential of graphene oxide is approximately 6.2. Notably, graphene oxide exhibits a positive surface charge at pH below 6.2, a negative surface charge at pH above 6.2, and no surface charge at pH 6.2. At a pH of 6.2, both graphene oxide and xylene are uncharged, leading to optimal xylene removal.

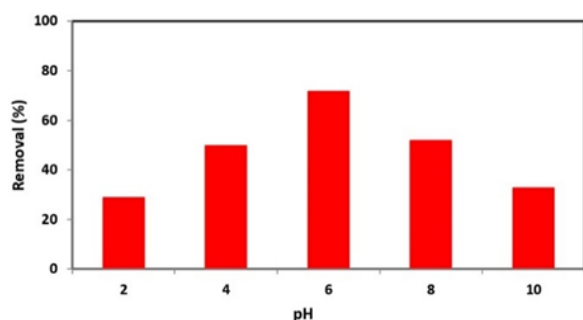


Fig 3. Effect of pH

Irridiation time= 50 min.; [GO]0=0.01 g/100mL

IV. CONCLUSION

In this research, the xylene compound as a hazardous material was removed from aqueous solutions using graphene oxide photocatalytic under UV light. The effect of some key parameters affecting photocatalytic degradation such as irradiation time, pH, and photocatalyst dosage on xylene removal was studied. The results confirmed that xylene removal decreases with increasing adsorbent dosages and increases with increasing irradiation time. Maximum removal of xylene was also observed at a pH of about 6.

REFERENCES

- [1] X. Chen, W. Zhu, S. Feng, and J. Chen, "Photodegradation of xylene isomers: Kinetics, mechanism, secondary pollutant formation potential, and health risk evaluation. *Journal of Environmental Sciences*, Vol.136, pp.658-669.
- [2] B. Bina, M.M. Amin, A. Rashidi, and H. Pourzamani, "Water and wastewater treatment from BTEX by carbon nanotubes and Nano-Fe," *Water resources*, Vol. 41, pp. 719-727, 2014.
- [3] K.T. Chuang, S. Cheng, and S. Tong, "Removal and destruction of benzene, toluene, and xylene from wastewater by air stripping and catalytic oxidation," *Industrial & engineering chemistry research*, Vol.31, pp.2466-2472, 1992.
- [4] S.H. Kim, J.H. Park, J. H. and C.Y. Lee, "Surface-functionalized mesoporous silica nanoparticles as sorbents for BTEX," *Journal of Porous Materials*, Vol.20, pp. 1087-1093, 2013.
- [5] R. Hosseinzadeh, R. Tahmasebi, K. Farhadi, A.A. Moosavi-Movahedi, A. Jouyban, and J. Badraghi, J. "Novel cationic surfactant ion pair-based solid-phase microextraction fiber for nano-level analysis of BTEX," *Colloids and Surfaces B: Biointerfaces*, Vol.84, pp. 13-17, 2011.
- [6] H. Shim, E. Shin, and S.T. Yang. "A continuous fibrous-bed bioreactor for BTEX biodegradation by a co-culture of *Pseudomonas putida* and *Pseudomonas fluorescens*," *Advances in Environmental Research*, Vol. 7, pp. 203-216, 2002.
- [7] A.K. Mathur, C.B. Majumder, S. Chatterjee, "Combined removal of BTEX in air stream by using a mixture of sugar cane bagasse, compost, and GAC as biofilter media," *Journal of Hazardous Materials*, Vol.148, pp.64-74, 2024.
- [8] J. M. M.de Mello, H. de Lima Brandão, A. A. U. de Souza, and S. M. D. A. G. Ulson, "Biodegradation of BTEX compounds in a biofilm reactor—modeling and simulation," *Journal of Petroleum Science and Engineering*, Vol.70, pp. 131-139, 2010.
- [9] Y. ayawardhana, S.R. Gunatilake, Mahatantila, K. M.P. Ginige, and M. Vithanage, "Sorptive Removal of Toluene and M-Xylene by Municipal Solid Waste Biochar: Simultaneous Municipal Solid Waste Management and Remediation of Volatile Organic Compounds," *Journal of Environmental Management*, Vol. 238, pp.323–330, 2019.
- [10] Z. Cheng, J. Wang, D. Chen, J. Yu, S. Zhang, S. Wang, and Y. Dai, "Insights into Efficient Removal of Gaseous p-Xylene Using Cerium-Doped ZnO Nanoparticles through Photocatalytic Oxidation," *Catalysis Science & Technology*, Vol.11, pp. 612–623, 2021.
- [11] Z.L. Ye, Q.Y. Han, Y.F. Jiang, S.D. Zhang, L. Shu, and R.X. Zhang, "Synergetic Effect Between Plasma and UV for Toluene Conversion in Integrated Combined Plasma Photolysis Reactor with KrCl/KrBr/XeCl/Xe2 Excilamp," *Canadian Journal of Chemical Engineering*, Vol. 93, pp. 1168–1175, 2015.
- [12] H.M. Lin, S.J. Tzeng, P.J. Hsiau, and W.L. Tsai, "Electrode effects on gas sensing properties of nano crystalline zinc oxide," *Nanostructured Materials*, Vol. 10, pp.465-477, 1998.
- [13] M.S. Tokumoto and C.V. Santilli, "Preparation of ZnO nanoparticles and structural study of the molecular precursor," *Journal of Sol-Gel*

- Science and Technology, Vol. 2003, pp.547-551, 2017.
- [14] A. Adán-Más and D. Wei, "Photoelectrochemical Properties of Graphene and Its Derivatives," *Nanomaterials, Review*, Vol. 3, pp.325-356, 2013.
- [15] A. Esmaeili and M.H. Entezari, "Facile and fast synthesis of graphene oxide nanosheets via bath ultrasonic Irradiation," *Journal of Colloid and Interface Scienc*, Vol. 432, pp. 19-25,2014.
- [16] H. Khan, "Graphene-based semiconductor oxide photocatalysts for photocatalytic hydrogen (H₂) production, a review," *International Journal of Hydrogen Energy*. Vol.84, pp. 356-371, 2024.
- [17] E. Fathi, F. Derakhshanfard, P. Gharbani and Z. Ghazi Tabatabaei, "Facile synthesis of MgO/C₃N₄ nanocomposite for removal of reactive orange 16 under visible light," *Journal of Inorganic and Organometallic Polymers and Materials*, Vol 30, pp.2234-2240, 2020.
- [18] T. A. P. Mendonça, A. S. Giroto, J. T. Chambi, S. L. Cuffini, N. C. S. Vieira, and M. Gonçalves, "Efficient photocatalyst based on activated carbon/graphene oxide/TiO₂ synthesized under acidic conditions for environmental remediation," *Journal of Photochemistry and Photobiology A: Chemistry*, Vol. 462, pp.116244, 2025.
- [19] M. Bashiri and M. A. Hosseini-Sarvari, "comprehensive investigation into the synthesis, characterization, and photocatalytic performance of modified graphene oxide via imino bond with ferrocene as a novel photocatalyst for thioamide synthesis," *Catalysis Science & Technology*, Vol.14, pp.4655-4673, 2024.
- [20] M. Urmimala, K. S. Subrahmanyam, K. Gopalakrishnan, N. Kumar, R. Kumar and A. Govindaraj, "Potential of nanocarbons and related substances as adsorbents and chemical storage materials for H₂, CO₂ and other gases," *Indian Journal of Chemistry, Section A: Inorganic, Physical, Theoretical and Analytical Chemistry*, Vol. 51, pp. 15-31, 2012.
- [21] F. Xiaofeng, W.T. Zheng, and J. L. Kuo, "Adsorption and Diffusion of Li on Pristine and Defective Graphene," *American Chemical Society*, Vol 50, pp. 345-765. 2012.
- [22] M.R. Sohrabi, M. Moghri, H.R. Fard Masoumi, S. Amiri and N. Moosavi, "Optimization of Reactive Blue 21 removal by Nanoscale Zero-Valent Iron using response surface methodology," *Arabian journal of chemistry*, Vol. 9.4, pp. 518-525, 2016.
- [23] B.H. Fard, R.R. Khojasteh, and P. Gharbani, "Preparation and characterization of visible-light sensitive nano Ag/Ag₃VO₄/AgVO₃ modified by graphene oxide for photodegradation of reactive orange 16 dye," *Journal of Inorganic and Organometallic Polymers and Materials*, Vol.28, pp.1149-1157. 2018.

THIS PAGE IS INTENTIONALLY LEFT BLANK.