

Optimization of Vermiculite Modification Conditions as TiO₂ Carrier Material for Removal of Norfloxacin in Aqueous Environment

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Abstract. Antibiotic contamination in water environment remains a serious issue in Vietnam, primarily caused by untreated and/or ineffectively wastewater from hospitals, pharmaceutical factories, and antibiotic overuse in aquaculture and livestock. High levels of antibiotic residues, often in µg/L range, have been detected in major rivers, fostering the spread of antibiotic-resistant bacteria and genes. Despite the implementation of Vietnam's National Action Plan on Antimicrobial Resistance (2020–2025), weak wastewater treatment infrastructure continues to limit effective control. The use of vermiculite (Ver) and TiO₂ carrier enhances the removal efficiency of norfloxacin (NOR) from water by improving adsorption capacity and photocatalytic activity. Ver provides a large surface area support for contaminant capture, while TiO₂ facilitates photocatalytic degradation of NOR under UV or visible light irradiation. In this study, Ver was acid modified using HNO₃, H₂SO₄ and HCl with concentration ranging from 1 to 3M. The soaking time ranged from 1 to 7 days. Modified Ver was used as a TiO₂ carrier by sol-gel method to enhance the efficiency of both photocatalytic and adsorption processes. The properties of the TiO₂/modified Ver material were evaluated using SEM, XRD, and Zeta potential analysis. With increasing soaking time, SEM images reveal that the modified Ver surface becomes more cracked and porous compared to the smooth surface of the original Ver. However, no significant difference was observed with changing soaking time. Additionally, the Ver surface modified with HNO₃ found more uniform porosity and cracks compared to the other used acids. The XRD spectra of TiO₂/modified Ver using HNO₃ 3M showed the strongest and clearest anatase TiO₂ peak compared to the other samples. The TiO₂/modified Ver (soaked for 1 day in HNO₃ 3.0M) also showed better adhesion and a more uniform TiO₂ coating. The Zeta potential of this modified material was the lowest and negative, indicating the strongest reduction in TiO₂ particles electrostatic interaction, resulting in the most stable dispersion and a more uniform surface. The removal efficiency of norfloxacin by Ver was only 20% whereas TiO₂/modified Ver material using H₂SO₄ 3M, HNO₃ 3M and HCl 3M achieved of 74, 60 and 45%, respectively, under fluorescent light with an initial norfloxacin concentration of 20 ppm and a material dose of 2.0g/L after 6.0 hours. The treatment efficiency reached the highest 99% with flow rate 1mL/min.

Introduction

Norfloxacin (NOR), a fluoroquinolone antibiotic, is widely used in aquaculture. In Vietnam, it is among the five most commonly used antibiotic groups in this sector [1]. The risk of NOR entering the environment and affecting human health and aquatic life is high due to its persistence and potential to induce antibiotic resistance. Therefore it is necessary to have studies to evaluate the level of residues in surface water and measures to reduce and handle them. A study conducted in 2016–2017 analyzed wastewater from 39 healthcare facilities and detected NOR in all samples, with an average concentration of $9.6 \pm 9.8 \mu\text{g/l}$ [2]. Integrated livestock farming systems bring economic benefits but also pose a risk of surface water pollution due to antibiotic residues. According to the research results of Le Hung Anh and colleagues in Ben Luc district, Long An province, the existence of antibiotic residues was assessed. In 5 sampling locations, Ap 2 canal detected NOR antibiotic residues at $1.5 \mu\text{g/L}$ [3]. The standard level for antibiotic contamination is often guided by Predicted No Effect Concentrations (PNECs) to prevent ecological adverse effect and the selection of antibiotic resistance. For norfloxacin (NOR), the PNEC for aquatic ecotoxicity, about $0.1 \mu\text{g/L}$ [4]. While Vietnam does not currently have official threshold values for specific antibiotics in surface water. Studies have shown the risk of antibiotic contamination in general and NOR in surface water due to the use and inadequate control of waste sources [5,6]. Norfloxacin was detected in Saigon River water at concentrations of 207.8 - 230.0 ng/L [7]. Many methods have been studied and applied to remove antibiotic residues in the environment such as advanced oxidation (AOP) using ozonation, photolysis, photocatalysis, adsorption, and biology. In particular, the photocatalytic method, using nano titanium dioxide (TiO_2) material, is of great interest because it creates hydroxyl free radicals ($\bullet\text{OH}$) that can completely treat most organic substances, including antibiotic residues [8-12]. Thermally modified kaolin was used as an adsorbent to remove NOR with a fairly high efficiency (88.53%) with the mechanism of creating F, H, O atoms in antibiotics that will covalently bond with O of kaolin and aluminum oxide, hydroxide [13].

Vermiculite (Ver) is a natural mineral with a specific gravity of about 2 to 2.5; Vermiculite in the unswelled state is dark brown or white with different sizes: 0.1 to 0.7 (mm); 0.7 to 2 (mm) [14]. Ver has neutral pH, is very light, has high porosity, contains many minerals such as zinc, aluminum, magnesium and holds water well. However, the Ver surface is quite smooth, so it is difficult to coat the surface with substances, so it is necessary to modify the Ver surface with acid to create a rough surface, to effectively coat TiO_2 by Sol-gel method. The resulting TiO_2 /modified Ver material has both the photocatalytic properties of TiO_2 and the adsorption properties of modified Ver, so it will be a promising material for treating micropollutants such as NOR antibiotics in the water environment. Nano TiO_2 coated on Ver synthesized by the sol-gel process is a super light material, suspended or floating on the water surface, increasing the ability to contact with air and thus further increasing the photocatalytic properties of the material [15]. In the study of Thuong et al. (2024), Co, N-doped TiO_2 immobilized on acid-activated vermiculite was used to remove ciprofloxacin from hospital wastewater. The removal efficiency achieved over 80% thanks to a highly porous and roughened vermiculite surface enhancing photocatalytic degradation [16]. The vermiculite/ TiO_2 composite material prepared by the sol-gel method initially adsorbed organic pollutants (methylene blue) and then underwent photocatalytic degradation by TiO_2 . The photocatalytic efficiency was increased by about 5.3 times compared to the unmodified one and can be applied to treat antibiotics such as NOR. Similarly, the Vermiculite/ TiO_2 composite nanofiber material containing 2wt% vermiculite showed enhanced dual functionality: vermiculite provided the adsorption capacity, while TiO_2 enabled photocatalytic degradation (tested with methylene blue as a model). The optimized nanofibers reached a faster reaction equilibrium and outperformed pure TiO_2 fibers in terms of adsorption-photodegradation synergy [15,17].

Research Methods

Water samples

Norfloxacin water samples were prepared using 1g/L Norfloxacin standard solution and distilled water with an initial concentration of 20ppm. Norfloxacin was purchased from Tokyo chemical Ltd.

Equipment and chemicals

Equipment: The main equipment used in the study is given in Table 1.

Table 1. The main equipment used in the study.

No	Equipment/Apparatus	Specifications	Origin	Laboratory
1	Fluorescent lamp	10W, T8, 60cm, white light	Vietnam	Institute of Energy and Environmental Science – Vietnam Academy of Science and Technology (IEES - VAST)
2	UV lamp	365nm, 8W		
3	Analytical balance	Accuracy 10^{-4} mg ADAM	UK	
4	Heating stove with magnetic stirrer	Hotplate Stirrer Jenway 1000	UK	
5	Furnace	maximum temperature 1000 °C Carbolite	Germany	
6	Ultrasonic vibrator	35 kHz, 225/450W, Bandelin SONOREX Super PR	Germany	
7	Drying oven	INB 500 Memmert	Germany	
8	X-ray diffraction	Siemens - D5000	USA	Institute of Chemistry, VAST
9	High performance liquid chromatography	Shimadzu	Japan	IEES - VAST
10	SEM	Hitachi S-4800 FE-SEM	Japan	Institute of Materials Science, VAST

Chemicals: Tetra isopropyl orthotitanate $\text{Ti}(\text{OC}_3\text{H}_7)_4$ 98% (TTIP) Merck, Germany; Diethanolamine $\text{C}_4\text{H}_{11}\text{NO}_2$ (98%) (DEA), China; Ethanol $\text{C}_2\text{H}_6\text{O}$ (99%) (EtOH) China; HNO_3 , H_2SO_4 and HCl : Merck, Germany.

Method of surface modification of Ver material by acid

Vermiculite (Ver) was modified using HNO_3 , H_2SO_4 and HCl acids with concentration ranging from 1 to 3 M according to the following diagram (Fig. 1) [18-20].

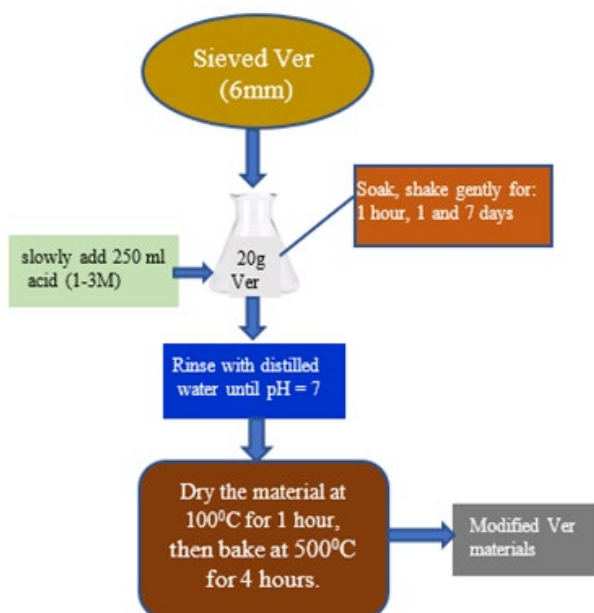


Fig. 1. Ver acid modification process using HNO_3 , H_2SO_4 and HCl (concentration from 1 to 3M).

Coating the modified Ver material with sol nano TiO₂

Procedure for coating the modified Ver material with nano TiO₂ using sol-gel method was as follow [21,22]:

- Weigh 20 g of modified Ver into a 250 mL conical flask, slowly pour 100 mL of TiO₂ sol solution into the flask, mix well. Seal the flask with a cork stopper.
- Shake gently for 1 hour.
- Leave the flask open for a period of time until a milky white gel layer forms on the modified Ver layer.
- Mix well the gel layer + modified Ver.
- Dry at 90°C for 2 hours.
- After drying, the material is baked at 500°C for 30 minutes and 550°C for 3 hours (heating rate 2°C/min) for TiO₂ forms nano-coating on Ver when the sample is calcined.
- After heating, let the nano TiO₂/modified Ver materials cool to room temperature.

Investigation of NOR removal ability of TiO₂/modified Ver material

Assessment of the NOR degradation (removal) efficiency of the TiO₂/modified Ver material under visible light is convenient in laboratory scale system (Fig. 2) based on the previous studies [23,24]. For each experiment, 2 g of photocatalyst were packed into a quartz tube (1 cm inner diameter, 20 cm length), which was illuminated using a T8 LED lamp (60 cm, 10 W, Rang Dong, Vietnam) as the visible light source. A 2-liter aqueous solution containing 20 ppm norfloxacin was placed in a reservoir and continuously circulated through the system using a diaphragm water pump at flow rates of 1.0; 1.5 and 2.0 mL/min up to 25 hours based on the previous study [16]. The concentration of NOR in the water samples was quantified using high-performance liquid chromatography (HPLC, Shimadzu LC-10AD vp, Japan) equipped with a C18 Resteck column (4.6 × 150 mm) and a UV-Vis SPD-10A detector set at a wavelength of 280 nm [25].

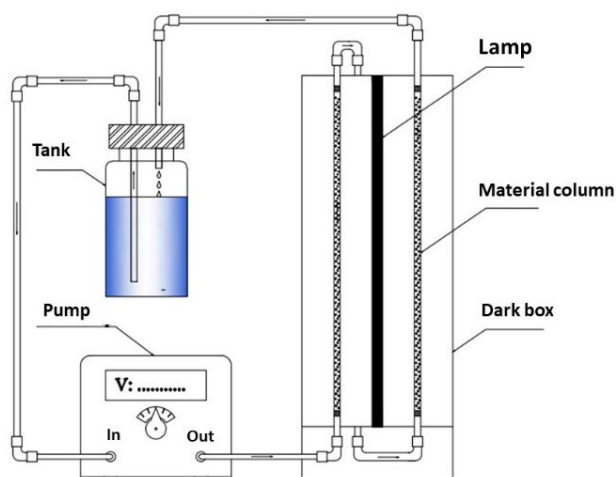


Fig. 2. Schematic diagram of experimental system to evaluate the efficiency of NOR degradation (removal) by fabricated materials.

Results and Discussion

Morphology of modified Ver and nano TiO₂/modified Ver material

Based on the previous research where soaking time investigated was 5-7 days [26] and the study of Herrera & Aylón (2019) which reported that the optimal soaking time is 1-2 days [27], in this study, the soaking times chosen were 1-7 days. The finding showed a clear difference was seen between days 1 and 7 so only these results were presented (figure 3,4). SEM images (Fig. 3) of the control (unmodified VER material (Fig. 3a) and soaked in HNO₃, H₂SO₄ and HCl 3M acids (Fig. 3b-d). As shown in Fig. 3a, the surface of the Ver material is smooth, making it difficult to coat TiO₂ on the surface, while Fig. 3b,c and d show that the surface of the Ver material shows signs of cracking,

peeling and roughness after 1 day of soaking in acid solution. When increasing the soaking time from 1 day to 7 days, the results show that the Ver surface becomes more cracked, porous and rough (Fig. 3e-g). The porosity and cracking of the Ver soaked in HNO_3 solution are more uniform than those of other acids. However, when increasing the soaking time to more than 7 days, the change is insignificant, so in the next study, the soaking time will be chosen as 1 day. In addition, for all 3 acids, the results showed that the best Ver surface modification was when used at the highest acid concentration 3M. The acid modification of Ver is a time-dependent process involving cation exchange and dehydroxylation. Soaking Ver in strong acids (HNO_3 , H_2SO_4 , or HCl) replaces interlayer cations (Mg^{2+} , Ca^{2+} , K^+) with H^+ , increasing surface area and porosity while leaching structural cations (Al^{3+} , Fe^{3+}) and reducing cation exchange capacity (CEC). The reaction typically follows pseudo-first- or pseudo-second-order kinetics: a rapid phase (1–3 hours) involves ion exchange and surface dissolution, followed by a slower phase (up to 24–48 hours) with deeper structural degradation. A 1-day soaking time was chosen in this study to balance effectiveness and prevent excessive leaching or collapse [27].

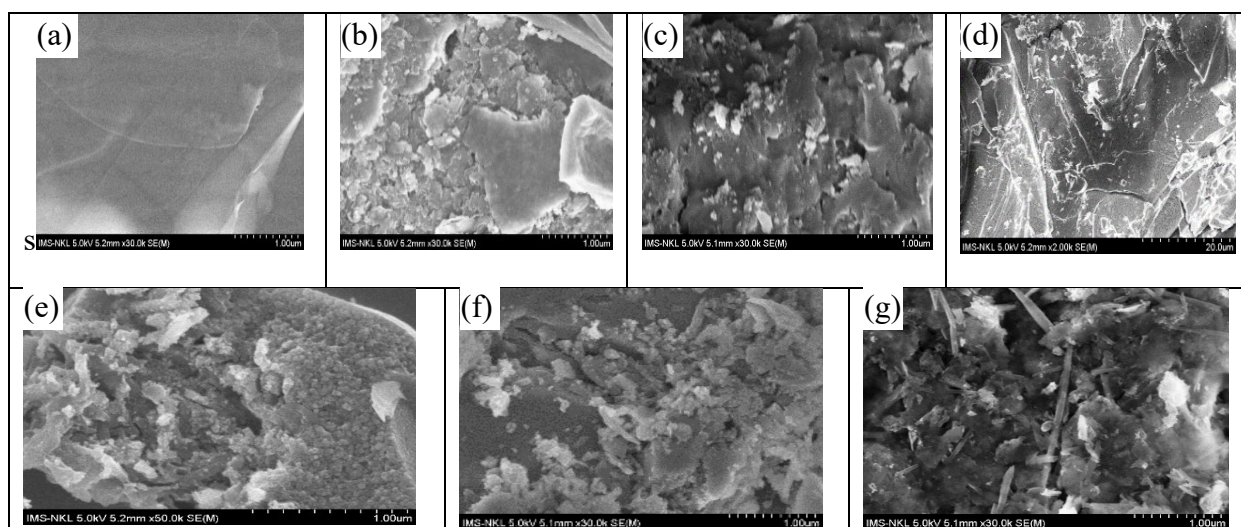


Fig. 3. SEM images of modified VER when VER was modified in acids with different soaking times: Control- unmodified VER material (a); Modified Ver – HNO_3 3M, 1 day (b); Modified Ver – H_2SO_4 3M, 1 day (c); Modified Ver, HCl 3M, 1 day (d); Modified Ver - HNO_3 3M, 7 days (e); Modified Ver – H_2SO_4 3M, 7 days (f) and Modified Ver – HCl 3M, 7 days (g).

For nano TiO_2 /Ver materials and the nano TiO_2 /modified Ver coating when Ver was soaked in acid solution for 1 and 7 days, there was a significant difference in adhesion and TiO_2 coating density. Fig. 4a-c are SEM images of nano TiO_2 /Ver samples soaked for 1 day, acid concentration was 1M and Fig. 4d-f soaked for 7 days in HNO_3 , H_2SO_4 and HCl 1M solutions, respectively. However, the obtained TiO_2 crystals had a more uniform and dense adhesion on the Ver surface when Ver was soaked in HNO_3 3M. This means that the TiO_2 crystals will have high quality and good photocatalytic activity.

The results showed that the modified Ver was a suitable substrate material for TiO_2 , with the surface displaying small round particles with a grain size of 5 to 10 nm, uniformly distributed on the Ver surface. Some rod-shaped crystals with a size from $10 \times 10 \times 50$ to 500 nm were presented after 7-day soaking (see Fig. 4d-f). The rough surface of the material enhanced the adhesion and contact of the catalyst material and pollutants in the aquatic environment.

XRD analysis of unmodified raw Ver and nano TiO_2 /modified Ver material

The XRD patterns of nano TiO_2 /Ver samples are illustrated in Fig. 5. The high peak at $2\theta = 6.28^\circ$ related to vermiculite (0,0,2) phase of $\text{Al}_{0.721}\text{Fe}_{0.24}\text{H}_3\text{Mg}_{1.338}\text{O}_9\text{Si}_{1.36}$ composition. For the TiO_2 /Ver samples, the significant diffraction peak at 25.4° can be clearly observed, which is indexed to the (101) plane of TiO_2 anatase (Figure 5c-e). After treating Ver with HNO_3 , H_2SO_4 , or HCl , the peak positions remained unchanged, but the intensity of the TiO_2 anatase peaks increased compared to the

corresponding peaks observed for the unmodified samples. Additionally, the diffraction peak at 25.4° of Ver treated with HNO_3 was slightly narrower than those of other acid treatments, suggesting that this acid might be suitable for preparing Ver support.

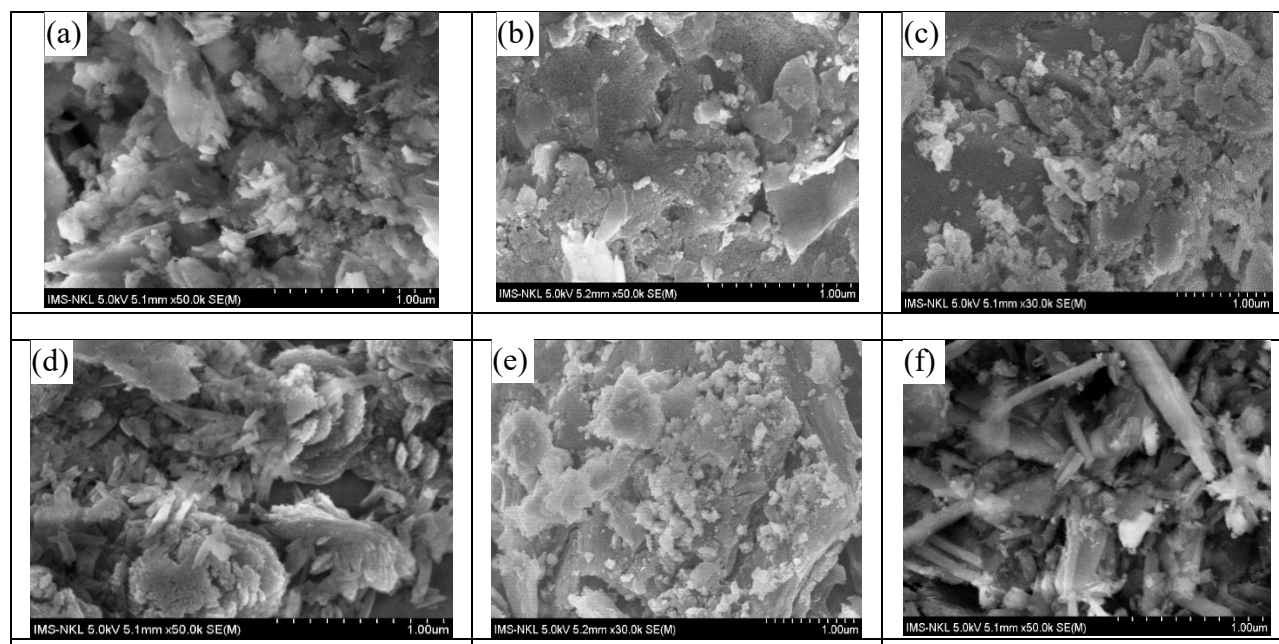


Fig. 4. SEM images of Nano TiO_2 / modified Ver using 3 acids with different soaking times: Nano TiO_2 /modified Ver - HNO_3 1M, 1 day (a); Nano TiO_2 /modified Ver – H_2SO_4 1M, 1 day (b); Nano TiO_2 /modified Ver - HCl 1M, 1 day (c); Nano TiO_2 /modified Ver - HNO_3 1M, 7 days (d); Nano TiO_2 /modified Ver – H_2SO_4 1M, 7 days (e) and Nano TiO_2 /modified Ver - HCl 1M, 7 days (f).

For the nano TiO_2 /Ver sample modified in H_2SO_4 environment, the TiO_2 peak intensity in the samples is almost similar, insignificant difference is seen in both concentration of H_2SO_4 . For the HCl solution, it is also similar, the anatase TiO_2 /Ver peak intensity in the samples modified at different acid concentrations are all insignificantly different. Comparing the 3 acidic environments (HNO_3 , H_2SO_4 and HCl), XRD analysis shows that HNO_3 significantly increases the intensity of the TiO_2 anatase peaks in the modified TiO_2 /Ver sample, while HCl and H_2SO_4 do not show significant improvements in these intensities. The results in Fig. 5 also show that the TiO_2 / modified Ver using HNO_3 3M is the most promising, the anatase TiO_2 peak intensity is the strongest and clearest compared to the remaining samples.

Zeta measurement

Use the Zeta measurement method in this study to evaluate the stability of the interaction between particle and solution. As can be seen in Table 2, the nano TiO_2 /modified Ver materials using HNO_3 3M with the most negative zeta values. This means that the TiO_2 /modified Ver material- HNO_3 3M for the lowest zeta value, the stronger the electrostatic repulsion between particles, leading to better dispersion stability in the solution [28]. The negative zeta potential of the material is also consistent with the results of some previous studies related to materials fabricated from modified Ver. In the study of Turan Uysal, the zeta potential of unmodified Ver and hexylamine-modified vermiculite (HEX-Ver) was measured across a pH range of 2 to 11.

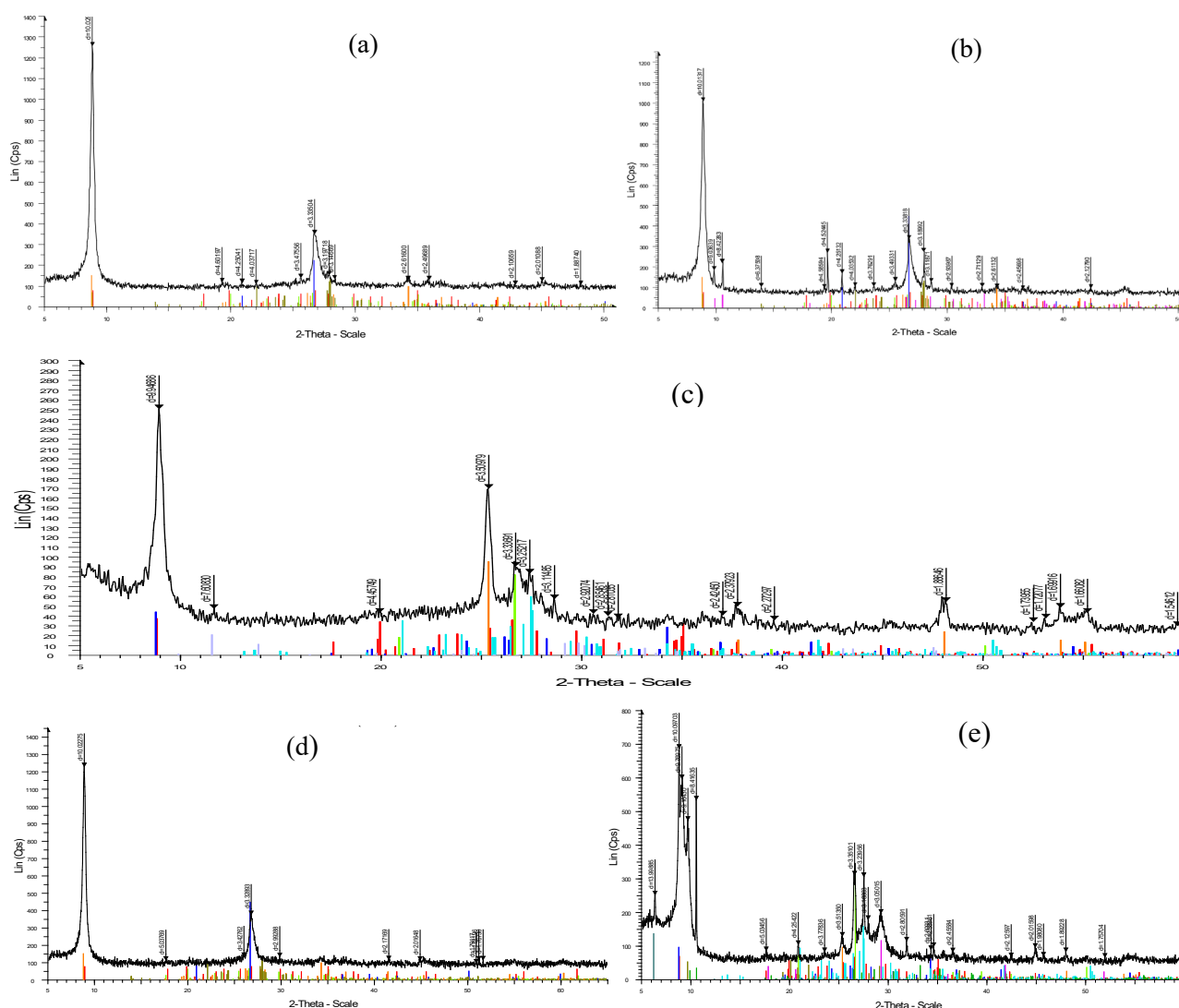


Fig. 5. XRD pattern of raw Ver before modification (a), XRD pattern of nano TiO₂/Ver (b) and nano TiO₂/1-day modified Ver by HNO₃ 3M (c), H₂SO₄ 3M (d) and HCl 3M (e).

The results demonstrated that both materials exhibited consistently negative zeta potentials throughout the entire pH range, with values ranging from -8 to -34 mV for Ver and from -18 to -39 mV for HEX-Ver. These findings suggest that surface modification with hexylamine increased the magnitude of the negative surface charge but did not substantially alter the overall charge characteristics of vermiculite [29]. When TiO₂ absorbs light in HNO₃ solution, the electrons generated during the photocatalytic process can be oxidized by HNO₃, preventing the recombination of electrons and holes. This increases the efficiency of the photocatalytic process (corresponding to the increased anatase peak intensity) compared to that in other acid solutions. Meanwhile, HCl can generate Cl⁻ ions that affect the crystallization of TiO₂ due to complexation with titanium precursors, resulting in lower crystallinity or amorphous structure; H₂SO₄ can lead to the formation of surface sulfate groups, which can also affect the growth of anatase [30].

Additionally, a study on TiO₂/SiO₂ composites reported that unmodified TiO₂ exhibited zeta potential values ranging from $+8$ to -48 mV across a pH range of 1.7–11, with an isoelectric point at pH 4.9. This indicates that TiO₂ can exhibit both positive and negative surface charges depending on the pH, which is crucial for understanding its interaction with pollutants in photocatalytic applications [31].

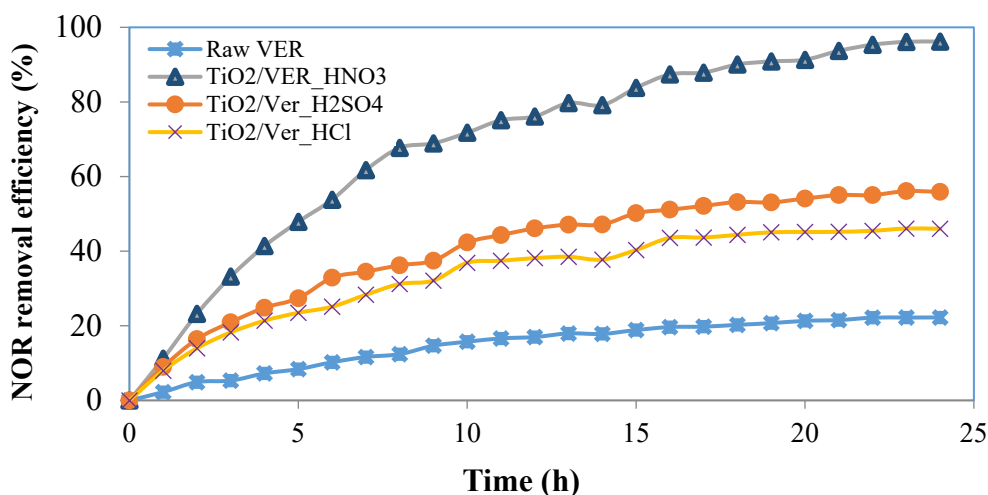
Table 2. Zeta value of TiO₂/raw Ver and TiO₂/modified Ver materials using HNO₃ at different concentrations.

Materials	Zeta potential (mV)	Zeta deviation (mV)	Conductivity (mS/cm)
TiO ₂ /VER	-29.5	8.44	0.0055
TiO ₂ /VER HNO ₃ 1M	-24.1	45.6	0.00857
TiO ₂ /VER HNO ₃ 2M	-25.2	49.8	0.0097
TiO ₂ /VER HNO ₃ 3M	-34.8	8.28	0.00417

The negative zeta potential of TiO₂/modified vermiculite composites suggests that these materials are stable in suspension and less likely to aggregate, which is beneficial for photocatalytic processes. The surface charge influences the adsorption of pollutants and the overall efficiency of the photocatalytic degradation. Understanding the zeta potential is essential for optimizing the performance of these composites in environmental remediation applications [32].

The effectiveness of NOR removal of nano TiO₂/modified Ver materials

Testing the effectiveness of NOR removal using unmodified (raw) Ver materials, nano TiO₂/modified Ver_HNO₃ 3M; nano TiO₂/modified Ver_H₂SO₄ 3M and nano TiO₂/modified Ver_HCl 3M under fluorescent light conditions is shown in Fig. 6. The carrier material is Vermiculite with a large specific surface area, capable of absorbing NOR well, so it is necessary to investigate the change in concentration over time under fluorescent lighting conditions and dark conditions. The results showed that the TiO₂ material covered on Ver modified with all 3 acids gives significantly higher removal efficiency than unmodified Ver materials. In which, nano TiO₂/modified Ver_HNO₃ 3M material shows the superiority, for the highest efficiency reaching about 60 and over 90% after 7 and 20 hours, respectively, about 2 times higher than that of nano TiO₂/modified Ver materials in H₂SO₄ and HCl 3M. This study showed higher NOR removal efficiency but with longer time than the study of Senem Yazici Guvenc *et. al* (2023) [33]. In their study, under optimal conditions—specifically, 1 mg/L initial NOR, 4 mM sodium percarbonate (SPC), pH 3, and 50 minutes for the UV-SPC system; and 1 mg/L initial norfloxacin, 1 mM sodium hypochlorite (SHC), pH 7, and 8 minutes for the UV-SHC system—the removal efficiencies were 71.8 and 72.1% for UV-SPC and UV-SHC, respectively.

**Fig. 6.** The NOR removal efficiency of nano TiO₂/modified Ver materials versus treatment time.

The flow rate across the NOR column containing 2 g of the preparation material had a significant effect on the efficiency of the process (Fig. 7). At a flow rate of 1 mL/min, the treatment efficiency was stable at around 80-99% for up to 6 hours, then the efficiency decreased slightly to 75% at 9 hours. The developments for the remaining two flow rates (1.5 and 2 mL/min) showed a similar trend, however the NOR removal efficiency of nano TiO₂/modified Ver-H₂SO₄ 3M was found higher than that of nano TiO₂/modified Ver-HCl 3M, reached 51 and 32% after 6 hours, respectively. This performance is quite similar to that of TiO₂/graphene oxide composites in the study of Liu *et al.* (2020), in which the NOR removal capacity using Fe₂O₃/g-C₃N₄ reached 86.7–94.7% under visible

light and ultrasound [34]. Similarly, the NOR degradation capacity of $\text{Ln}_2\text{O}_3/\text{TiO}_2$ heterostructure under visible light reached 100% after 10 min with an influent Nor concentration of 20 mg/L [35]. However, these studies were conducted in batch reactors, while the present study used a continuous flow system, which is more suitable for practical wastewater treatment. In addition, the NOR removal efficiency decreased with material reuse as in the study of Li et al. (2024), the Nor removal efficiency of Z-type heterojunction photo-catalyst $\text{Pg-C}_3\text{N}_4$ (PCN)/Nitrogen doped biochar (N-Biochar)/ BiVO_4 decreased from 92.5 to 75% after 4 reuses of the material [36].

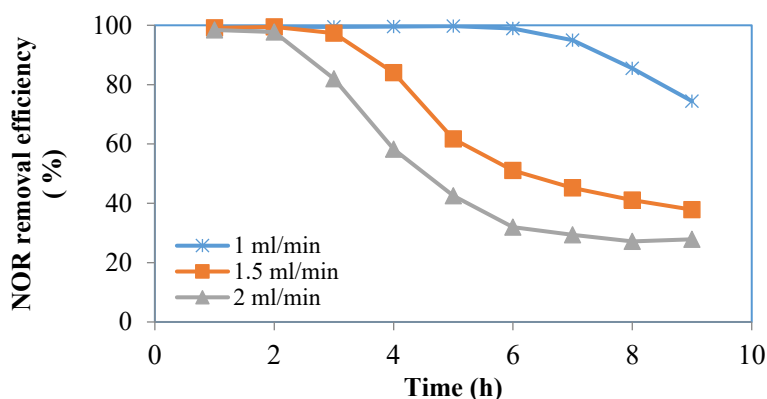


Fig. 7. The efficiency of NOR removal depends on the flow rate through the column using nano TiO_2 /modified Ver- HNO_3 3M.

The NOR removal efficiency obtained is as high as that of some other modified materials used. The electro sorption performance of modified activated carbon fiber felt (MACFF) for NOR and the factors influencing this process were systematically investigated. Activated carbon fiber felt (ACFF) was modified using 20% nitric acid. Under optimal conditions (a voltage of 1.0 V, a solution pH of 6, and an electrode spacing of 10 mm) the maximum adsorption capacity of MACFF for NOR reached 128.55 mg/g [37]. An airlift-electrocoagulation (AL-EC) reactor was applied to remove NOR from aqueous solutions. The optimal removal efficiency (reached 93.5%) was achieved using an iron anode and aluminum cathode, with a current density of 2 mA/cm², initial pH of 7, treatment duration of 32 minutes, and an air flow rate of 200 mL/min [38]. The efficiency achieved in our study was higher than that of Adnan et. al. (2024). Under visible light conditions, using carbon-doped TiO_2 (C- TiO_2) fabricated via sol-gel method, which can remove 74-81% (initial concentration 100ppm after 2.5 hours) [39]. The mechanism of action of NOR removal in aqueous environment is given as follows: modified vermiculite or clay acts as an adsorbent, concentrating NOR on its surface. Nano- TiO_2 coating provides photocatalytic activity. This synergistic effect enhances NOR removal by Increasing local concentration of NOR near photocatalyst sites, stabilizing TiO_2 particles and improving dispersion and allowing continuous adsorption–degradation cycles [40].

Conclusion

Modified Ver material using HNO_3 , H_2SO_4 and HCl acids, has suitable properties as a carrier for nano TiO_2 coating. The most suitable soaking time was determined as 1 day. The results of material characterization by SEM, XRD and Zeta potential analysis showed that the fabricated material has adsorption and photocatalytic properties. The fabricated nano TiO_2 /modified Ver material using HNO_3 3M has a rough surface, uniform porosity and cracks, and better adhesion than other acids. The XRD spectrum of nano TiO_2 /Ver modified using HNO_3 3M also shows the strongest and clearest anatase TiO_2 peak compared to other samples. The Zeta potential of this modified material is the lowest and negative, indicating the strongest reduction in the electrostatic interaction of TiO_2 particles, leading to the most stable dispersion and more uniform surface. The removal efficiency of NOR by nano TiO_2 /Ver material modified using HNO_3 3M; H_2SO_4 3M and HCl 3M achieved 74, 60 and 45%, respectively, under fluorescent light with an initial NOR concentration of 20 ppm and a material dosage of 2g/L after 6 hours, significantly increasing compared to unmodified Ver (only 20%). With a flow rate of 1mL/min, the efficiency reached 99% after 6 hours. In the next study, the

efficiency of NOR removal under sunlight will be investigated to evaluate the feasibility of practical application and the influence of some environmental factors: pH, temperature, presence of ions or other organic compounds on the efficiency of NOR treatment will be studied to optimum the process.

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