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Xueming Chen *Editor*

New Developments in Environmental Science and Engineering

Proceedings of the 2025
15th International Conference
on Environmental Science and
Engineering (ICESE 2025; September
19–21, 2025; Yokohama, Japan)

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Xueming Chen
Editor

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Editor

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Preface

We are delighted to welcome you to the proceedings of the 2025 15th International Conference on Environment Science and Engineering (ICESE 2025), held in Yokohama, Japan, on September 19–21, 2025. This conference provided a vital platform for researchers and practitioners from diverse scientific disciplines to exchange ideas, present cutting-edge advancements, and explore future trends in environmental science and engineering.

The conference featured four distinguished keynote speeches and two invited speeches delivered by renowned experts: Prof. Mikio Ishiwatari (Meiji University, Japan), Prof. Kaimin Shih (The University of Hong Kong, China), Prof. Guangwei Huang (Sophia University, Japan), Prof. Byoung Ryong Jeong (Gyeongsang National University, Republic of Korea), Dr. Hai-Hsuan (Henry) Cheng (National Cheng Kung University, Taiwan, China), and Assoc. Prof. Qiang Wang (Beijing Normal University, China). We extend our deepest gratitude to these speakers for their insightful and inspiring contributions, which greatly enriched the discussions and set a productive tone for the conference.

ICESE 2025 attracted a global audience, with participants from Japan, Turkey, Australia, Nigeria, Indonesia, Thailand, South Korea, China, Sri Lanka, Malaysia, India, Chile, Saudi Arabia, the USA, and South Africa.

All submitted papers underwent a rigorous peer-review process. The accepted papers are compiled in this proceedings volume, organized into five thematic parts:

1. Sustainable Architectural Design Strategies and Performance Optimization.
2. Energy Efficiency and Emission Mitigation Technologies.
3. Environmental Pollutant Exposure and Health Risk Assessment.
4. Waste Valorization and Circular Economy.
5. Innovative Water Treatment Technologies and Water Resources Management.

We hope this volume serves as a valuable resource for researchers and practitioners, inspiring further innovation in environmental science and engineering.

We sincerely thank all the authors for their high-quality contributions, the program committee members for their expertise and constructive feedback, and the organizing team for their tireless efforts in ensuring a seamless and successful event.

Fuzhou, China

Xueming Chen
Proceedings Editor

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Sustainable Architectural Design Strategies and Performance Optimization

Valorization of Coconut Shell-Derived Photocatalyst for Ammoniacal Nitrogen Removal from Wastewater



Samuel Xiang Ching Tie, Nurul Ashraf Razali, Ibrahim Yakub,
Siti Kudnie Sahari, Cirilo Nolasco-Hipólito, and Yanping Qu

Abstract Biomass waste can serve as a sustainable support material for photocatalysts in wastewater treatment, simultaneously addressing waste valorization and pollution remediation. In this study, coconut shell was converted into activated carbon (AC) and composited with titania (CSAC/TiO₂) via a sol–gel method to remove ammoniacal nitrogen. The characterization using Scanning Electron Microscope (SEM) revealed that tiny TiO₂ particles are attached at the external surface of the CSAC, whereas the Fourier-Transform Infra-Red (FTIR) analysis exhibited the formation of Ti–O–C bonds over the photocatalyst surface. It was found that the initial concentration of ammoniacal nitrogen pH of the wastewater and ultraviolet irradiation time are crucial to the photocatalytic activity. The maximum removal of 88% was obtained at 5 mg/L initial concentration, pH 10 and 30 min contact time. Furthermore, kinetic studies indicated the adsorption process is chemisorption, fitting the pseudo-second-order model at low concentrations and pseudo-first-order at high concentrations. The findings showed that coconut shell activated carbon doped with TiO₂ can be utilized as a photocatalyst for ammoniacal nitrogen removal that demonstrates a viable alternative use of abundant coconut waste.

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Keywords Biomass · Activated carbon · Ammoniacal nitrogen

1 Introduction

Rapid urbanization, industrialization, and rising living standards have led to increased generation of municipal solid waste (MSW), resulting in environmental issues and challenges related to its disposal [1]. Nowadays, each person generated an average of 1.17 kg of waste per day. In 2021, Malaysia's population was approximately 32.7 million, with a growth rate of 0.2%. A significant portion of the MSW, around 44.5%, consisted of food waste [2]. When solid waste undergoes physicochemical transformations and microbial processes, it produces a concentrated liquid known as leachate, which contains high levels of humic substances, ammoniacal nitrogen, sulfate, phosphate, heavy metals, and suspended solids [3, 4]. The elevated concentration of ammoniacal nitrogen in leachate poses risks to aquatic life, making its treatment essential for addressing environmental concerns [5].

Several methods exist for removing ammoniacal nitrogen from leachate and other wastewater, including biological, chemical, and physical techniques such as membrane filtration, chemical precipitation, oxidation, coagulation, adsorption, ion exchange, and air stripping [3, 6]. Zhou and co-workers reviewed the advantages and disadvantages of chemical precipitation, adsorption, and biological methods for removing $\text{NH}_3/\text{NH}_4^+$ from wastewater [7]. Biological processes are among the most effective technologies for ammonium ion removal, achieving efficiencies of approximately 17–99%. However, their effectiveness decreases at high concentrations of ammoniacal nitrogen [6, 7]. Other solutions for ammoniacal nitrogen issues in leachate include membrane filtration and electrochemical treatment. The main challenges of membrane filtration are membrane fouling and high operational and maintenance costs, while electrochemical treatment is limited by high energy consumption [8].

Photocatalysis, a type of advanced oxidation process (AOP), utilizes light energy to generate reactive free radicals that convert stable toxic compounds into biodegradable or less harmful substances [9], ultimately reaching acceptable concentration levels. Titanium dioxide (TiO_2) is commonly used for photocatalytic reactions due to its excellent photoactivity, affordability, chemical and biological inertness, and non-toxicity [10]. Mishra and co-workers demonstrated that CaTiO_3 nanoparticles could achieve 35.71% ammoniacal nitrogen removal from leachate [8]. Additionally, Li et al. reported over 90% ammoniacal nitrogen removal using Al and N-doped carbon/nano- TiO_2 photocatalytic oxidation [9], while a TiO_2 /perlite photocatalyst achieved 64.3% ammoniacal nitrogen removal [11].

Biochars and waste materials can be produced from readily available and low-value biomass residues. Agricultural waste accounts for 91% of all biomass, and Malaysia produces approximately 160 million tons of biomass annually, including oil palm waste, coconut waste, rice husks, sugarcane waste, and municipal waste [12]. As the world's tenth largest coconut producer, with 540,000 tons, Malaysia has

significant potential to convert coconut waste into a catalyst source [13]. According to Kuok et al., activated carbon from coconut shells effectively treated river water, removing ammoniacal nitrogen and total suspended solids [14]. TiO_2 /coconut shell activated carbon photocatalysts have also been used for the degradation of methylene blue [15]. Shi et al. studied the degradation of methylene blue using TiO_2 /sludge-derived activated carbon composites, achieving 70.13% and 95.48% removal rates through physical mixing and hydrothermal methods, respectively [16]. TiO_2 supported on coffee husk activated by CaCl_2 successfully enhanced the photocatalytic degradation of Victoria Blue B dye by over 96% [17].

While there has been significant research on activated carbon/ TiO_2 photocatalysts for dye removal, there is limited work on their use for ammoniacal nitrogen removal in leachate treatment. To address this research gap, this study focuses on the synthesis and characterization of a coconut shell activated carbon (CSAC) composite doped with TiO_2 (CSAC/ TiO_2) and evaluates its efficacy for the photocatalytic removal of ammoniacal nitrogen. The composite was synthesized via sol-gel method and characterized using scanning electron microscopy (SEM) and Fourier-transform infrared spectroscopy with attenuated total reflectance (FTIR-ATR) to elucidate its morphology and surface functional groups. Photocatalytic performance was assessed by treating synthetic landfill leachate in a controlled, UV-irradiated batch reactor, with operational parameters such as initial pollutant concentration and pH being rigorously evaluated. Furthermore, the reaction kinetics were quantitatively analyzed by fitting experimental data to established pseudo-first-order and pseudo-second-order models to determine the underlying removal mechanisms.

2 Materials and Methods

2.1 Materials

Activated carbon prepared from coconut shell was obtained from a local supplier in Sarawak, Malaysia. The activated carbon was ground and sieved at < 600 nm mesh size. Titania (TiO_2) (Douglas P25), titanium (IV) isopropoxide ($\text{Ti}(\text{OCH}(\text{CH}_3)_2)_4$), ethanol ($> 99.5\%$), ammonia solution (25%), sodium hydroxide ($> 97\%$), and hydrochloric acid (36%) were purchased from Sigma Aldrich (Malaysia).

2.2 Preparation of Coconut Shell-Based CSAC/ TiO_2

The coconut shell-based CSAC/ TiO_2 was prepared using sol-gel method in the manner reported by Zhang et al. [18]. 25 g of pristine activated carbon (CSAC) was immersed in 50 mL ethanol. 25 mL of titanium (IV) isopropoxide ($\text{Ti}(\text{OCH}(\text{CH}_3)_2)_4$) was mixed in 20 mL of distilled water, and the solution was gently stirred and placed

in an ice-water bath. The solution was then mixed with 30 mL of distilled water followed by the ethanol mixture. Dropwise addition of ammonia was continuously added until it reaches pH 10. The mixture was stirred at 80 °C for 2 days until the solvent was evaporated. The precipitate formed was collected, and dried at 300 °C for 2 h. Then, the catalyst was calcined in a nitrogen ambient at 600 °C for 4 h using multi-position mini tube furnace BSG-1200X (Berkeley Scientific, USA), and denoted as CSAC/TiO₂.

2.3 Catalyst Characterization

Information of the surface morphology was obtained via scanning electron microscopy (SEM) TM4000Plus (Hitachi, Japan) for the AC, TiO₂ and CSAC/TiO₂ photocatalysts with magnification between 50–100 μm . All three samples were also characterized in terms of the surface functionalities via Fourier-transform infrared spectroscopy—Attenuated Total Reflectance (FTIR-ATR) (Shimadzu IRAffinity 1S). In this analysis, the sample was pressed against the ATR crystal that transmits a beam of IR light over a range of 400–4000 cm^{-1} wavenumber. This information is crucial to identify chemical bonds and structures over the material's surface (depth of 2 μm).

2.4 Catalyst Activity

The ability for the catalyst to remove ammoniacal nitrogen was investigated in a closed batch reactor with magnetic stirrer. 1 M ammonia solution was used as a synthetic wastewater containing ammoniacal nitrogen, diluted using distilled water to 5, 10, 15, 20 mg/L. 0.25 M NaOH and 0.25 M HCl were added to adjust the pH. In all experiment, 0.5 g of sample was added into the synthetic wastewater solution, and stirred under ultraviolet lamp in a specified time. The concentration of ammonia was measured initially, and for every 10 min using DR900 colorimeter (HACH) and salicylate test method. The removal efficiency was calculated as in Eq. 1.

$$\text{Removal efficiency (\%)} = (C_0 - C_e) / C_0 \times 100\% \quad (1)$$

where, C_0 is the concentration of ammoniacal nitrogen at initial state (mg/L); and C_e is the concentration of ammoniacal nitrogen at equilibrium state (mg/L).

The data obtained from the ammoniacal nitrogen removal experiments were analyzed for kinetic study. The kinetics of ammoniacal can be expressed in accordance to the equations of pseudo-first order model and pseudo-second order models, shown by Eqs. 2 and 3, respectively.

$$\log(q_e - q_t) = \log q_e - k_1 t \quad (2)$$

$$t/q = 1/(k_2q_e) - 1/q_e \quad (3)$$

where, q_e is the amount of adsorption at the equilibrium; q_t is the amount of adsorption at time t ; k_1 is the pseudo-first order kinetic constant; and k_2 is the pseudo-second order kinetic constant.

3 Results and Discussions

3.1 Characteristics of Catalysts

The SEM images of coconut shell AC, TiO_2 and CSAC/ TiO_2 are shown in Fig. 1. It is seen as an overall granule that the coconut shell AC is relatively smooth with tiny pores appearing on the surface of the coconut shell AC (Fig. 1a), similar to the work done by Anisuzzaman et al. [19]. Powdered TiO_2 on the other hand (Fig. 1b), has grainy boundaries and exhibits agglomeration appearance. However, for CSAC/ TiO_2 , tiny TiO_2 granules can be observed to adhere at the external surface of AC and showing irregular spiky structure as shown in Fig. 1c.

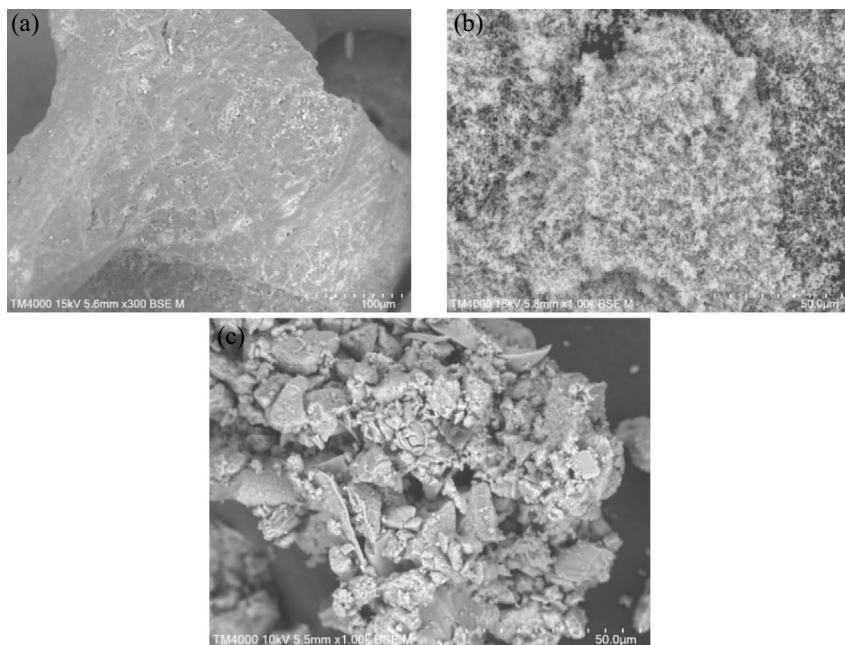


Fig. 1 SEM micrographs of; **a** coconut shell AC; **b** TiO_2 ; and **c** CSAC/ TiO_2

Figure 2 shows a comparison between three different FTIR spectra of AC, TiO_2 and CSAC/ TiO_2 . The appearance of a sharp peak near 3750 cm^{-1} for coconut shell AC suggests a free (non-H-bonded) O–H, as was also reported by Dai et al. over coal [20]. Additionally, the C=O stretching vibration in the carboxylic groups is responsible for a minor band seen at 1690 cm^{-1} , and a strong band at 1580 cm^{-1} is ascribed to C=C stretching variation in aromatic rings, which is common for an activated carbon. In general, these bonds are observed to reduce or disappear over CSAC/ TiO_2 due to the anchoring of TiO_2 particles. In addition, CSAC/ TiO_2 and TiO_2 contain similar surface functional groups especially the TiO_2 characteristic bands. Ti–O–Ti bonding is represented by the band around 600 cm^{-1} observed in both samples [21]. However, CSAC/ TiO_2 showed weaker peaks around 600 cm^{-1} due to less crystallinity and formation of other bond such as Ti–O–C. Chobchun et al. (2020) reported that the electron affinity of C and Ti–O is illustrated by peak intensity [21]. Moreover, Gain et al. reported that CO stretching bands in metal carbonyl complexes typically appear at $1900\text{--}2100\text{ cm}^{-1}$, as can be seen for CSAC/ TiO_2 [22].

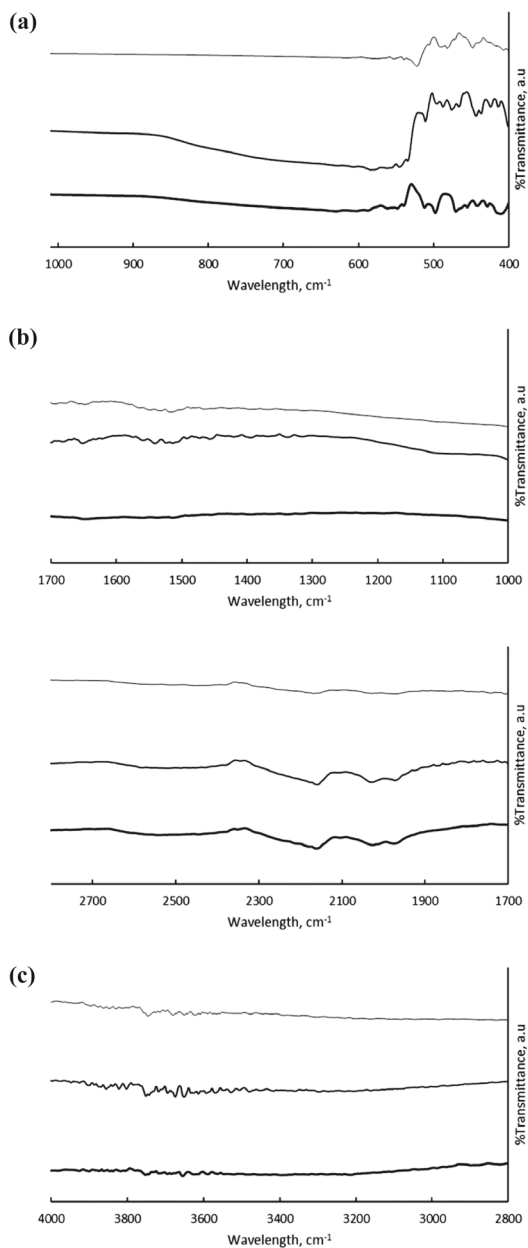
3.2 Ammoniacal Nitrogen Removal by the Catalysts

The effects of initial ammonia concentration on the removal efficiency in synthetic wastewater are presented in Fig. 3. It was observed that the initial concentration has significant impacts on the removal, where high removal efficiency was observed upon the introduction of low initial concentration of ammonia (5 mg/L), followed by 10, 15 and 20 mg/L. The removal efficiency has reached up to 88% after 30 min of reaction. At higher initial concentration (20 mg/L), the removal efficiency is slightly lower, 74%, in contrast to the other concentrations. Hamzah and co-worker reported that only 55% removal efficiency of ammonia (from aquaculture wastewater) was observed at 30 min upon employing hydroxyapatite as the adsorbent. Then, the removal efficiency of ammonia has been increased to 80% after 240 min [23].

The performance of CSAC/ TiO_2 to remove ammoniacal nitrogen was tested in the pH range of 5–10 as shown in Fig. 4. The ammoniacal nitrogen removal capacity was strongly affected by the solution pH. The maximum amount of removal efficiency of ammoniacal nitrogen after 30 min was observed when the pH was unaltered, i.e. pH 10. When acid was added to adjust the pH, the removal efficiency reduced, down to 10% for pH 5 and pH 7. In acidic environment, the surface of the catalyst became positively charged, preventing adsorption over the surface due to electrostatic repulsion with ammonium ions. This causes the fluctuation in removal efficiency throughout the reaction time. On the other hand, in basic environment, the production of hydroxyl radicals is faster favoring photodegradation, as seen for pH 10 [24, 25].

Table 1 shows the kinetic parameters and the calculated constants, while Fig. 5 shows the results of the linearized fits of both pseudo-first and pseudo-second order kinetic models. The pseudo-first order kinetic adsorption model assumes that the diffusion step controls the adsorption process, whereas the pseudo-second order

Fig. 2 FTIR spectra of AC, TiO₂ and AC/TiO₂ at;
a 400–1600 cm⁻¹;
b 1600–2800 cm⁻¹; and
c 2800–4000 cm⁻¹



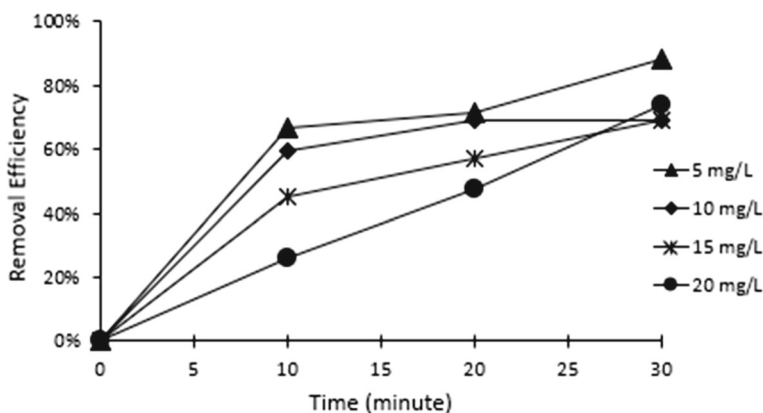


Fig. 3 The ammoniacal nitrogen removal efficiency by CSAC/TiO₂ under UV- irradiation at different initial concentrations, at unaltered pH within 30 min

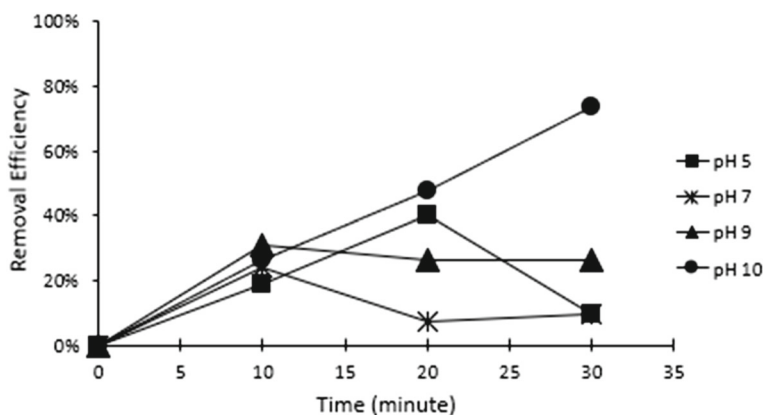


Fig. 4 The ammoniacal nitrogen removal efficiency by CSAC/ TiO₂ under UV- irradiation with different pH, in 20 mg/L initial concentration within 30 min

kinetic adsorption model assumes that the chemical adsorption step controls surface adsorption process [26].

When comparing the correlation coefficients (R^2) at low initial concentrations (5 and 10 mg/L), R^2 values for the pseudo-second order kinetic model are higher than 0.95, which indicates it fits better the ammoniacal nitrogen removal employing CSAC/TiO₂ in contrast to the pseudo-first order. This observation implies that, at these low concentrations, the adsorption process is primarily governed by chemical interactions, where the rate of occupancy of adsorption sites is proportional to the square of the number of unoccupied sites, indicative of a second order kinetics behavior. However, at higher concentration (20 mg/L), the reaction fits the pseudo-first order kinetic model, where the $R^2 = 0.89$. This shift suggests that the adsorption

Table 1 Parameters on the kinetics of removal of ammoniacal nitrogen exhibited by CSAC/TiO₂

Concentration (mg/L)	Pseudo-first order			Pseudo-second order		
	q _e (mg/g)	k ₁ (h ⁻¹)	R ²	q _e (mg/g)	K ₂ (g/mg h)	R ²
5	0.243	6.139	0.004	1.824	0.318	0.969
10	0.192	8.603	0.132	2.701	0.142	0.952
15	0.597	4.623	0.769	4.034	0.038	0.768
20	1.825	1.903	0.891	8.583	0.003	0.106

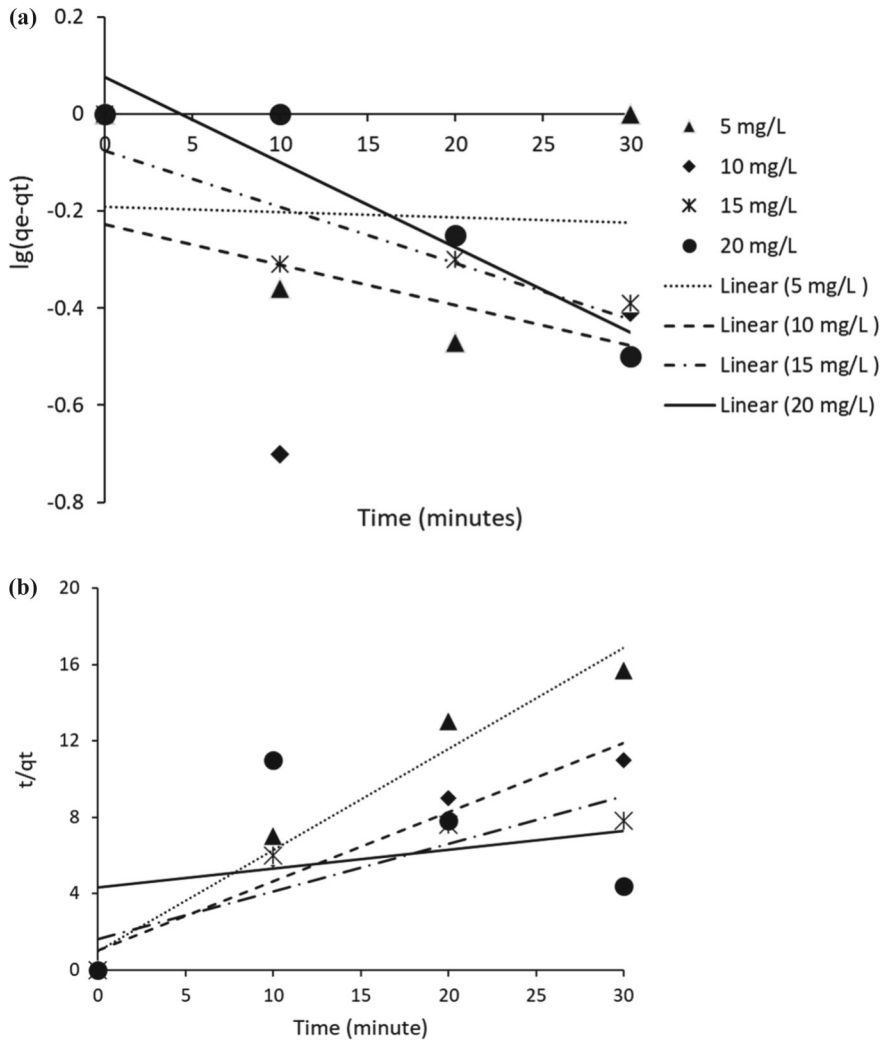


Fig. 5 **a** Pseudo-first order kinetic; and **b** pseudo-second order kinetic models

mechanism changes with increasing concentration, possibly due to saturation effects where the available active sites on the adsorbent become limited. In such cases, the uptake rate is more dependent on the concentration of the adsorbate itself rather than the available active sites, corresponding to the characteristics typical of first order kinetics where a constant fraction of the remaining adsorbate is removed per unit time.

More experimental works should be done at several initial concentration and at a longer time interval in order to have better idea that this work fits the pseudo-first or pseudo-second order kinetic model.

4 Conclusion

The increasing co-generation of coconut shell over the years, combined with the challenges of treating ammoniacal nitrogen in domestic and industrial wastewater, motivates this work. This study explores the application of activated carbon derived from coconut shell as a photocatalyst to remove ammoniacal nitrogen from wastewater. The results show that a coconut shell CSAC/TiO₂ composite was successfully prepared via the sol-gel method and removed up to 88% of ammoniacal nitrogen (a removal efficiency of 0.88) from wastewater with an initial concentration of 5 mg/L, a catalyst dosage of 0.5 g, and a reaction time of 30 min.

SEM imaging revealed that tiny TiO₂ granules were attached to the external surfaces of the activated carbon. FTIR spectra exhibited Ti–O–Ti and Ti–O–C bonds on the photocatalyst, which replaced some of the free O–H, C=O, and C=C bonds present on the pristine activated carbon surface. The impacts of pH and initial ammoniacal nitrogen concentration on the removal efficiency were also investigated. The highest efficiency was obtained at the unaltered pH (pH 10) and at the lowest initial ammoniacal nitrogen concentration, with efficiency decreasing as concentration increased.

Finally, a kinetic study was performed to understand the reaction mechanism. The removal kinetics of CSAC/TiO₂ in wastewater were better fitted by the pseudo-second-order model at low concentrations and the pseudo-first-order model at high concentrations, implying that the adsorption process involves chemisorption. More experimental works should be done at several initial concentration and at longer time interval to strengthen this finding. It is suggested that future work should focus on higher ammoniacal nitrogen concentrations and the replacement of titania to address the need for sustainable wastewater treatment solutions.

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