

Research Article

Biosynthesized SnO₂ Nanoparticles as the Effective Photocatalyst for Water Treatment

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Abstract: The discharge of dye effluent from textile industries has become a serious topic of environmental pollution. As a result, there is an urgent need to treat dye-polluted water effectively so that the clean water supply can be utilized safely by humans and aquatic systems. Nowadays, the utilization of photocatalysts in water treatment is proven to be effective in that it could replace the application of expensive water treatment. Therefore, in this research article, we demonstrated the application of photocatalysts namely tin (iv) oxide nanoparticles (SnO₂ NPs) that were successfully biosynthesized using leaves extract of Malaysia Shrub, *Chromolaena odorata* (*C. odorata*). This green biosynthesis route is straightforward, easy to handle, economical, and reproducible. The purity of SnO₂ NPs photocatalyst was characterized using XRD analysis, indicating the formation of the tetragonal crystallite with the presence of three prominent peaks: (110), (101), and (211). While FTIR analysis confirmed the construction of pure SnO₂ NPs with two absorption peaks corresponding to Sn-OH and Sn-O-Sn groups at 1028 cm⁻¹ and 603 cm⁻¹. The evaluation of SnO₂ NPs was tested on methylene blue dye, in which the degradation kinetic was found to follow the pseudo-first-order kinetic model. The result of the photocatalytic evaluation suggests that SnO₂ NPs stand as one of the potential candidates for facilitating the treatment process of dye-polluted water, with no secondary pollutant being generated making it suitable as a sustainable catalyst.

Keywords: Tin (iv) oxide nanoparticles; *Chromolaena odorata*; XRD; FTIR; methylene blue dye.



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1. INTRODUCTION

At present, the irresponsible and negligent act of the textile industries in discharging dye-polluted water into the mainstream has created a global issue of environmental pollution. Dye molecules are hard to be degraded attributed to their complicated structure; thus it remains in the water system leading to several drawbacks such as blockage to sunlight penetration which later disturb the photosynthesis process of aquatic organism. Moreover, dye molecules are carcinogenic, can lead to mutagenic issues, and could affect human breathing activity. Based on this scenario, researchers have developed several photocatalysts based on metal oxide nanoparticles for eliminating dye molecules in effluent. Among them, tin (iv) oxide nanoparticles (SnO₂ NPs) have attracted attention since it has a wide band gap of around 3.6 eV, are highly stable, have a high surface-to-volume ratio, have low resistivity, and are highly adsorbed. Having these characteristics, SnO₂ NPs are fabricated to be suited to numerous applications such as in lithium-ion batteries, gas sensors, electrodes, solar cells, biomedical, and many more. In this research work, the preparation of SnO₂ NPs was carried out via a green process namely biosynthesis in which the utilization of *Chromolaena odorata* (*C. odorata*) leaf extract assisted the formation of this photocatalyst. The biosynthesis process to prepare SnO₂ NPs is environmental-friendly, safe, straightforward, reproducible, and economical in contrast to the traditional process; ball milling, laser ablation, pyrolysis, hydrothermal, sol-gel, solvothermal, electrolysis, and microwave methods. During the mechanism of biosynthesis, the flavonoid groups contained in the leaf extract are functionalized as the capping and reducing agent of the Sn⁴⁺ to become Sn⁰. Previous reports described the biosynthesis process for the preparation of SnO₂ NPs using *Calotropis gigantea*, *Pandanus amaryllifolius*, *Camellia sinensis*, *Citrus aurantifolia*, *Aspalathus linearis*, *Piper betle*, *Litsea cubeba*, *Cyphomandra betacea*, *Psidium guajava*, *Daphne alpine*, *Persia americana*, and many more. The analysis was carried out based on the characterization using X-ray diffraction (XRD) and Fourier-transform infrared (FTIR) to confirm the crystallinity and the pure construction of SnO₂ NPs. The evaluation of the photocatalytic performance of SnO₂ NPs was evaluated in the degradation kinetic of methylene blue dyes (Manenti, Soares, Módenes, Espinoza-Quñones, Boaventura, Bergamasco, Vilar, 2015; Rafiq, Ikram, Ali, Niaz, Khan, Khan, Maqbool, 2021; Buniyamin, Akhir, Nurfazianawatie, Omar, Malek, Rostan, Eswar, Rosman, Abdullah, Asli, Khusaimi, Rusop, 2023; Yakupova and Ziyatdinova, 2021; Buniyamin, Eswar, Asli, Abd Halim, Khusaimi, Rusop, 2023; Matussin, Harunsani, Tan, Mohammad, Cho, Khan, 2020).

2. METHOD & MATERIAL

To the stirred solution of SnCl₄·5H₂O was added leaves extract of *C. odorata* and the brownish solution was left to continuously stirred for three hours. Later, a gel solution was developed from the solution and brought to the centrifugation process. The precipitate was collected and dried at 50°C within 12 hours. Thermal treatment followed the procedure in which calcination was conducted at 700°C for 3 hours to yield SnO₂ NPs. The confirmation on the purity was performed under characterization procedures such as using X-ray diffraction (XRD) and Fourier-transform infrared (FTIR) measurement (Buniyamin, Akhir, Asli, Khusaimi, Mahmood, 2021).

3. FINDINGS

From the analysis of the spectroscopic measurements using XRD and FTIR, the purity based on the diffraction plane and functional groups was identified. The capability of SnO₂ NPs as the photocatalyst was evaluated under photocatalytic testing to degrade the simulated dye namely methylene blue.

3.1 XRD and FTIR analysis

The diffraction peaks were indexed according to (JCPDS No: 01-077-0452) which discovered a formation of the tetragonal rutile crystalline phase, with all peaks tallied to former reports (Figure 1a). The prominent peaks with 2θ values were discovered at 26.9° , 34.3° , and 52.1° are corresponded to (110), (101) and (211) planes, respectively. The result of XRD analysis evidenced a pure formation of SnO_2 NPs in which no trace of alien phase was observed. The formation of SnO_2 NPs was further confirmed by the analysis using FTIR (Figure 1b). From the result, two prominent anti-symmetric vibrations belonging to Sn-OH and Sn-O-Sn groups were identified at absorption peaks 1028 cm^{-1} and 603 cm^{-1} , proving the pure construction of SnO_2 NPs (Elango, Kumaran, Kumar, Muthuraja, Roopan, 2015; Gomathi, Jayapriya, Arulmozhi, 2021).

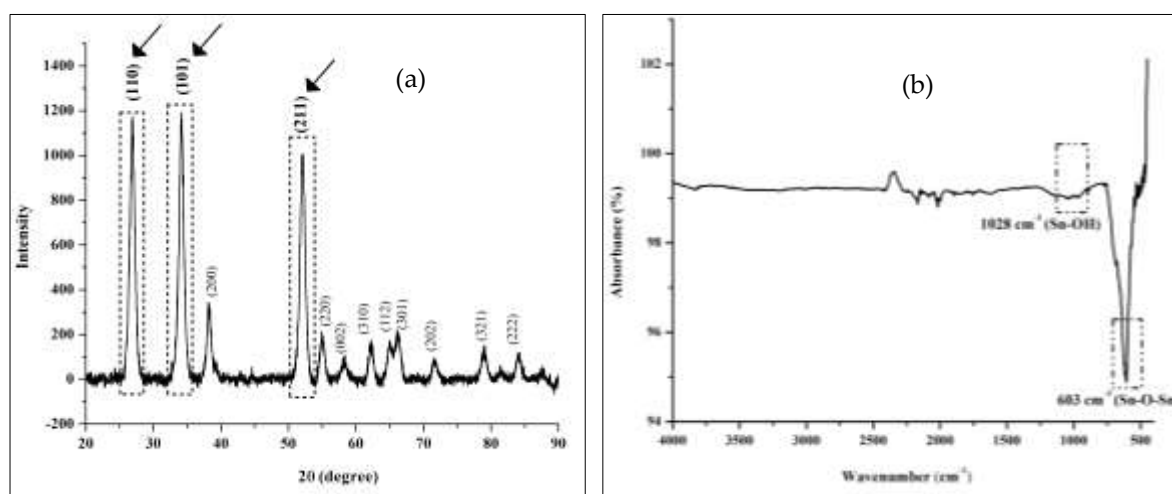


Figure 1. (a) XRD diffraction pattern of biosynthesized SnO_2 NPs (b) FTIR showing the functional groups of biosynthesized SnO_2 NPs.

3.2.2 Photocatalytic activity

In 100 ml of 15 ppm methylene blue, was added 100 mg of SnO_2 NPs and left to stir in the dark to allow adsorption-desorption equilibrium, followed by three different irradiations: UV, sunlight, and fluorescent in the next 30 minutes. About 5 mL of the solution was taken within 10 min intervals and brought to centrifugation. The clear supernatant solution was analyzed using UV-Vis measurement (Abdellah, Nosier, El-Shazly, Mubarak, 2018).

4. DISCUSSION

The evaluation of the photocatalytic performance using a simplified Langmuir-Hinshelwood (L-H) kinetic model (Equation 1) was portrayed in Figure 2. The result indicated a linear relationship as it followed the first-order kinetic. The reaction rate constant (k) belongs to UV irradiation close to sunlight with values of 0.0136 min^{-1} and 0.0141 min^{-1} . While for fluorescent, the K value was found to be lower at 0.0116 min^{-1} , compared with the other two irradiations. From this kinetic result, the potential of SnO_2 NPs was discovered in degrading the methylene blue dyes, meaning it is capable to be involved in the treatment of dye-polluted water. Apart from that, the degradation was almost completed within 70 minutes by only applying natural irradiation, which is sunlight. Having this this

finding, the photocatalytic process is definitely easy to be handled and therefore involved zero cost (Praveen Kumar, Lakshmana Reddy, Karthikeyan, Chinnaiah, Bramhaiah, Durga Kumari, Shankar, 2016).

$$-\ln (C/C_0)= kt \dots\dots (1)$$

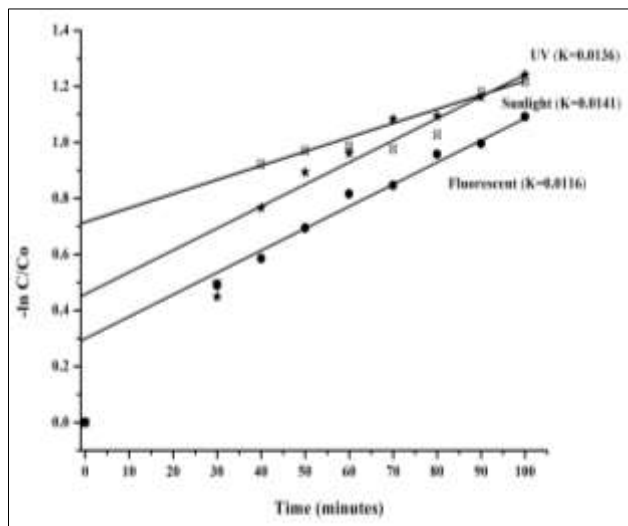


Figure 2. Kinetics evaluation of SnO₂ NPs.

5. CONCLUSION

In this research work, the preparation of SnO₂ NPs was successfully conducted via the biosynthesis route by the employment of leaf extract namely *C. odorata*. The product was obtained through an immaculate, economical, and straightforward process, where the purity was later confirmed by the characterizations using XRD and FTIR. The pure SnO₂ NPs were subjected to the photocatalytic process, in which the evaluation was tested on methylene blue dye. From the result, the photocatalytic activity followed first-order kinetics, giving reaction rate constant (k) for UV irradiation as close as sunlight with values of 0.0136 min⁻¹ and 0.0141 min⁻¹, respectively. Therefore, the biosynthesized SnO₂ NPs recommend a helpful escalation for the treatment of dye-polluted water by utilizing sunlight, in substitute to other irradiations.

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