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Supplementary Materials

Sustainable Synthesis of Silver Nanoparticles Using Marine Algae for Catalytic Degradation of Methylene Blue

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Abstract: Herein, *Sargassum coreanum* (marine algae)-mediated silver nanoparticles (AgNPs) were successfully synthesized by a simple reduction method. The synthesized AgNPs were characterized using ultraviolet-visible spectroscopy, attenuated total reflection Fourier transformed infrared spectroscopy, X-ray diffractometry, field emission scanning electron microscopy (FESEM) with energy-dispersive X-ray (EDX) spectroscopy, and high-resolution transmission electron microscopy (HR-TEM) analysis. The acquired colloidal AgNPs were strongly absorbed around 420 nm and displayed brown color under visible light. The XRD pattern of AgNPs exposed their face-centered cubic geometry along with crystalline nature. The HRTEM images of synthesized AgNPs confirmed the mean particle size of 19 nm with a distorted spherical shape, and the calculated interlayer distance (d-spacing value) was about 0.24 nm. Further, the catalytic degradation of methylene blue using sodium borohydride and AgNPs was monitored using UV–vis spectroscopy. The result revealed that AgNPs performed as a superior catalyst, which completely degraded MB in 20 min. The rate constant for MB degradation was calculated to be 0.106 min^{-1}, demonstrating that the marine algae-mediated AgNPs had outstanding catalytic activity. This approach is easy and environmentally benign, which can be applied for environmental-based applications such as dye degradation and pollutant detoxification.

Keywords: *Sargassum coreanum*; marine algae; silver nanoparticles; methylene blue; catalytic degradation

Instrumentation Methods

The synthesized silver nanoparticle (AgNPs) from *Sargassum coreanum* (Marine algae) were characterized by various physicochemical characterization techniques such as transmittance electron microscopy (TEM)/high-resolution TEM (HRTEM), X-ray diffraction (XRD), attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopy, and ultraviolet-visible (UV-vis) absorption spectroscopy. TEM/HRTEM images were performed with an FEI-Tecnai TF-20 transmission electron microscope with an operating accelerating voltage of 120 kV. XRD measurements were carried out using a PANalytical X'Pert^3 MRD diffractometer with monochromatized Cu Kα radiation (λ = 1.54 Å) at 40 kV and 30 mA and were recorded in the range from 10 to 90° (2θ). ATR-FTIR spectra were recorded in transmittance mode on a Perkin Elmer Spectrum 100 in the wavenumber range from 400 to 4000 cm^{-1} by the addition of 8 scans at a resolution of 8 cm^{-1} at the core research support center for natural products and medical materials of Yeungnam University. The photodegradation measurements of MB dye were carried out in the neutral aqueous medium at room temperature under UV-light irradiation by UV–vis absorbance. The UV-vis absorption spectra were recorded from 200 to 800 nm using an OPTIZEN 3220UV spectrophotometer.

Catalytic Degradation Measurements

The catalytic performance of AgNPs was tested against the degradation of methylene blue (MB) using $NaBH_4$. The degradation experiments were carried in a quartz UV cuvette, where 2 mL (50 µM) of MB was mixed with 0.95 mL (0.005 M) of aqueous NaBH4 and 0.05 mL of AgNPs. The degradation dynamics of MB were observed using an OPTIZEN 3220UV spectrophotometer.

The degradation efficiency (%) and kinetic rate constant as per the pseudo-first-order were calculated using the following equations (1), (2).

$$\text{Degradation efficiency (\%)} = \left(\frac{A_0 - A_t}{A_0}\right) \times 100 \quad (1)$$

$$\text{Pseudo-first-order } (-kt) = ln\left(\frac{A_t}{A_0}\right) \quad (2)$$

where, A_0 initial absorbance of MB, A_t is the absorbance of MB at time t and k is the rate constant.

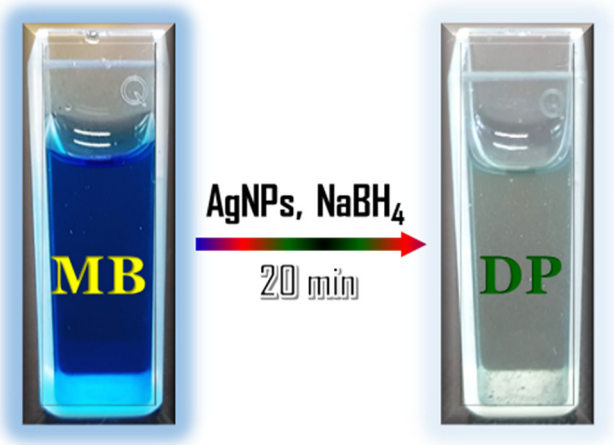

Figure S1. Visual observation of Methylene blue degradation using AgNPs.