Letters in Applied NanoBioScience
Open-Access Journal (ISSN: 2284-6808)

Article
Volume 12, Issue 4, 2023, 102
https://doi.org/10.33263/LIANBS124.102

Photocatalytic Degradation of Textile Dye Using Green Synthesized Nanoparticles

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Received: 6.05.2022; Accepted: 23.06.2022; Published: 17.09.2022

Abstract: In recent years, plants have been used as reducing agents for the synthesis of nanoparticles in a short time, and it consists of low cost, and there is no harmful effect on the environment; In this study, silver nanoparticles are synthesized from $AgNO_3$ using leaf extract of *Solena amplexicaulis* (Lam.) Gandhi. The leaf extract is mixed with $AgNO_3$ solution, and color change occurs from whitish-yellow to dark brown at room temperature within a few minutes. After incubation, the suspension was centrifuged, and particles were separated and dried. The green synthesized AgNPs were characterized by UV-visible spectroscopy in a maximum wavelength of 393 nm, FTIR, SEM, EDAX, DLS, XRD, and ZETA POTENTIAL; Photocatalytic degradation of Victoria blue or basic blue dye was investigated by green synthesized Ag nanoparticles with solar irradiation technique by biometrically at different time intervals. The UV-visible characteristic peak absorption of Victoria blue solution was 250 nm. The photocatalytic activity at different time intervals [control, treated controls, 30 min, (1, 2, 3, 5, 8, 12, 24, 48, 60, 72) hrs] was collected and decreased the peak intensity and was measured using UV-visible spectroscopy and Fourier Transform Infrared Spectroscopy. Green synthesized Ag nanoparticles effectively degraded the Victoria blue dye solution in total exposure time.

Keywords: *Solena amplexicaulis*; Victoria blue dye; green synthesis; photocatalytic activity.

1. Introduction

Dyes are the major pollutants widely used in textile and plastic industries and are hazardous in water and soil. Dyes are a major class of synthetic organic compounds released by many industries, such as paper, plastic, leather, food, cosmetics, textile, and pharmaceutical [1–3]. Large amounts of water and chemicals are used in the wet processing of textiles by the textile industries. The chemical reagents employed range from inorganic chemicals to polymers and organic products. [4–6]. The very low concentration of dyes in sequent is highly visible and undesirable [7–9].

It has been a serious issue in environmental pollution and causing many problems. These dyes must be accumulated highly in water. The accumulation of dyes in the water causes eutrophication that reduces the reoxygenation capacity and destroys aquatic algae, phytoplankton, zooplankton, microbes, fishes, frogs, etc. [10]. They are also resistant to microbial attack, and there is not readily degradable, not removed from water by wastewater treatment [11]. Through the formation in 1974 of the Ecological and Toxicological Association of the Dyes and Manufacturing Industry (ETAD), aims were established to minimize environmental damages, protect users and consumers, and co-operate fully with government and public concerns over the toxicological collision of their products [12].

Nanotechnology has been expanded to wastewater treatment in recent years. Due to their high surface area, silver nanoparticles exhibit enhanced reactivity [13]. The study of photocatalytic degradation in silver nanoparticles is a compatible method, with no formation of polycyclic, rapid oxidation, and quick oxidation of pollutants. It is a rapid technique for eliminating pollutants from wastewater [14,15]. In recent years, plant-mediated synthesis of AgNPs has been a great achievement and is considered to be done in low time and low cost [16–18].

Before the nineteenth century, natural dyes were the primary sources of dyes, which were collected from plants [19]. The use of natural dyes was largely removed by the mid-nineteenth century following the identification of artificial colors [20]. The environment has been damaged due to the increased use of chemical dyes, which lead to adverse health repercussions on living systems [21]. The current research emphasizes making silver nanoparticles from a plant source and using these Ag-NPs to break down the synthetic dye [22,23]. *Solena amplexicaulis* [Lam.] Gandhi is a prostrate or climbing scabrid herbal plant distributed in deciduous forests of the south Indian region. It is a dicotyledonous plant used for inflammation and jaundice herbal medicine. *S. amplexicaulis* is a cucurbitaceous family. These plants contain secondary metabolites of terpenoids [24,25]. This present study followed that green synthesizes silver nanoparticles using *S. amplexicaulis* plant extract as a reducing agent. The current investigation focus on *S. amplexicaulis* leaf extracted mediated green synthesis of Ag nanoparticles and its characterization followed by photocatalytic degradation of dye under sunlight.

2. Materials and Methods

2.1. Plant collection.

Solena amplexicaulis [Lam.] GANDHI plants were collected from the region of Thanjavur district from Tamilnadu, India. These plant species were botanically identified and authenticated by Dr. S. JohnBritto, Director, The Rapinat Herbarium and center for molecular systematic, St. ’Joseph’s College, Tiruchirapalli, Tamil Nadu.

2.2. Preparation of leaf extracts.

S. amplexicaulis healthy plant leaves are collected freshly and washed several times with deionized water before extraction. A 20g weight of freshly washed leaves was cut into fine pieces and boiled with 100 ml of double deionized water for 10 min at 65°C using a water bath. The boiled *S. amplexicaulis* plant extract was centrifuged and filtered using Whatman No. 1 filter paper. Finally, samples were collected and stored at 4°C for further analysis.

2.3. Synthesis of silver nanoparticles.

A 1 mM quantity of double deionized water was used to create the silver nitrate aqueous solution. We bought $AgNO_3$ from HiMedia GRM408. 90 ml of an aqueous solution of silver nitrate were combined with 10 ml of newly produced *S. amplexicaulis* leaf extract in an Erlenmeyer flask.. The flask was incubated in a dark place at room temperature (to reduce silver ions). The control was kept without leaf extract. The silver nanoparticle solution was obtained and centrifuged at 7000 rpm for 20 min. The pellet was collected and air-dried at 100°C, and the precipitate was collected and made into powdered form.

2.4. Characterization of synthesized silver nanoparticles.

The reduction of silver ions was observed by examining the double beam UV-Vis spectra of the reaction medium at various wavelengths between 190 and 1100 nm at various functional periods (PerkinElmer, Singapore). XRD analyzed crystalline natures of the Ag nanoparticles at 2θ ranges from 20 to 80°C (MiniFlex 400MF). Scanning Electron Microscope found the morphology and size of the silver nanoparticles, and elemental analysis of silver was carried out by EDAX (Philips XL-30). The FTIR spectrum, which is involved in converting silver ions into AgNPs, verified the functional biomolecules linked to Ag nanoparticles. (IR TRACER-100). The average particle size values and poly disparity of the size distribution were determined from Dynamic Light Scattering (DLS) using a zeta plus analyzer (Brookhaven). Zeta potential is the charge that interfaces between a solid surface and its liquid medium and were measured using a zeta potential analyzer (Malvern Zetasizer Nano range).

2.5. Photocatalytic degradation of dye.

The green synthesized Ag nanoparticles were further used to study the degradation of dyes. Dyes were collected from Tirupur and Erode district, Tamilnadu. The 10mg of Victoria blue dye was attached to 1000 ml of double deionized water and used as a stock solution. 10 mg of green synthesized Ag nanoparticles was affixed to 100 ml of dye solution. There was also a control run without any silver nanoparticles. The reaction suspension was well mixed by magnetic stirring for 30 minutes before being exposed to the light to demonstrate the symmetry of the working solution. Eventually, the dispersion was put downward in the sunlight and examined from morning to sunset [26]. At specific time intervals, aliquots of 2-3 ml interruption were sieved and used to assess the photocatalytic degradation of dye. The 'supernatant's immersion spectrum was eventually estimated using a UV-Vis spectrophotometer at a disparate wavelength. The retention value calculated consolidation of dye during degradation at 660 nm.

3. Results and Discussion

3.1. Phytoreduction of Ag ions.

A study on the green synthesis of silver nanoparticles by the *S. amplexicaulis* leaf extract was carried out in this method. Ag 'ions' reduction was visually identified from yellow to dark brown within 1h after incubation, whereas silver nitrate was no color change without

S. amplexicaulis leaf extract (Figure 1). The formation of dark brown color has confirmed Ag nanoparticles' formation due to surface plasmon reactions [27].

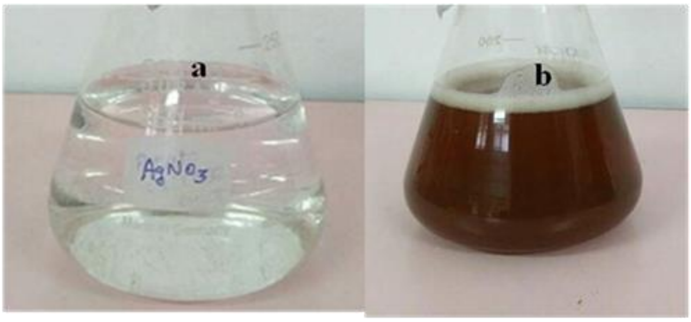

Figure 1. The aqueous solution of 1mM AgNO3 with *S. amplexicaulis* leaf extract. (a). without the addition of leaf extract. (b). after addition of leaf extract at1h incubation.

3.2. UV- visible spectrum of Ag nanoparticles.

The is of Ag nanoparticles was examined with the help of UV-visible spectroscopy. The penetration of the UV-spectra was recorded from 200 to 1100nm; the appearance of the peak, fitting to a Surface Plasmon Resonance (SPR) band, is a sensible record for different metal nanoparticles with a size range from 1nm to 100nm [28]. Figure 2 shows that UV-visible spectra observed that maximum absorbance of silver nanoparticles occurs at 280-400nm.

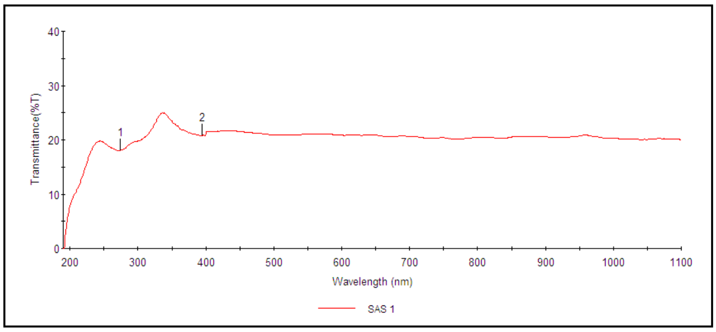

Figure 2. UV-visible spectra of Ag nanoparticles synthesized by the plant-mediated method.

3.3. FT-IR analysis.

Fourier Transform Infrared Spectroscopy measurement was conveyed to recognize the potential functional groups in the *Solena amplexicaulis* (Lam.) Gandhi leaf extract. The spectrum of the *S. amplexicaulis* leaf extract was analyzed in the 400-4000 cm^{-1}. The results showed the wider band for *S. amplexicaulis* extract at 3438.14 cm^{-1} regions in which the presence of O-H stretched with the alcohol and phenols groups. The sharp peak showed that range of 1636.53 cm^{-1} due to the presence of N-H bend with the functional groups of 1° amine (Figure 3). The intensity peak cleaved the FT-IR spectrum of green synthesized Ag nanoparticles into three different peaks. The peak intensity at 1730.07 cm^{-1} has been reduced with the region due to the presence of C=O stretch with the aldehyde functional groups [29,30]. A peak at 755.59 cm^{-1} favor C-H bending, whereas a peak at 668.39 cm^{-1} favor strong C-I stretching. Stretching vibrations occur when the interatomic distance between two atoms changes continuously along the bond's axis. A bending vibration is a shift in the angle between two bonds.

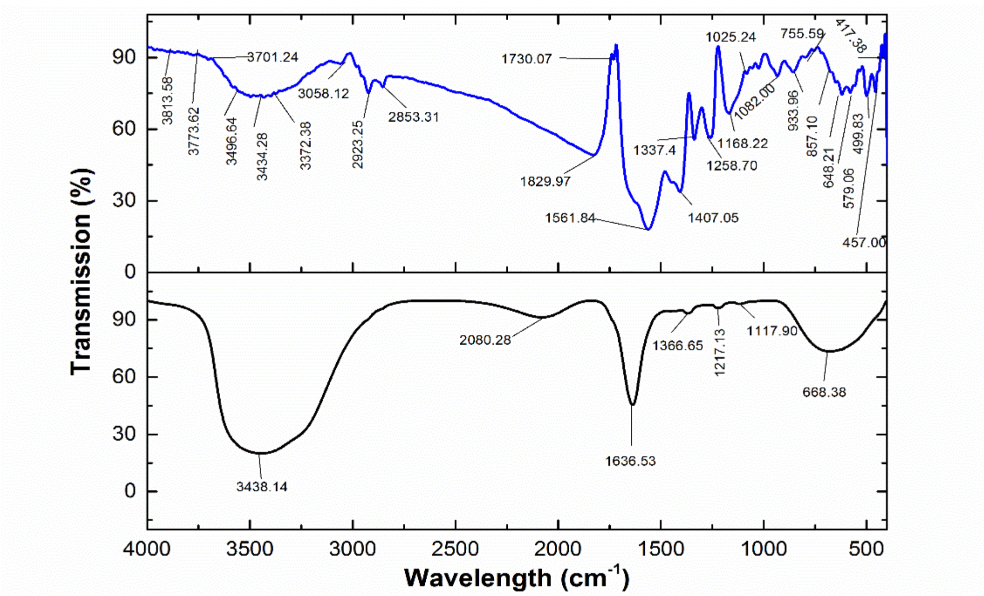

Figure 3. FT-IR spectrum of *Solena amplexicaulis* leaf extract (top panel) and FT-IR spectrum of Ag nanoparticles (bottom panel).

3.4. XRD and EDS analysis.

Green synthesized Ag nanoparticles were expedited manifest and confirmed by the characteristic peaks observed in XRD analysis, shown in Figure 4a. In XRD analysis, the three strongest peaks are identified at 2θ values of 32.0448, 37.9887, and 46.0589, sets of lattice planes were observed, which may be catalog to the (101), (111), and (200) reflections of the face-centered cubic structure of silver (JCPDS File No:03-0921). The XRD pattern demonstrated that the Ag nanoparticles were crystalline, and the average crystal size was 15nm, calculated by Scherer's equation. The high-intensity diffraction peak was observed at 32.0448, corresponding to the crystalline Ag. It is confirmed that the nanoparticles were composed of pure crystalline silver [31,32]. Another characteristic of Ag nanoparticles analyzed by EDS confirmed the strong silver and oxygen peaks and chloride peaks, which may originate from AgNPs and show a pure Ag peak without any impurities (Figure 4b). Ag nanocrystallites display an optical absorption band peak at 3keV due to the absorption of surface plasmon resonance of silver nanocrystals.

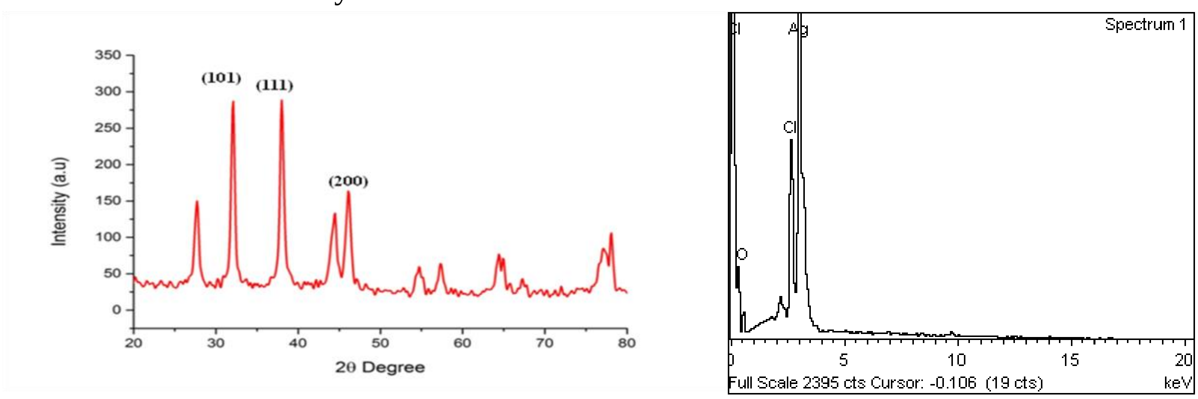

Figure 4. (a) XRD pattern and (b) EDS analysis of Ag nanoparticles synthesized from *S. amplexicaulis* leaf extract.

3.5. SEM analysis.

Ag 'nanoparticles' size and morphological structure were studied with SEM analysis (Figure 5). The presence of nanosized particles in the suspension was revealed by SEM analysis. More importantly, the particles are well dispersed. FESEM determined the morphological nature and size, showing that Ag nanoparticles are spherical with a size between 20-40nm [33].

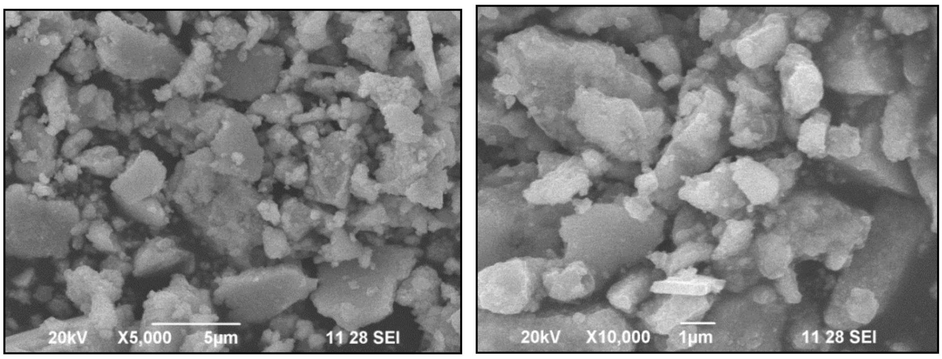

Figure 5. SEM analysis of Ag nanoparticles.

3.6. DLS analysis.

Dynamic Light Scattering (DLS) analysis of synthesized Ag nanoparticles in *Solena amplexicaulis* leaf extract is shown in Figure 6. The colloidal solution of synthesized Ag nanoparticles contains particles of various sizes. Some were with averages ranging from 20 to 254.9 nm. But in, the case contains 128nm conforming particles. The average size of a nanoparticle is 254.9nm [11].

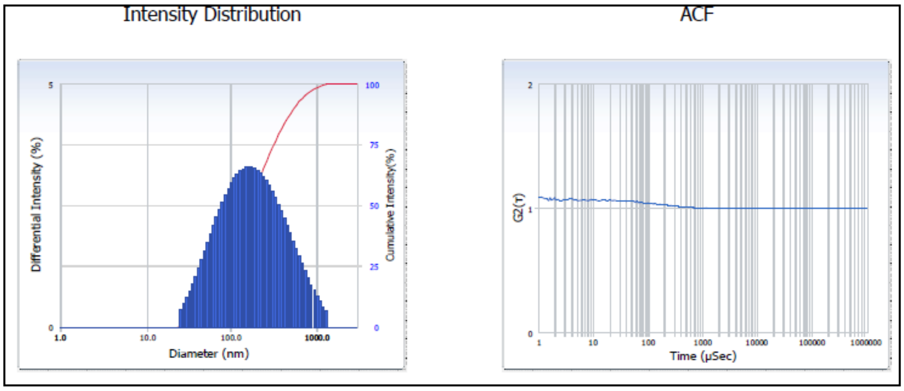

Figure 6. DLS analysis of Ag nanoparticles.

3.7. ZETA potential analysis.

The ZETA potential analysis of silver nanoparticles in water extract was found analyzed, and it was found to be -16.3mv, which indicates good capping of nanoparticles by negatively charged groups (Figure 7). This study also confirmed the Incipient Instability of the silver nanoparticles [34].

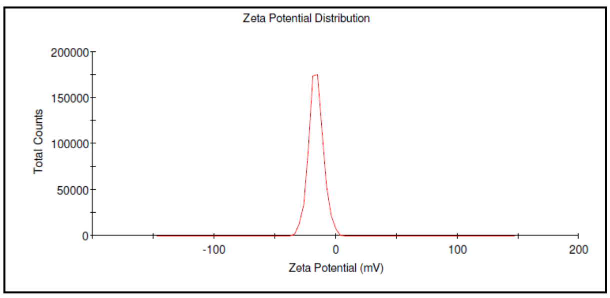

Figure 7. ZETA Potential analysis of Ag nanoparticles.

3.8. Photocatalytic degradation of dye.

Photocatalytic degradation of victoria blue or basic blue dye was investigated by green synthesized AgNPs with sunlight irradiation technique biometrically at different time intervals, as shown in Figure 8. The characteristic absorption peak of victoria's blue solution was found to be 250 nm (Figure 9). A decrease visualized degradation of victoria blue in peak intensity within 2 hours of incubation. It was completely decreased at 24 hours after incubation of solar irradiation. There is no considerable shift in peak position for victoria blue solution without exposure to synthesized AgNPs sample. Visible light was expended in bleach dyes in the presence of silver impetus. The absorption of silver nanoparticles onto the dye solution was low and then heightened with the constant increase in time.

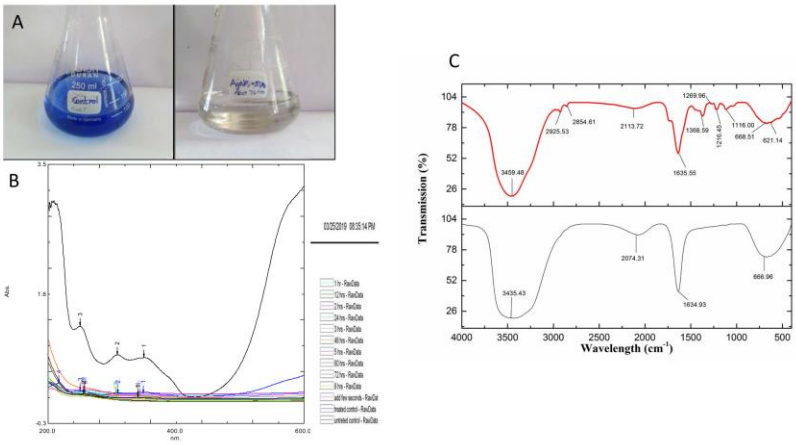

Figure 8. Photocatalytic degradation of dye (A). FT-IR analysis of victoria blue dye (B). FT-IR analysis of Photocatalytic Degradation after 72 hours (C).

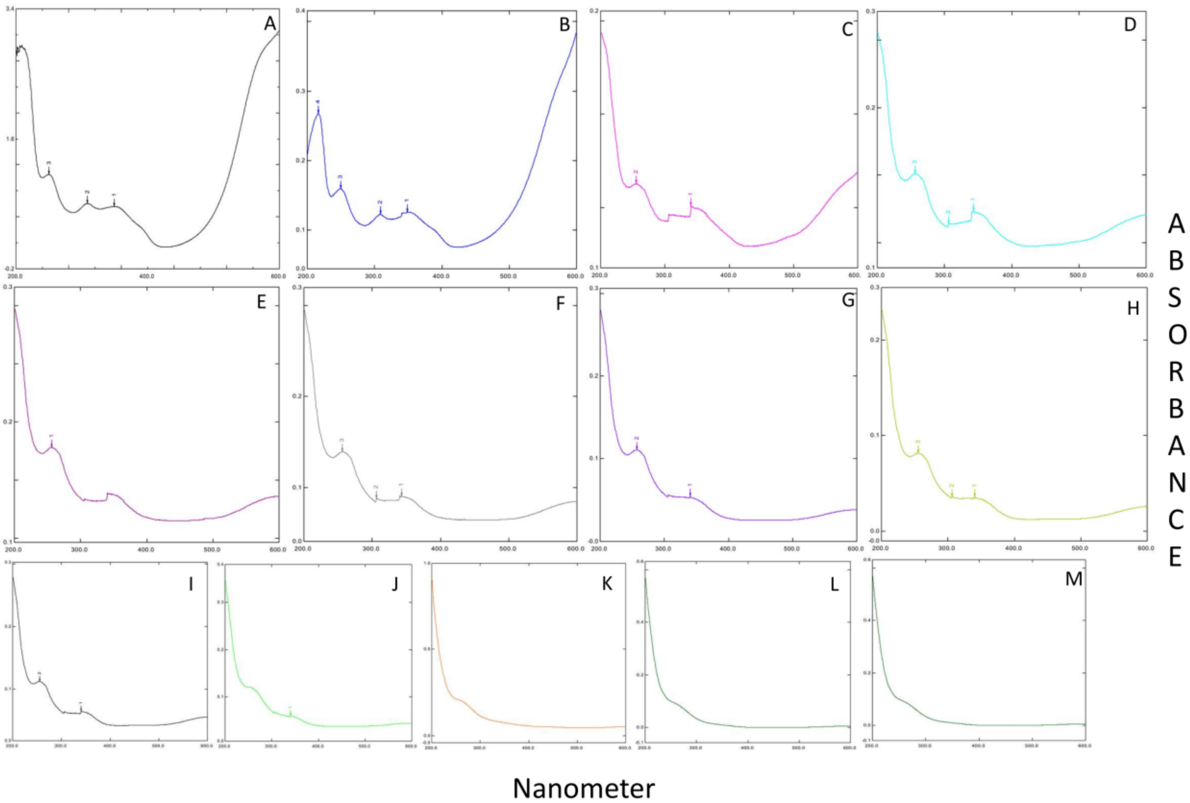

Figure 9. The UV- visible absorption spectra of victoria blue tested at various time intervals in the presence of Ag nanoparticles synthesized using *Solena amplexicaulis.* (A. Control, B. AgNPs Added, C. After 30 mins, D. 1 hour, E. 2 hours, F. 3 hours, G. 5 hours, H. 8 hours, I. 12 hours, J. 24 hours, K. 48 hours, L. 60 hours, and M. 72 hours).

The reduction in the structure of the Ag nanoparticles favors the proliferation in the amount of the coordinate atoms. It enhances the adsorption of molecules on the surface of the stimulant, thus improving the degradation of dye. Thus, the synergist activity of the AgNPs was established to be controlled by the particle size and shape. During degradation, catalysis occurs on the surface region of Ag. Therefore, increasing the surface area availability will significantly improve the catalyst's efficiency. Ag nanoparticles support the electron (e-) relay from the donor to the acceptor and act as a substrate for the electron transfer reaction. The reactants obtain an e- and are decreased due to being adsorbed on the metal surface during the e-transfer process. Thus AgNPs act as an efficient catalyst through the electron transfer process of catalytic reactions [34]. The FT-IR analyses of the Victoria blue dye and after 72 hours photocatalytic reaction of samples are shown (Figure 8B and Figure 8C). The FT-IR spectrum analyzed another confirmation test of photocatalytic degradation of Victoria blue and identified the peak intensity and functional groups.

4. Conclusions

Nanotechnology of the green approach is gaining significance due to removing harmful reagents and synthetic chemicals. The green synthesized silver nanoparticle is more suitable, environmentally safe, low cost, and less time-consuming. The AgNPs were synthesized using plant leaf extract of *Solena amplexicaulis* and characterized by UV-spectroscopy that showed absorbance and wavelength of 393 nm. The size was absorbed by SEM 10-40 nm. XRD characterized crystalline nature. EDAX analyzed a compound's level of AgNPs. The photocatalytic activity of green synthesized AgNPs was tested with Victoria blue (Basic blue dye). The high absorption peak is at 240 nm. The range was decreased with exposure to sunlight. It indicated the photocatalytic degradation of Victoria blue dye. The Photocatalytic activity of different time intervals was collected, and the decreased peak intensity was measured using UV-visible spectroscopy and Fourier Transform Infra-red Spectroscopy. Green synthesized AgNPs effectively degraded the dye 99 % at 72 hours of exposure. The current study revealed photocatalytic activity against textile dyes used in dye effluent treatment and water purification.

Funding

This research received no external funding.

Acknowledgments

This research has no acknowledgment.

Conflicts of Interest

The authors declare no conflict of interest.

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