

Eco-Friendly Silver Nanoparticles Derived from Sansevieria Zeylanica: Catalytic Performance for Environmental Sustainability

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Abstract

This article examines the synthesis of silver nanoparticles utilizing *Sansevieria Zeylanica* leaf extract (SZ-AgNPs) as a green stabilizing and reducing agent. The biosynthesized SZ-AgNPs exhibit distinct properties, characterized by a well-defined morphology and size, as validated through UV-Vis spectroscopy, X-ray diffraction, and scanning electron microscopy analyses. The research investigates the potential applications of eco-friendly obtained SZ-AgNPs in environmental remediation, with a particular focus on their catalytic performance in degrading synthetic dyes, notably crystal violet and Congo red. Furthermore, the antimicrobial activity of the SZ-AgNPs is assessed against various bacterial and fungal strains. The findings reveal substantial dye degradation percentages and significant zones of inhibition against both gram-positive bacteria, underscoring the dual advantages of environmentally friendly nanoparticle synthesis for sustainable applications in wastewater treatment and antimicrobial interventions. The study underscores the pivotal role of green nanotechnology in tackling pressing environmental challenges, advocating for the adoption of eco-friendly approaches in nanoparticle synthesis for a more sustainable future.

1. Introduction

The development of advanced nanomaterials has initiated novel pathways within the field of environmental remediation, particularly in the focus of photocatalytic degradation of organic dyes [1]. Silver nanoparticles (AgNPs) stand out among these pioneering materials, demonstrating considerable potential for effective and sustainable photocatalytic processes. The method of the green-synthesis and characterization of AgNPs have undergone notable advancements, affording precise manipulation of their size, morphology, and surface characteristics [2–3]. These developments, coupled with the distinctive optical and electronic properties inherent to AgNPs, synergistically enhance their photocatalytic activity. Recent investigations emphasize the pivotal role played by the localized surface plasmon resonance phenomenon exhibited by AgNPs, which intensifies light absorption and facilitates charge separation, thereby amplifying the efficiency of photocatalytic reactions.

In a multitude of industries spanning textiles, paper, plastics, food, cosmetics, and pharmaceuticals, synthetic organic dyes serve as ubiquitous components [4]. However, the emissions from these industries significantly contribute to environmental pollution. Extensive studies have revealed that many of these dyes possess mutagenic, carcinogenic, and environmentally hazardous properties [5]. Their vibrant hues disrupt aquatic ecosystems and pose serious threats to aquatic species. Efforts to mitigate this pollution have involved various physical, chemical, and biological treatment methodologies. These encompass a wide array of techniques such as chemical oxidation and reduction, membrane filtration, adsorption, photochemical and electrolytic treatments, anaerobic processes, and more [6–11].

Conventional treatment methods often falter due to the chemical stability of dye contaminants, rendering them resilient to degradation. Moreover, standard biological treatment methods struggle to adequately decolorize water-soluble pigments owing to their significant microbial resistance [12]. Consequently, novel

approaches are required to address this persistent challenge. Recent advancements in the field of wastewater treatment have seen the integration of nanotechnology, offering promising solutions [13]. By leveraging the unique properties of nanoparticles, such as their high surface area-to-volume ratio and catalytic activity, nanotechnology presents innovative avenues for more efficient and effective remediation of dye-contaminated water.

In recent years, the field of nano catalysis has experienced a remarkable surge, heralding a transformative era in catalytic processes. The distinct physical and chemical properties exhibited by metallic nanoparticles distinguish them from their bulk counterparts [14]. Notably, their expansive surface area-to-volume ratio, finite dimensions, and primarily size-dependent reactivity underscore their unique nature. Leveraging these attributes, metallic nanoparticles have emerged as highly efficient catalysts, offering unprecedented catalytic capabilities. Numerous investigations have been demonstrated the efficacy of nanocatalysts in the removal of various colouring agents from diverse substrates [15–17]. Among these nanocatalysts, silver nanoparticles, or AgNPs, continue to captivate interest within the realm of nanotechnology. Renowned for their potent toxicity against a wide array of microorganisms and exceptional optical and electrical properties, AgNPs remain a focal point of investigation and application in various fields.

Several synthetic methodologies have been developed for the production of silver nanoparticles, encompassing chemical [18], photochemical [19], sonochemical [20], radiolytic [21], polyol [22], and biological approaches [23]. However, many of these methods necessitate stringent reaction conditions and the use of hazardous substances. Therefore, stabilizing silver nanoparticles in suitable solutions is imperative for their synthesis and application. Nevertheless, the chemical reagents commonly employed as stabilizers and reducing agents pose significant environmental risks due to their toxicity, limiting their practical utility.

In response to environmental concerns, considerable research efforts have been directed towards nano synthesis using readily available and non-toxic materials. Embracing the principles of green nanoparticle synthesis—utilizing non-toxic and environmentally benign reducing agents, cost-effective and renewable stabilizing agents, and environmentally safe solvent systems—the biological synthesis of nanoparticles in aqueous media has garnered substantial attention. This approach not only addresses environmental concerns but also offers several advantages over traditional thermal heating techniques, including faster reaction times, reduced energy consumption, and enhanced product yield [24].

Plant-mediated synthesis offers a unique approach to achieve homogeneous growth and nucleation conditions for nanoparticles, facilitated by rapidly and uniformly heating the reaction solution. Recent years have seen a surge in successful research endeavours focusing on the eco-friendly production of silver nanoparticles [25–26]. However, notably less investigations from the literature are addressing the utilization of nanoparticles generated from *Sansevieria zeylanica* for dye degradation. This technique holds considerable promise as an environmentally benign alternative, as all components utilized in the process are deemed safe for the environment. Beyond its eco-friendliness, this approach is characterized

by its ease of use, rapidity, and affordability, making it a highly accessible and practical solution for nanoparticle synthesis.

A study conducted by Rama Krishna et al., [27] elucidated the process of synthesizing, characterizing, and utilizing Ag-nanoparticles for both biological research and ecological remediation purposes. They discovered that the leaves of the *Sansevieria roxburghiana* plant contain natural reducing agents that facilitate the conversion of metal ions into metal nanoparticles [27]. In an unconnected study, Ferin et al., demonstrated the antifungal efficacy of pure and Fe-doped ZnO nanoparticles against three postharvest pathogenic fungi: *Aspergillus niger*, *Aspergillus favus*, and *Rhizopus*. Their findings revealed that the inclusion of iron enhanced the inhibitory effect on fungal growth compared to pure ZnO nanoparticles. Particularly, the antifungal activity of Fe-doped ZnO nanoparticles was comparable to that of the conventional drug *mycostatin*, exhibiting an inhibition zone of 18 mm against *Aspergillus niger* [28].

The production of silver nanoparticles using *Sansevieria zeylanica* leaf extract offers a sustainable and environmentally friendly approach to nanomaterial synthesis. *Sansevieria zeylanica*, commonly known as bowstring hemp or Ceylon bowstring hemp, is a resilient plant native to Sri Lanka and India, known for its medicinal and ornamental properties. The leaf extract of *Sansevieria zeylanica* contains various phytochemicals such as flavonoids, phenols, and terpenoids, which serve as reducing and stabilizing agents in the synthesis of silver nanoparticles. The synthesis of silver nanoparticles using *Sansevieria zeylanica* leaf extract represents a promising avenue for the sustainable production of nanomaterials with diverse applications in science, technology, and medicine.

The objective of this study is to demonstrate the synthesis of silver nanoparticles using plant-mediated methods in an aqueous environment, employing a novel reducing agent derived from *Sansevieria zeylanica* leaf extract. This extract also serves as a stabilizing agent for investigating antibacterial activity and dye degradation. The reduction reactions of crystal violet and conga red were conducted as model reactions to evaluate the catalytic efficacy of silver nanoparticles stabilized by plant extract in dye degradation processes. Furthermore, this research explores the utilization of biosynthesized silver nanoparticles in antimicrobial activity and photocatalytic degradation of organic dyes, elucidating their notable catalytic properties and potential applications.

2. Materials and Methods

2.1 Preparation of *Sansevieria zeylanica* plant extract

The fibers of *Sansevieria zeylanica* (snake plant leafs) were collected from the lush surroundings of Ramanputhur (Latitude: 8.159726, Longitude: 77.418275) nestled of the Kanyakumari District, Tamil Nadu, India. Initially, the freshly procured fibers from the leaves of *Sansevieria zeylanica* were tenderly washed with double-deionized water, ensuring purity and cleanliness. Subsequently, they were delicately air-dried in the cool shade, allowing them to retain their natural essence over the course of a week. After being thoroughly dried in a systematic manner, the leaves were cut into small pieces of 2–3 cm and finely

ground using a mortar and grinder, guaranteeing uniformity and consistency throughout the synthesis process. To extract the bioactive components, 5 grams of the powdered leaves were carefully measured and placed into a water bath containing 200 mL of deionized water. The mixture was then subjected to gentle heating at 70–80 °C for a duration of 2 hours, facilitating optimal extraction. Following this, the resulting extracts were gradually reduced to 100 mL and allowed to cool to ambient temperature. To ensure purity and clarity, the extracts were meticulously filtered using Whatman No. 1 paper filters, removing any impurities or particulate matter. Subsequently, the extracts were judiciously preserved to facilitate the synthesis of silver nanoparticles and stored in a refrigerator at -4°C, these extracts stand poised for further experimentation and analysis.

All chemicals utilized in this experiment were sourced from Sigma-Aldrich. Initially, an aqueous solution containing 1 mM (80 mL) of silver nitrate was combined with 20 mL of freshly prepared *Sansevieria zeylanica* plant extract, maintaining a ratio of 9:1. The resulting mixture was subjected to stirring at 1000 rpm at room temperature ($30 \pm 2^\circ\text{C}$) for a duration of 1440 minutes. Throughout this process, the reduction of silver ions was observed by monitoring changes in the color of the reaction mixture. The observable shift in the color of the reaction mixture from light yellow to deep tan signified the reduction of Ag^+ ions. Notably, the absence of any color change in the absence of plant extract underscores its crucial role in the reduction process. The emergence of the characteristic peak of Ag nanoparticles after 1440 minutes of reaction time serves as tangible evidence confirming the successful formation of Ag nanoparticles. Following the completion of the reaction, the resultant nanoparticles (SZ-AgNPs) were purified using centrifugation at 8000 rpm for 10 minutes. Subsequently, the precipitate containing the silver nanoparticles was collected, while the liquid supernatant was discarded. To ensure the removal of any impurities adhering to the surface of the nanoparticles, the centrifugation process was repeated five times. Finally, the purified silver nanoparticles were obtained after air-dried at 60°C. Further, this meticulous drying procedure eliminated any residual materials that might have been absorbed onto the surface of the nanoparticles.

2.2 Characterization of the silver nanoparticles

The various characterization techniques were employed to validate the biosynthesized SZ-AgNPs nanoparticles in this study. UV-Vis spectroscopy, utilizing the UV-1800 series UV-Vis spectrophotometer, was utilized to obtain the optical properties of the nanoparticles. The crystalline nature of the biosynthesized SZ-AgNPs nanoparticles was examined using the D2 PHASER mobile bench-top X-ray diffractometer, scanning in the diffraction angle (2θ) range from 10 to 80° . TESCAN VEGA3 SBH Scanning electron microscopy (SEM), coupled with BrukerEasy Energy Dispersive x-ray Spectroscopy (EDS), was employed to envisage the morphology and elemental composition of the biosynthesized SZ-AgNPs nanoparticles. Fourier Transform Infrared (FTIR; SHIMADZU IR Affinity-1) spectroscopy analysis was conducted in the spectral range of $4000\text{--}400\text{ cm}^{-1}$ frequencies at room temperature to identify the functional groups present in the plant extracts responsible for the reduction of Ag ions. This spectrum was accomplished using the pellets of biosynthesized silver nanoparticles mixed with KBr (1:100).

Antimicrobial activity of the biosynthesized SZ-AgNPs was assessed against a variety of bacterial and fungal species using the disk diffusion method [29]. Gram-positive bacteria such as *Bacillus subtilis* and *Staphylococcus aureus*, gram-negative bacteria including *Escherichia coli* and *Pseudomonas aeruginosa*, as well as fungal species like *Rhizopus microsporus* and *Candida albicans*, were involved in the study. The inhibitory zones around the biosynthesized SZ-AgNPs discs were measured after 24 hours of incubation at 37°C. The catalytic activity of the silver nanoparticles in dye degradation was investigated. Crystal violet and Congo red dyes were chosen for degradation studies, each at a concentration of 0.01 mM mL⁻¹. The degradation process was monitored by measuring the absorbance maxima (λ_{max}) of the dye solutions over time, utilizing UV-visible spectroscopy. The percentage degradation of the dyes and the kinetics of dye degradation were analyzed using the pseudo first-order reaction kinetics equation. After preparing each dye solution, 25 mL of the solution was combined with 0.025 g of biosynthesized silver nanoparticles in a beaker. This mixture was then exposed to UV light with a wavelength of 365 nm. Using a magnetic stirrer, the samples were continuously agitated. The absorbance maximum was monitored by periodically scanning the sample in the beaker at various time intervals between 300 and 800 nm. The degradation rate and percentage were calculated based on the λ_{max} values obtained for each time point.

To calculate the percentage degradation of each dye, the following Eq. (1) was applied:

$$\text{Dye degradation \%} = \frac{A_0 - A_t}{A_0} \times 100 \quad (1)$$

Following a pseudo first-order reaction mechanism induced by the catalytic activity of metallic nanoparticles, the degradation kinetics of the dye were analyzed using Eq. (2):

$$\ln \frac{A_t}{A_0} = -kt$$

2

where, A_0 represents the absorbance at zero time, A_t represents the absorbance at time t, and k denotes the rate constant [29]. Phytochemical analysis was conducted on the aqueous floral extract derived from the *Sansevieria zeylanica* flower. Our aim was to ascertain the presence of various phytochemical constituents including *saponins*, *tannins*, *flavonoids*, *steroids*, *terpenoids*, *alkaloids*, and *glycosides*. This comprehensive examination was essential for understanding the chemical composition and potential bioactive properties of the floral extract. The findings of this analysis contribute to the broader understanding of the therapeutic and medicinal potential of *Sansevieria zeylanica* [28].

3. Results and Discussion

3.1 X-ray Diffraction pattern of synthesized SZ-AgNPs

The X-ray diffraction (XRD) pattern depicted in Fig. 1 offers profound insights into the structural characteristics of the synthesized silver nanoparticles (Ag NPs). Notably, the distinct peaks at specific 2 θ

angles, namely 38.229°, 44.301°, 64.546°, and 77.677°, correspond to the (111), (200), (220), and (311) crystallographic planes of face-centered cubic (fcc) silver crystals, respectively [31], as per the powder XRD standards (JCPDS No. 01-087-0718). Of particular significance is the intensity of the (111) peak, which stands out prominently, indicating a preference for the orientation of Ag NPs along this crystallographic plane. This observation suggests a concentration of silver nanoparticles within the (111) facets, with this particular plane [32–33]. Such preferential orientation towards the (111) direction underscores the inherent crystallographic structure of fcc silver nanoparticles. Furthermore, employing Scherrer's equation allowed us to estimate the average crystallite size of the synthesized particles to be 36.86 nm. This measurement provides crucial insights into the nanoscale dimensions of the Ag NPs, highlighting their potential for various applications where size-dependent properties play a significant role. Thus, the XRD analysis offers a comprehensive understanding of the crystallographic structure and size distribution of the synthesized silver nanoparticles.

3.2 Spectral Analysis of ultraviolet-visible

The spectral analysis of SZ-AgNPs synthesized through an environmentally friendly method utilizing *Sansevieria zeylanica* extract, was conducted at room temperature, as illustrated in Fig. 2. UV-Vis spectrum analysis stands as a reliable technique for elucidating the bio-reduction process of Ag⁺ ions. In this study, the synthesized AgNPs showcased a distinctive surface plasmon resonance (SPR) peak at 463 nm (2.68 eV), indicating a noteworthy blue shift. Comparatively, previous research utilizing seed extracts of *Macrotyloma uniflorum* revealed surface plasmon absorption bands at a slightly shorter wavelength of 430 nm (2.88 eV) [33]. The significance of these findings lies in the correlation between spectral characteristics and nanoparticle properties. A thin line observed at a shorter bandgap typically denotes a reduction in particle size, while a pronounced peak at a longer wavelength suggests an increase in particle size [34]. Previous studies have reported a band gap of 2.9 eV [35], further contributing to our understanding of the synthesized SZ-AgNPs' properties. It's noteworthy that the UV absorption peak of SZ-AgNPs can exhibit significant shifts towards either the blue end (indicating lower absorption) or the red end (reflecting greater absorption). These shifts are influenced by various factors, including the surrounding dielectric medium, particle dimensions, shape, and aggregation state [32]. This underscores the intricate interplay between synthesis parameters and the resulting nanoparticle characteristics, enriching our comprehension of the behavior of SZ-AgNPs in different environmental contexts.

3.3 SEM-EDS studies of synthesized SZ-AgNPs

The investigation of the size, shape, and overall morphologies of SZ-AgNPs is made using scanning electron microscopy coupled with energy-dispersive X-ray analysis (SEM-EDX). The SEM imagery revealed a strikingly homogeneous formation of SZ-AgNPs, exhibiting controlled shapes. SEM images

vibrantly portrayed the honeycomb-like morphology of the SZ-AgNPs, as showcased in Fig. 3. Further analysis through energy-dispersive X-ray (EDX) mapping corroborated the proper distribution of Ag atoms crucial for forming AgNPs. The EDX mapping unveiled predominant signals of silver (96.62%) alongside oxygen (1.84%), offering solid confirmation regarding the formation of pure silver nanoparticles, as illustrated in Fig. 3. Remarkably, the observed diameter of the SZ-AgNPs fell within the range of 62–74 nm, aligning well with previous analyses [33]. This consistency underscores the reliability and reproducibility of the synthesis process, strengthening confidence in the obtained results and their potential applications.

3.4 FT-IR Analysis of synthesized SZ-AgNPs

Fourier-transform infrared (FT-IR) spectrum provided crucial insights into the dual role of the plant extract as both a reducing and stabilizing or capping agent for *Sansevieria zeylanica* Leaf extract and the biosynthesized SZ-AgNPs, as illustrated in Fig. 4. Analysis of the FT-IR spectrum revealed prominent peaks at 432, 652, 1049, 1329, 1661, 2361, 2887, 2978, and 3449 cm^{-1} , corresponding to ketone and hydroxyl groups, respectively [37]. Conspicuously, the significant bands associated with the biosynthesized SZ-AgNPs included at 3449, 2978 & 2887, 1661, 1329, and 1049 cm^{-1} are due to broad bands indicating O-H stretching vibration, CH_3 stretching vibration, C = O stretching vibrations of amide 1 group, C–O–H bending vibration, and C – N stretching vibration, respectively. Furthermore, characteristic bands of the silver nanoparticles were observed at 432 and 652 cm^{-1} . FT-IR spectrum revealed absorption in the range of 400 cm^{-1} to 600 cm^{-1} , which is indicative of the presence of silver nanoparticles [38]. This unequivocally confirms the formation of silver nanoparticles utilizing *Sansevieria zeylanica* extract, underscoring the dual function of *Sansevieria zeylanica* leaf extract as a stabilizing and environmentally benign reducing agent. The comprehensive of FT-IR characterization enriches our understanding of the synthesis process and the unique properties of the resulting nanoparticles, paving the way for diverse applications in various fields.

3.5. Efficacy of dye degradation

The nanoparticles of silver are well recognized for their ability to eliminate harmful dyes, insecticides, antibiotics, and other contaminants from wastewater. The SZ-AgNPs were utilized in this investigation to remediate dye from artificial wastewater. The neutralization of dyes from the synthetic wastewater existing at an initial concentration of 1 g L^{-1} was used to determine the catalytic activity of SZ-AgNPs. When SZ-AgNPs on a surface produce decolorization, the absorbance values at λ_{max} for Crystal violet (CV) at 592 nm and Congo red (CR) at 500 nm decreases. There was no discernible change in the dye upon exposure to ultraviolet radiation. However, up to 60–75% decolorization was seen within the dye-containing synthetic wastewater when SZ-AgNPs were combined with UV radiation.

The catalytic activity of SZ-AgNPs induced the decolorization of CV and CR dye, which was quantified by a reduction in absorbance peak with time, as seen in Fig. 5 and Fig. 5a shows the CV degradation in

presence of UV light and SZ-AgNPs 1 g L^{-1} . Figure 5b shows the CR degradation in presence of UV light and SZ-AgNPs 1 g L^{-1} . Up to 72% decolorization was observed for crystal violet dye and 66.37% decolorization was observed for Congo red dye. It was found that the time needed for full fading increased together with the original dye content in the synthetic wastewater. The multi-layer of dye molecules that have developed on the surface of SZ-AgNPs may be the cause of the longer decolorization period. Light penetration is necessary for the dye to break down into colourless components. Furthermore, during the dye breakdown reaction found in artificial wastewater, the surface of SZ-AgNPs serves as an electron transmit system. The movement of electrons from UV light to dye molecule via SZ-AgNPs is a likely mechanism of dye degradation produced by SZ-AgNPs in a condition of UV light. Figure 6. Shows dye degradation percentage of CV and CR at different time interval ranging from 0-120 min. Dye decolorization (%) Time (120 min) for (UV light + SZ-AgNPs + CV dye) is 72% and (UV light + SZ-AgNPs + CR dye) is 63%. Initially, the surface of SZ-AgNPs absorbs electrons from both the dye molecule and UV light. Additionally, an ongoing UV light source serves as a nucleophilic agent, donating an electron to SZ-AgNPs. The electron that is accessible on the surface of SZ-AgNPs, however, will be captured by dye molecules that have been absorbed into the surface of SZ-AgNPs, acting as an electrophilic agent. The dye molecule is broken down into a colourless component by this entire process, which initiates a dye degradation reaction.

The breakdown kinetics of Crystal violet and Congo red has a first-order disintegration kinetic that starts at 1 g L^{-1} of dye. The constant connection between in $[A_t/A_0]$ (A_t : The absorbance at time "t" and A_0 : Absorbance at "0 min") and t (breakdown time) can be used to illustrate the first-order degradation kinetic. A linear correlation was found between A_t/A_0 and the amount of time it took for CV and CR to degrade, as seen in Fig. 6. It was discovered that the rate of deterioration for both Congo red and crystal violet was $1 \times 10^{-2}\text{ min}^{-1}$. For the other dyes, including methyl orange, thymol blue, methylene blue, and green malachite, a comparable rise in degradation rate was noted [39–45]. Figure 6 shows the degradation of CV and CR dyes at different time intervals when SZ-AgNPs and UV light are present.

3.6. Enhanced Antimicrobial Activity of SZ-AgNPs

The antimicrobial activity of SZ-AgNPs against various destructive bacteria and fungi is widely acknowledged, with their efficacy significantly influenced by their structural characteristics. To evaluate the antimicrobial activity of SZ-AgNPs against four fungal species (*Rhizopus microsporus*, *Penicillium sp*, *Aspergillus flavus*, and *Candida albicans*) and six bacterial species (*Bacillus subtilis*, *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Streptococcus pyogenes*, and *Proteus mirabilis*), the measurement of zone of inhibition (ZOI) was conducted at Smykon Biotech in Kanyakumari, Tamil Nadu.

The inhibitory effect of SZ-AgNPs on bacterial growth, as indicated by the ZOI in millimeters, is presented in Table 1. Figures 7 and 8 depict the ZOI for different concentrations of SZ-Ag nanoparticles for positive ZOI of bacteria for SZ-AgNPs nanoparticles and ZOI of bacteria for varied concentration of SZ-AgNPs. These findings reveal notable antibacterial activity, particularly against *B. Subtilis* (15 mm) among gram-positive bacteria, and *S. aureus* (14 mm) and *E.coli* (14 mm) among gram-negative bacteria, surpassing

other experimental bacteria. Similarly, Table 2 illustrates the ZOI for fungal species, showcasing significant antifungal efficacy against *Penicillium* sp (18 mm), *Aspergillus flavus* (18 mm), and *Candida albicans* (18 mm), with higher inhibition compared to *Rhizopus microsporus* (15 mm).

Table 1
ZOI of bacteria for varied concentration of SZ-AgNPs

Concentration (µL)	Gram-Positive			Gram-Negative		
	<i>S.aureus</i>	<i>B. subtilis</i>	<i>E.coli</i>	<i>S.pyogenes</i>	<i>Paeruginosa</i>	<i>P.mirabilis</i>
SZ-Ag (20)	10	11	9	8	10	7
SZ-Ag (40)	11	11	10	9	10	9
SZ-Ag (60)	13	13	12	11	11	11
SZ-Ag (80)	14	15	14	13	14	13

Table 2
ZOI of fungi for varied concentration of SZ-AgNPs

Concentration (µL)	<i>Aspergillus flavus</i>	<i>Candida albicans</i>	<i>Penicillium sp</i>	<i>Rhizopus microspores</i>
SZ-Ag (20)	13	13	12	9
SZ-Ag (40)	13	13	14	12
SZ-Ag (60)	14	15	16	12
SZ-Ag (80)	18	18	18	15

The enhanced antibacterial action against gram-positive *B.Subtilis* compared to gram-negative bacteria could be attributed to differences in cell wall composition and thickness, with gram-positive bacteria possessing a thicker peptidoglycan layer. Notably, gram-negative bacteria exhibit greater susceptibility due to their thinner peptidoglycan layer, facilitating easier penetration by nanoparticles [46, 47]. Upon entering the cell, nanoparticles interact with DNA, disrupt proteins and enzymes, and elevate reactive oxygen species levels, potentially triggering apoptosis [48]. Interestingly, nanoparticles with sharp edges (e.g., triangular or hexagonal shapes) exhibit enhanced antibacterial activity compared to spherical or circular nanoparticles [46]. The graphical representation of reactive oxygen species of antimicrobial strategy is shown in Fig. 9. This study underscore the potent antimicrobial activity of SZ-AgNPs, coupled with their potential for efficiently degrading harmful textile dyes. Furthermore, the eco-friendly synthesis of AgNPs using *Sansevieria zeylanica* extract ensures their safety for various human medicinal applications, contrasting with chemically synthesized counterparts known for their toxicity and environmental hazards. This research overlays the way for the development of effective and sustainable antimicrobial agents with broad applicability [49].

4. Conclusion

This study presents a comprehensive investigation into the synthesis and characterization of silver nanoparticles (AgNPs) utilizing *Sansevieria zeylanica* extract, along with an assessment of their antimicrobial and dye degradation capabilities. The synthesized SZ-AgNPs underwent thorough characterization using techniques such as FT-IR, UV-Vis spectroscopy, XRD, and SEM. UV-Vis spectroscopy revealed a prominent absorption peak at 463 nm, indicative of π - π^* transition in the biosynthesized SZ-AgNPs. FT-IR analysis confirmed the presence of various functional groups including OH, CN, CH, CH₃, and CO on the surface of the SZ-AgNPs. XRD analysis provided valuable insights into the average crystalline size of the nanoparticles, estimated to be 36.86 nm using the Scherrer formula. SEM imaging displayed a uniform honeycomb surface morphology of the SZ-AgNPs, indicative of their structural integrity. Antimicrobial assays conducted against a range of bacterial and fungal species demonstrated the potent antibacterial activity of the SZ-AgNPs, particularly against gram-positive bacterium *B.subtilis*. However, their antifungal efficacy against *Rhizopus microsporus* was comparatively lower than other fungal species. Furthermore, the synthesized Ag nanoparticles exhibited remarkable stability even at room temperature and showcased excellent photodegradation efficiency for CV and CR dyes, achieving degradation rates of 72% and 63%, respectively. These photoactive SZ-AgNPs offer several advantages over conventional photocatalytic systems, highlighting their potential for diverse environmental remediation applications. Thus, the bio-fabricated SZ-AgNPs using *Sansevieria zeylanica* extract exhibit promising characteristics for antimicrobial and dye degradation applications, underscoring their potential as eco-friendly and efficient nanomaterials for various environmental and biomedical applications.

Declarations

Author Contribution

S. Sabadini: Conceptualization, Investigation, Software, Writing – Original Draft. Y. Christabel Shaji: Software, Formal analysis, Supervision. Y. Brucely: Review & Editing. B. Ganesh Babu: Validation, Review. K. Sakthipandi: Formal analysis, Review & Co- Supervision

References

1. A. Jain, F. Ahmad, D. Gola, A. Malik, N. Chauhan, P. Dey, P.K. Tyagi, Environ. Nanotechnol. Monit. Manag. **14**, 100337 (2020)
2. D. Garg, A. Sarkar, P. Chand, P. Bansal, D. Gola, S. Sharma, S. Khantwal, R. Surabhi, N. Mehrotra, Chauhan, R.K. Bharti, Prog Biomater. **9**, 81 (2020)
3. S. Naranthatta, P. Janardhanan, R. Pilankatta, S.S. Nair, ACS Omega. **6**, 8646 (2021)
4. J. Fabian, R. Zahradník, Angew Chemie Int. Ed. Engl. **28**, 677 (1989)
5. K.-T. Chung, C.E. Cerniglia, Mutat. Res. Genet. Toxicol. **277**, 201 (1992)

6. T. Robinson, G. McMullan, R. Marchant, P. Nigam, *Bioresour Technol.* **77**, 247 (2001)
7. P. Karthik, S. Ravichandran, V. Sasikala, N. Prakash, A. Mukkannan, J. Rajesh, *Surf. Interfaces.* **40**, 103088 (2023)
8. R. Maas, S. Chaudhari, *Process. Biochem.* **40**, 699 (2005)
9. V.K. Gupta, R. Jain, A. Mittal, M. Mathur, S. Sikarwar, *J. Colloid Interface Sci.* **309**, 464 (2007)
10. S.H. Lin, C.F. Peng, *Water Res.* **28**, 277 (1994)
11. M. Chander, D.S. Arora, *Dye Pigment.* **72**, 192 (2007)
12. S.M. Ghoreishi, R. Haghighi, *Chem. Eng. J.* **95**, 163 (2003)
13. E. Xingu-Contreras, G. García-Rosales, A. Cabral-Prieto, I. García-Sosa, *Environ. Nanotechnol. Monit. Manag.* **7**, 121 (2017)
14. S.C. Davis, K.J. Klabunde, *Chem. Rev.* **82**, 153 (1982)
15. X. Wan, M. Yuan, S. Tie, S. Lan, *Appl. Surf. Sci.* **277**, 40 (2013)
16. M.R. Kim, D.K. Lee, D.-J. Jang, *Appl. Catal. B Environ.* **103**, 253 (2011)
17. S. Joseph, B. Mathew, *J. Mol. Liq.* **204**, 184 (2015)
18. I. Pastoriza-Santos, L.M. Liz-Marzán, *Langmuir.* **18**, 2888 (2002)
19. S. Kumar Ghosh, S. Kundu, M. Mandal, S. Nath, T. Pal, *J. Nanoparticle Res.* **5**, 577 (2003)
20. K. Okitsu, Y. Mizukoshi, H. Bandow, Y. Maeda, T. Yamamoto, Y. Nagata, *Ultrason. Sonochem.* **3**, S249 (1996)
21. Y.N. Rao, D. Banerjee, A. Datta, S.K. Das, R. Guin, A. Saha, *Radiat. Phys. Chem.* **79**, 1240 (2010)
22. Y. Sun, Y. Xia, *Adv. Mater.* **14**, 833 (2002)
23. N. Kaur, A. Singh, W. Ahmad, J. Inorg. Organomet. Polym. Mater. **33**, 663 (2023)
24. M.N. Nadagouda, T.F. Speth, R.S. Varma, *Acc. Chem. Res.* **44**, 469 (2011)
25. K. Vijayaraghavan, S.P.K. Nalini, *Biotechnol. J.* **5**, 1098 (2010)
26. S. Husain, M. Sardar, T. Fatma, *World J. Microbiol. Biotechnol.* **31**, 1279 (2015)
27. A.G. Rama Krishna, C.S. Espenti, Y.V. Rami Reddy, A. Obbu, M.V. Satyanarayana, *J. Inorg. Organomet. Polym. Mater.* **30**, 4155 (2020)
28. A. Ferin Fathima, R. Jothi Mani, K. Sakthipandi, K. Manimala, A. Hossain, *J. Inorg. Organomet. Polym. Mater.* **30**, 2397 (2020)
29. Y.Y. Loo, Y. Rukayadi, M.-A.-R. Nor-Khaizura, C.H. Kuan, B.W. Chieng, M. Nishibuchi, S. Radu, *Front. Microbiol.* **9**, (2018)
30. S.M. Roopan, G. Rohit, A.A. Madhumitha, C. Rahuman, A. Kamaraj, Bharathi, T.V. Surendra, *Ind. Crops Prod.* **43**, 631 (2013)
31. Á. de Jesús Ruíz-Baltazar, S.Y. Reyes-López, D. Larrañaga, M. Estévez, R. Pérez, *Results Phys.* **7**, 2639 (2017)
32. V. Germain, J. Li, D. Inger, Z.L. Wang, M.P. Pileni, *J. Phys. Chem. B* **107**, 8717 (2003)

33. R. Shanmuganathan, D. MubarakAli, D. Prabakar, H. Muthukumar, N. Thajuddin, S.S. Kumar, A. Pugazhendhi, *Environ. Sci. Pollut Res.* **25**, 10362 (2018)
34. T.C. Prathna, N. Chandrasekaran, A.M. Raichur, A. Mukherjee, *Colloids Surf. B Biointerfaces.* **82**, 152 (2011)
35. N. Thirumagal, A.P. Jeyakumari, *J. Clust Sci.* **31**, 487 (2020)
36. S.L. Smitha, K.M. Nissamudeen, D. Philip, K.G. Gopchandran, *Spectrochim Acta Part. Mol. Biomol. Spectrosc.* **71**, 186 (2008)
37. T. Rasheed, M. Bilal, H.M.N. Iqbal, C. Li, *Colloids Surf. B Biointerfaces.* **158**, 408 (2017)
38. R. Yuvakkumar, J. Suresh, B. Saravanakumar, A. Joseph Nathanael, S.I. Hong, V. Rajendran, *Spectrochim Acta Part. Mol. Biomol. Spectrosc.* **137**, 250 (2015)
39. S. Pandey, J.Y. Do, J. Kim, M. Kang, *Carbohydr. Polym.* **230**, 115597 (2020)
40. R. Lu, *Int. J. Nanomed.* **12**, 2101 (2012)
41. S.S. Royji Albeladi, M.A. Malik, S.A. Al-thabaiti, *J. Mater. Res. Technol.* **9**, 10031 (2020)
42. P.C.L. Muraro, S.R. Mortari, B.S. Vizzotto, G. Chuy, C. dos Santos, L.F.W. Brum, W.L. da Silva, *Sci. Rep.* **10**, 3055 (2020)
43. M. Chandhru, S. Kutti Rani, N. Vasimalai, *J. Environ. Chem. Eng.* **8**, 104225 (2020)
44. A. Chatterjee, E. Perevedentseva, M. Jani, C.-Y. Cheng, Y.-S. Ye, P.-H. Chung, C.-L. Cheng, *J. Biomed. Opt.* **20**, 051014 (2014)
45. W. Lee, K.-J. Kim, D.G. Lee, *BioMetals.* **27**, 1191 (2014)
46. S. Tyagi, P.K. Tyagi, D. Gola, N. Chauhan, R.K. Bharti, *SN Appl. Sci.* **1**, 1545 (2019)
47. E. Moskvitina, V. Kuznetsov, S. Moseenkov, A. Serkova, A. Zavorin, *Mater. (Basel).* **16**, 957 (2023)
48. A. Dhaka, S. Chand Mali, S. Sharma, R. Trivedi, *Results Chem.* **6**, 101108 (2023)
49. H. Duan, D. Wang, Y. Li, *Chem. Soc. Rev.* **44**, 5778 (2015)

Figures

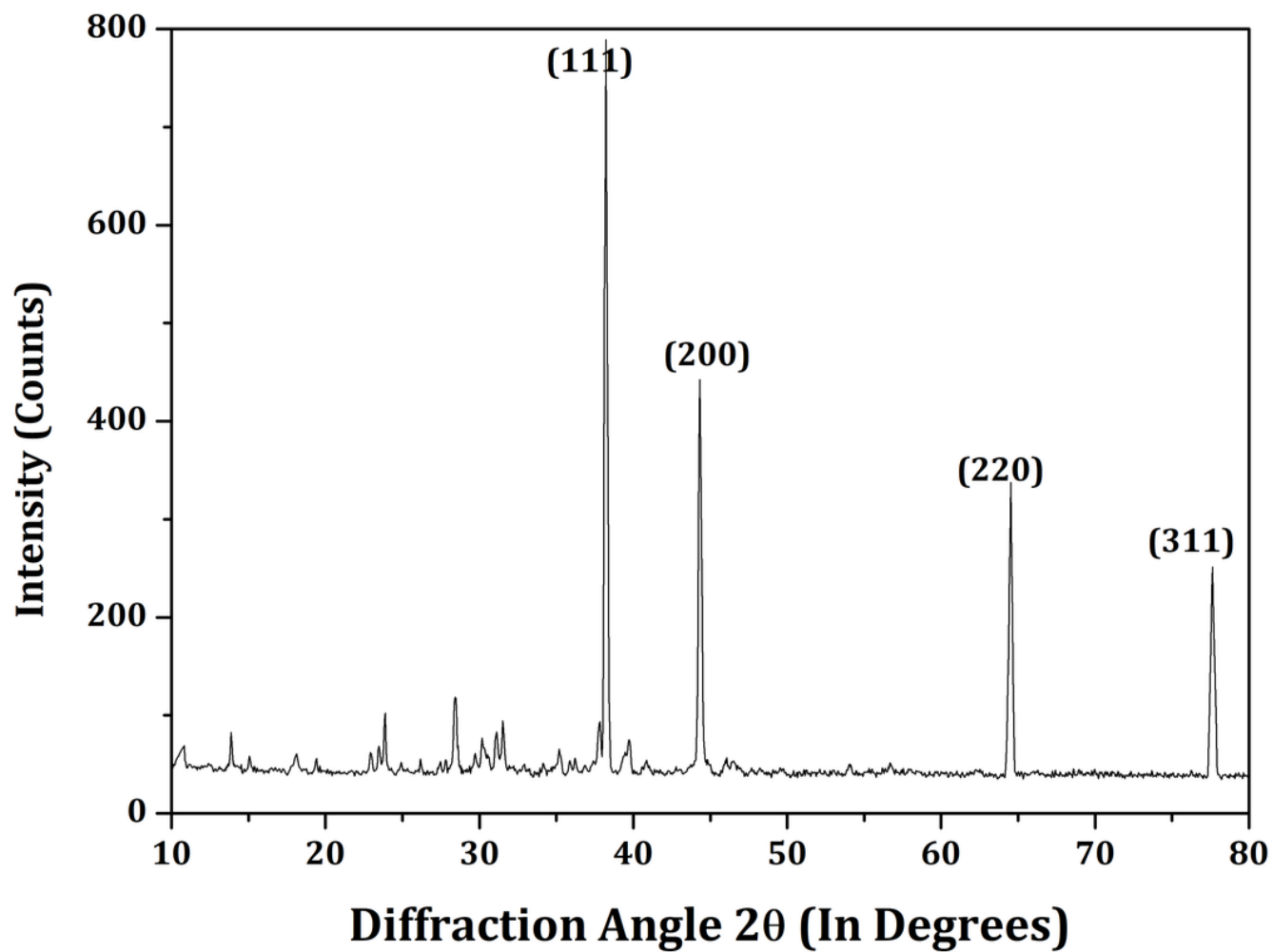


Figure 1

XRD spectrum illustrating the crystalline structure of SZ-AgNPs synthesized utilizing *Sansevieria zeylanica* extract

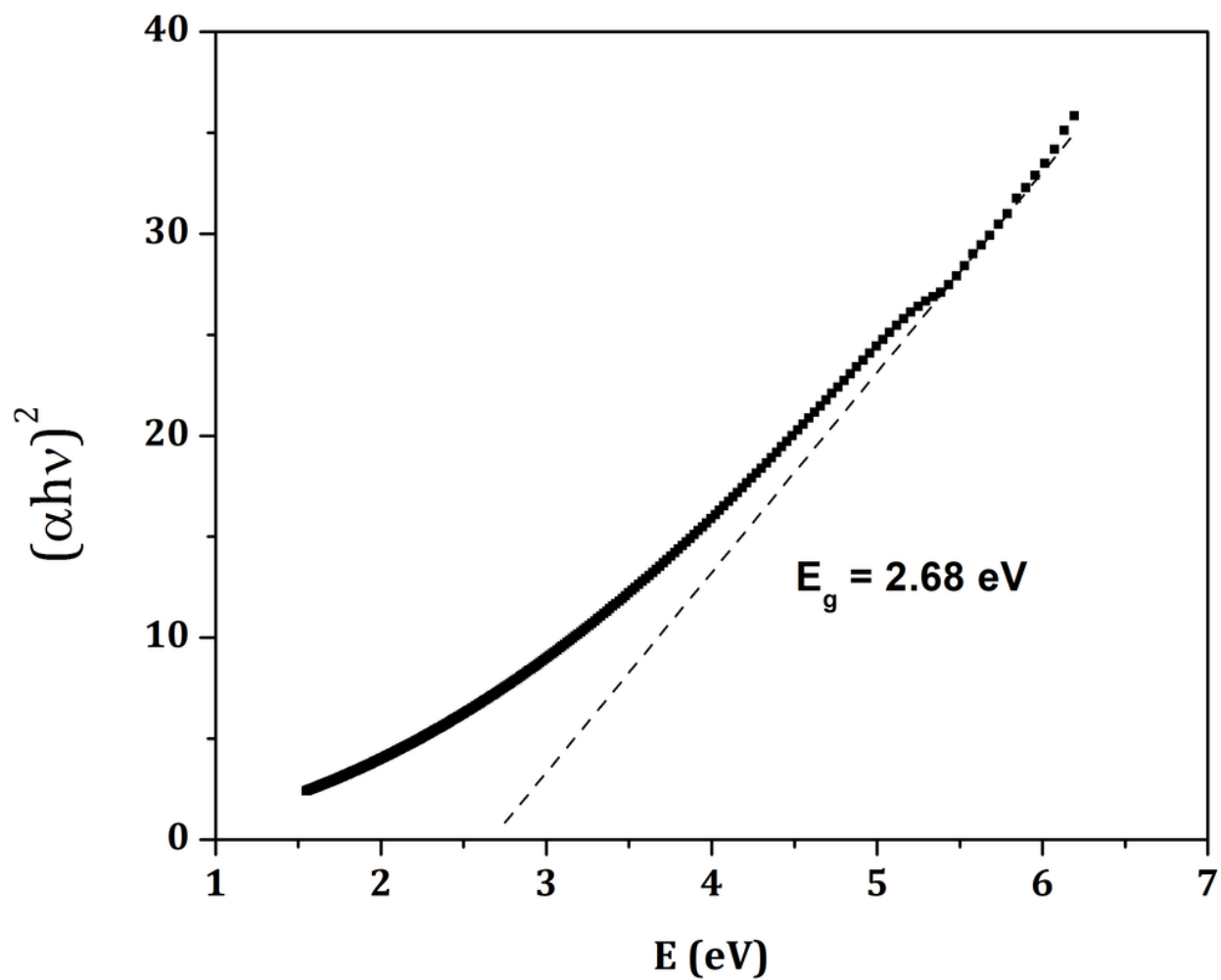


Figure 2

UV spectrum depicting the absorption characteristics of SZ-AgNPs synthesized using *Sansevieria zeylanica* extract

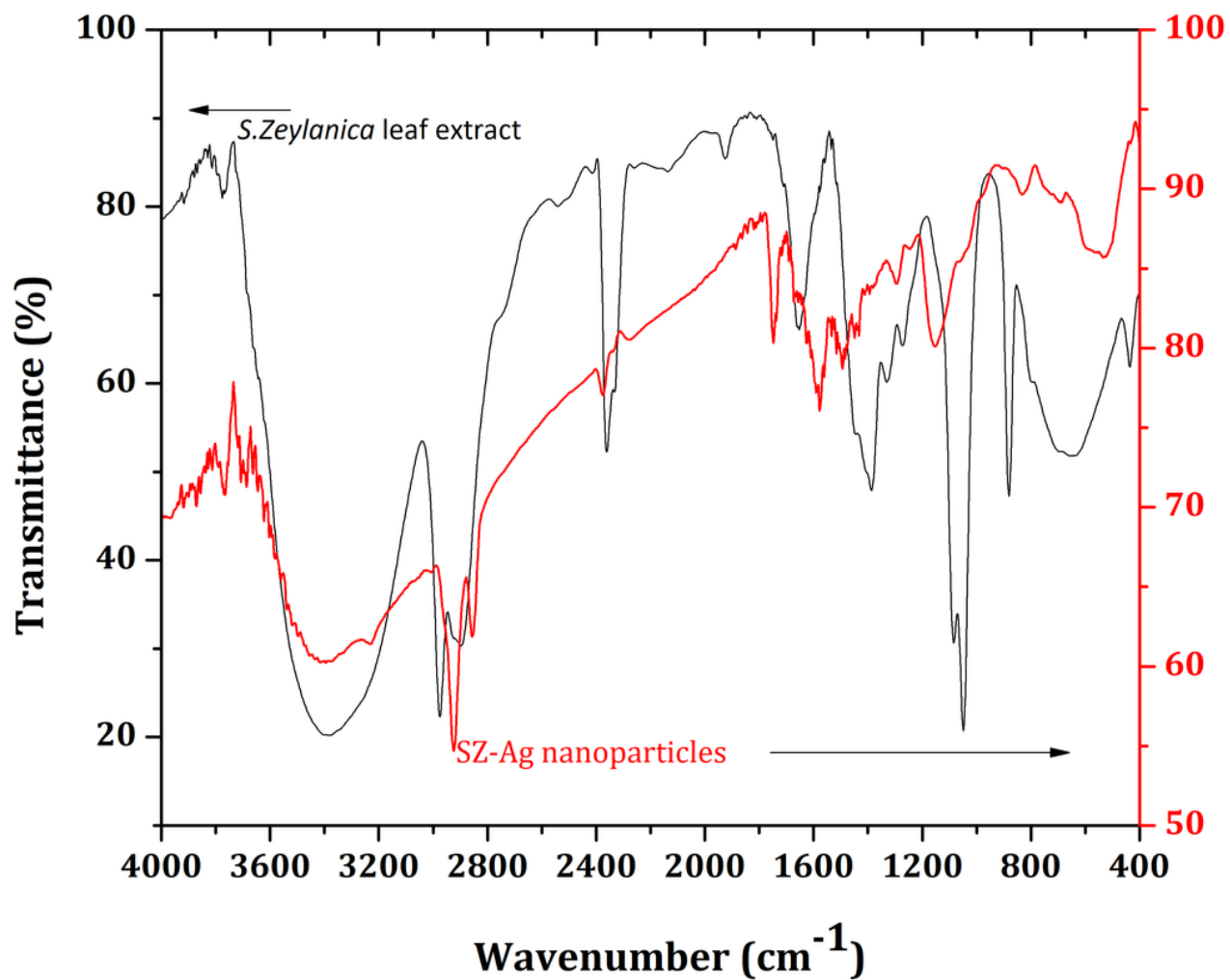
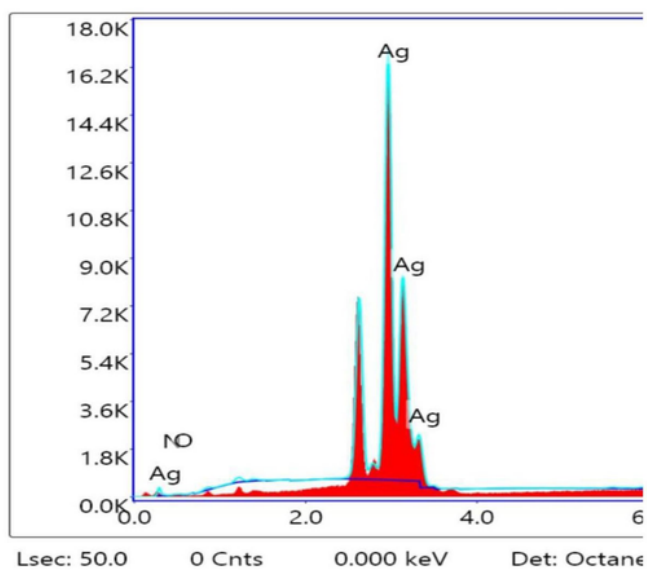
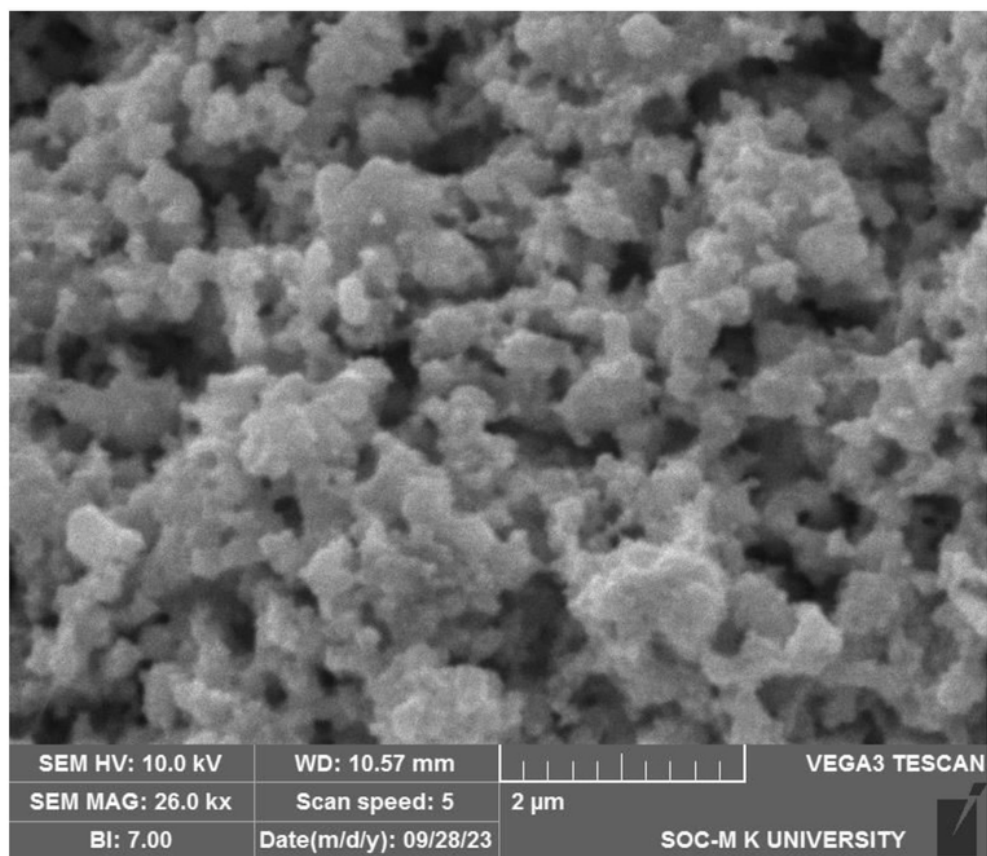


Figure 3

(a) SEM image revealing the surface morphology (b) EDX spectrum indicating the elemental composition of the synthesized SZ-AgNPs.



Element	Weight%	Atomic%
N	0.21	1.54
O	0.28	1.84
Ag	99.51	96.62

Figure 4

FT-IR spectra displaying characteristic absorption bands corresponding to functional groups present on the surface of SZ-AgNPs

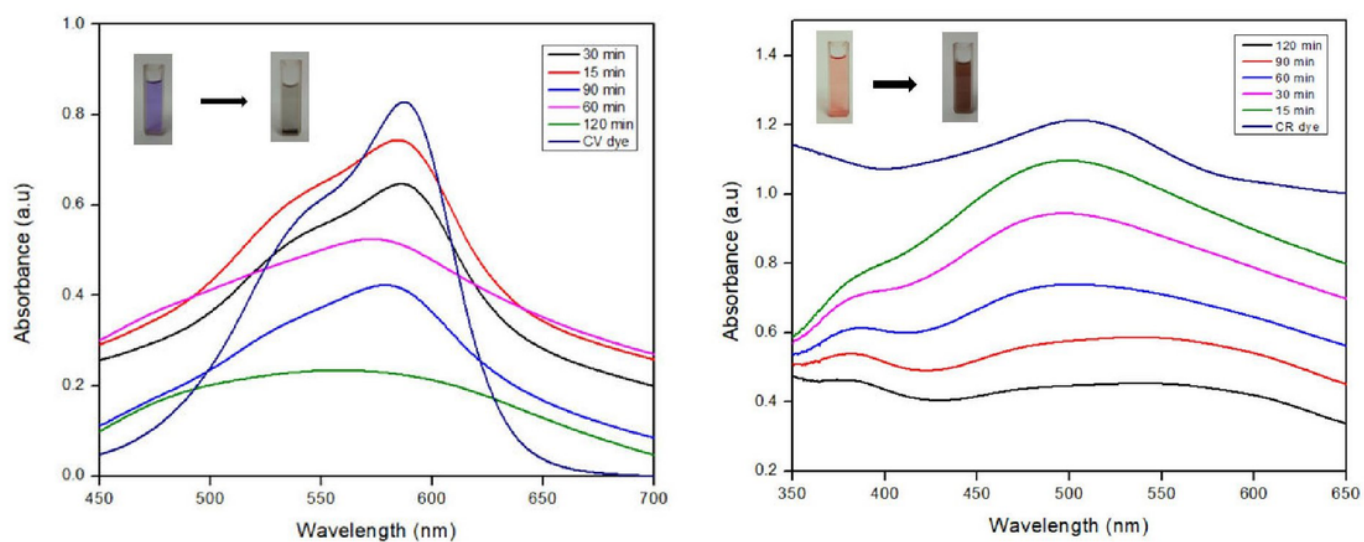


Figure 5

(a) Degradation of crystal violet (CV) dye (b) Degradation of congo red (CR) dye using SZ-AgNPs

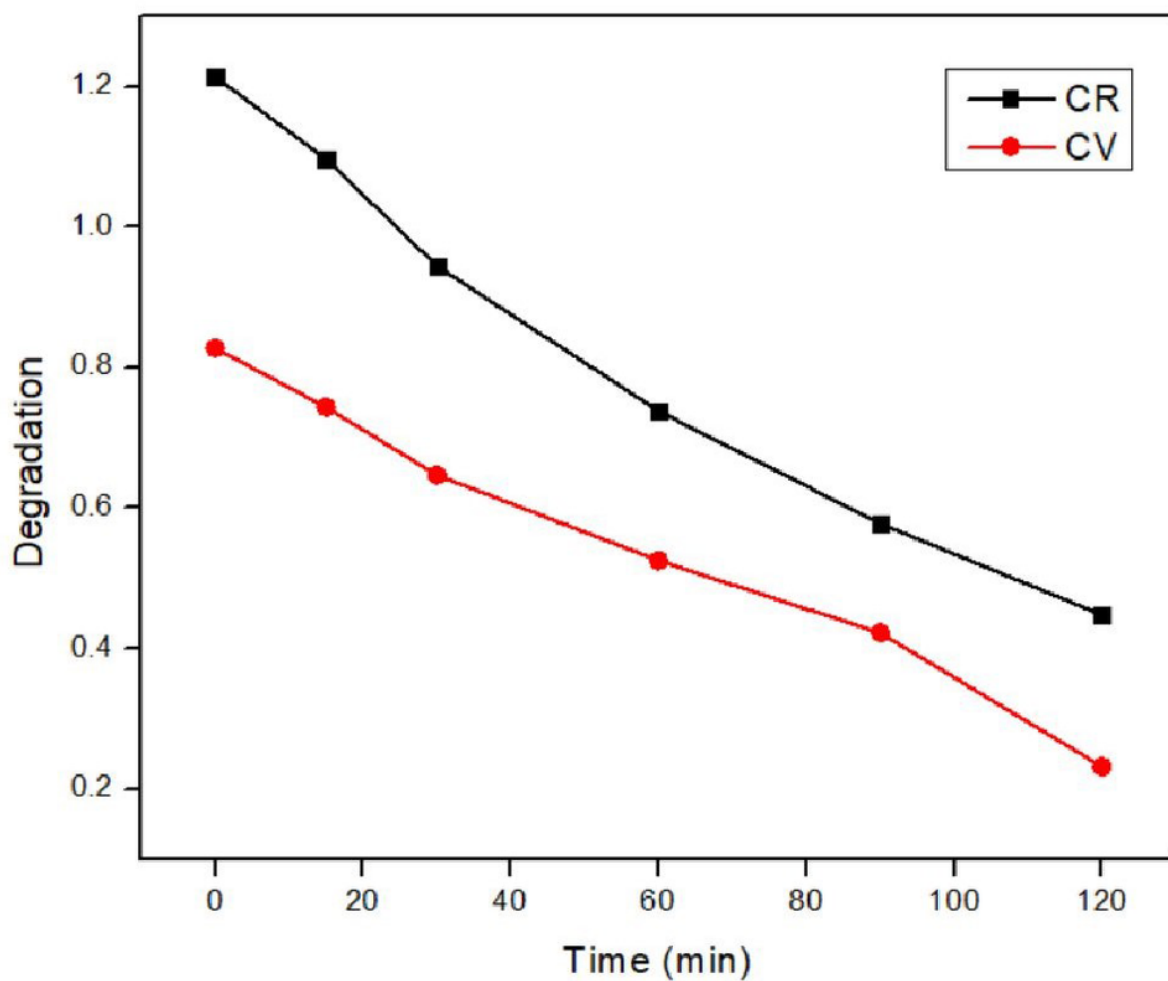


Figure 6

Graph depicting the degradation efficiency of crystal violet (CV) and Congo red (CR) dyes over time, utilizing SZ-Ag NPs

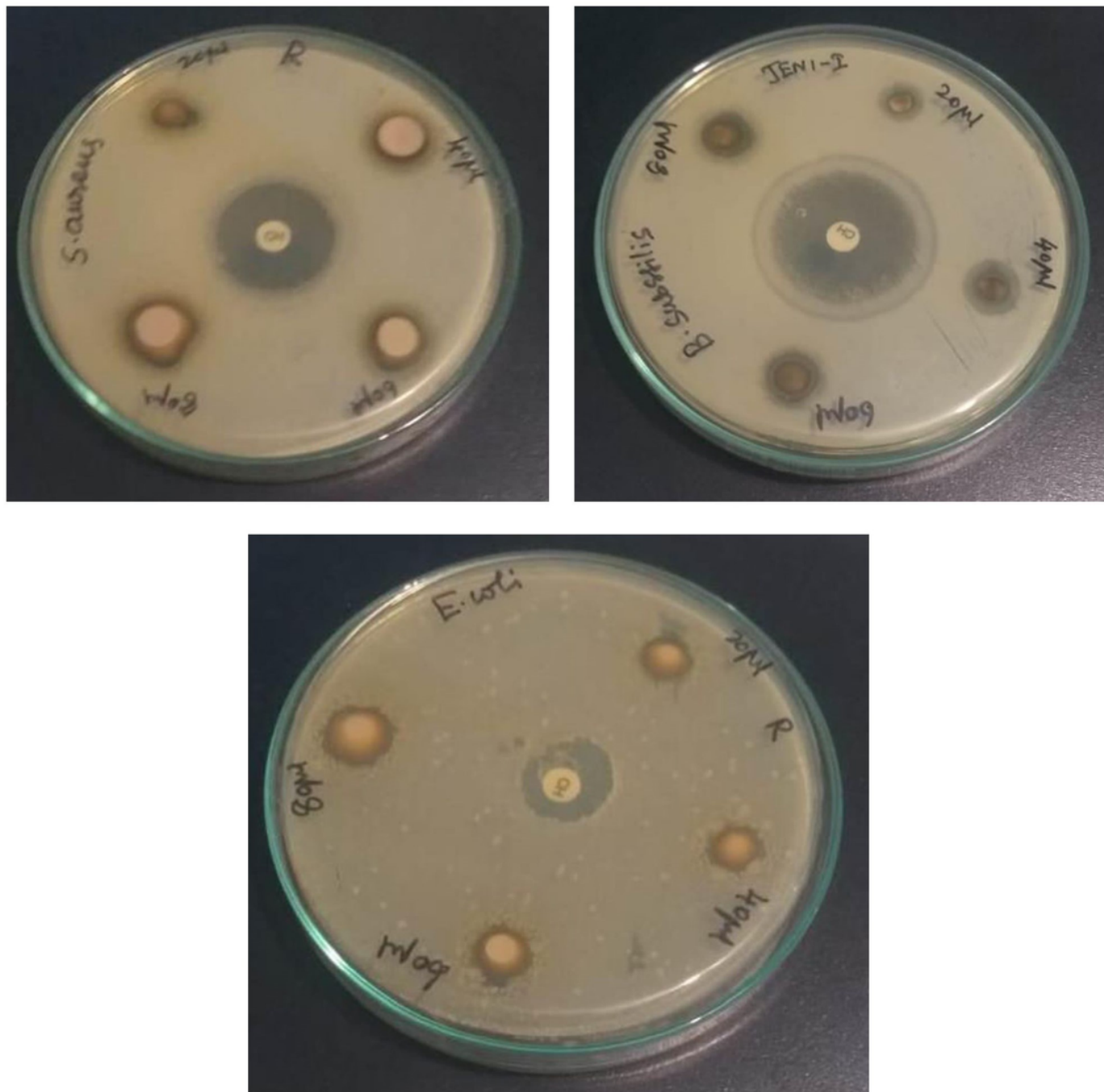


Figure 7

ZOI exhibited by bacteria for different concentrations of SZ-AgNPs

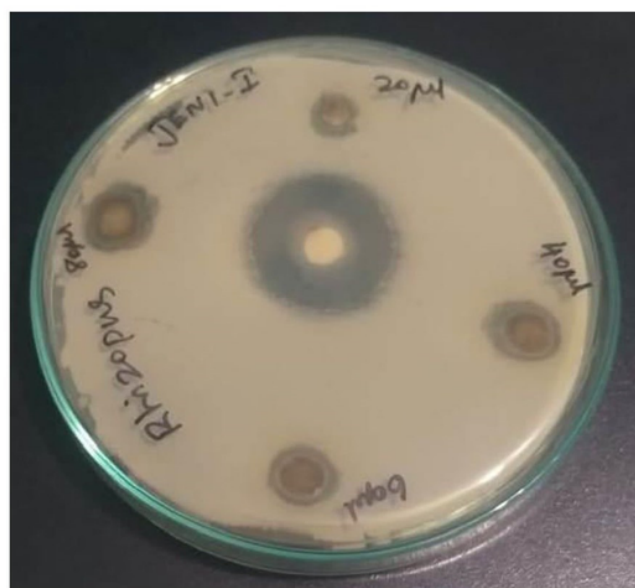


Figure 8

ZOI demonstrated by fungi for varying concentrations of SZ-AgNPs

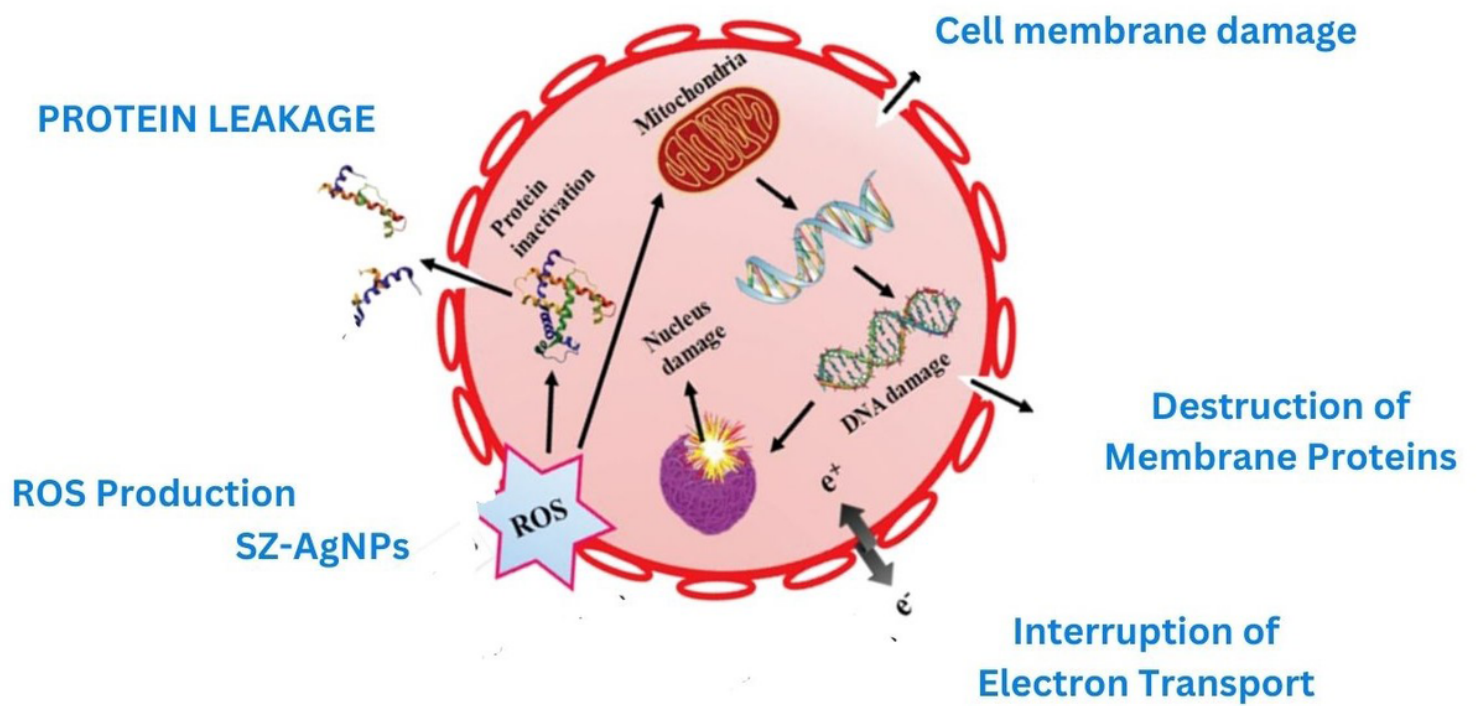


Figure 9

Graphical Representation of Reactive Oxygen Species in Antimicrobial Strategy of SZ-AgNPs