



Evaluation of Nano silver efficiency for removing contaminant and antimicrobial dyes for water filtration applications with Nano silver-coated filters

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Article Info

Article history:

Received 10, 02, 2024

Revised 11, 12, 2024

Accepted 12, 18, 2024

Published 10, 30, 2026

Keywords:

Antimicrobial activity, E. coli, silver nanoparticles, Photocatalytic, uv, ftir, Antibacterial, zeta, nano partiacial.

ABSTRACT

The aim of this study is to enhance our comprehension of the efficiency of dye removal when subjected to sunlight and various optical spectra, as well as to assess the elimination of microorganisms by filters coated with Nano silver that are employed in water purification. A specific quantity of Nano silver, along with other prepared forms of Nano silver, was introduced into the laboratory setting for investigation. The tautog-catalyst analysis provided insights into the color spectrum of the dye employed, as well as its removal efficacy. Previous research has indicated that silver exhibits limited removal effectiveness, but sample 1 demonstrated notable efficiency while sample 3, once prepared, also exhibited strong removal performance. In terms of bacterial removal efficiency, the enumeration of bacteria was conducted using the membrane filtration technique. The findings indicate that the nanoparticles are stabilized in the water. These two strains were cultured on nutrient agar medium to examine the impact of the prepared nanomaterials on them. The diffusion well method was employed to investigate the influence of silver nanoparticles, prepared at concentrations of [30, 20, 10, 0.0] µg/ml, on the growth of Gram-negative E. coli [25922 E. coli] and Gram-negative E. coli [25923 E. coli], as well as Staphylococcus aureus [25923 ATCC aureus]. Furthermore, the impact of silver nanoparticles loaded on filter papers with varying manufacturing specifications on E. coli ATCC 25922 was studied and illustrated in terms of percentage inhibition. This strain of bacteria, E. coli ATCC 25922, was the subject of investigation due to its prevalence in water as a result of fecal contamination. The presence of this strain may indicate the presence of other contaminants. The study focused on examining this particular strain on filters. Nano-silver nanoparticles and zeta-potential have demonstrated robust stability.

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1. INTRODUCTION

Nanotechnology plays a crucial role in various fields such as optics, electronics, biomedical sciences, chemical industry, chemical catalysis, energy sciences, and photoelectrochemical applications due to the distinctive properties of nanomaterials. These materials have been identified as innovative solutions for addressing health and environmental challenges. Nanoparticles are characterized by a high surface-to-volume ratio and minute size, resulting in alterations in their physical and chemical attributes when compared to similar materials. Among the numerous nanoparticle types, metallic silver nanoparticles [AgNPs] have garnered significant attention due to their unique optical, mechanical, thermal, and biological properties. Hence, various methods exist for the synthesis of silver nanoparticles (AgNPs), including chemical vapor deposition (CVD)

and sol-gel processes. However, the significant challenges in AgNP synthesis arise from the toxicity, cost, and environmental impact associated with these methods [1]. Nanotechnology is rapidly expanding and finding applications across various scientific and engineering disciplines, such as biomedicine, sensors, chemical engineering, photocatalysis, drug delivery, cell labeling, organelle labeling, imaging, and smart devices. The distinguishing feature of nanomaterials is their high surface area-to-volume ratio, which plays a crucial role in their antiviral, antibacterial, catalyst, antifungal, therapeutic, conductive and plasmonic applications. Various methods are available for synthesizing metal nanoparticles for practical use; however, many of these methods are costly or environmentally harmful and often involve the use of toxic reducing agents [2].

2. EXPERIMENTAL SETUP

The ready-made nanosilver was purchased from the factory and labeled as sample 1 and the other sample was prepared by chemical precipitation method of dissolving silver nitrate with water and distilling HCl with heating and circulating the solution and labeled as sample 3.

3. PREPARATION METHODS

The substance is received in a powdered state with a 99.98% purity. The third specimen is produced as a powder subsequent to being precipitated with HCL and then incinerated at 500 degrees Celsius. These powders demonstrate high efficacy in eliminating color dyes, such as methyl blue. While it has been demonstrated to be ineffective against silver, its efficacy has been verified for blue dye but not for yellow dye.

4. CHARACTERIZATION TECHNIQUES

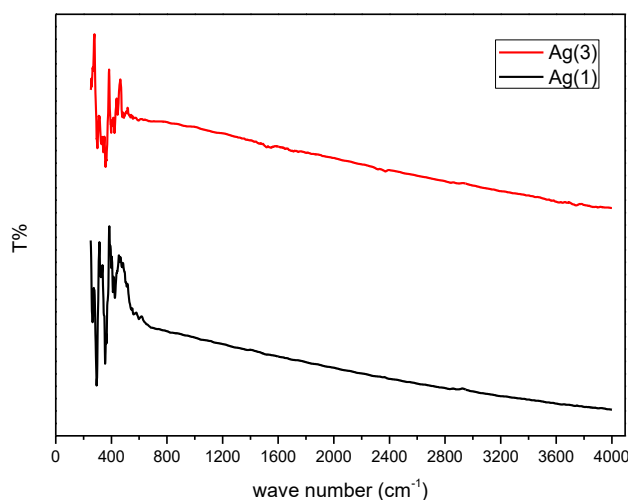
Several tests were conducted to verify the properties of the materials, including FTIR testing to identify chemical bonds, UV testing to determine substance characteristics, EDX testing to analyze composition and substances present, and photo catalyst testing to assess the ability of the materials to remove methyl blue dye. The study also examined the impact of nanomaterials. Additionally, the cultivation of two isolates on nutrient agar medium was observed to assess the influence of prepared nanomaterials on their external isolates. Furthermore, the effect of nanomaterials on bacterial isolates was investigated using the well diffusion method with silver nanoparticles at concentrations of [30, 20, 10, 0.0] micrograms to evaluate their impact on Gram-negative *Escherichia coli* [25922 ATCC] and Gram-positive *Staphylococcus aureus* [25923 ATCC]. Moreover, an investigation into the effect of silver nanoparticles loaded on filter papers with various manufacturing specifications on *E. coli* ATCC 25922 bacteria was conducted using the plate casting method. Silver is widely recognized as a versatile metal employed in various applications, including its use as an antibacterial agent, for optical actuation, and in electrical and medical and chemical sensors. Research interests are focused on the production of silver at the nanoscale, also known as silver nanoparticles (Ag NPs), due to the close relationship between material properties and the enhancement of chemical properties in nanomaterials across numerous applications. These nanoparticles are categorized as such based on their size, falling within the range of 1 – 100 nm. The synthesis of nanoparticles can be achieved through both top-down (physics) and bottom-up (chemistry) methods. The physics method involves breaking down solid metal into small nano-sized particles, whereas the chemical method entails forming nanoparticles from molecular precursors or ions. Various techniques, such as chemical and photochemical methods, as well as sonic chemical reduction, can be employed for the production of nanoparticles [3]. One of these techniques involves the use of high ultraviolet rays. There are numerous technologies available for generating nanoparticles, including chemical, photochemical, and sonic chemical reduction methods. However, the utilization of Ag-NPs for water treatment or purification purposes may pose challenges when considering their usage and potential reuse in treated water. To address this issue, alternative mechanisms have been explored to enhance the stability of Ag-NPs on a stable porous solid support and to improve their antibacterial and photosynthetic activities. Additionally, nano-silver nanoparticles and zeta potential have demonstrated stability and reliability [4].

5. RESULTS AND DISCUSSION

5.1. The FT-IR

The FT-IR spectra of the first purchased sample and the second sample show similar results. The broad peaks at 3452 cm are due to the stretching vibrations of OH and N-H, while the peaks at 2934 cm are related to the asymmetric vibrations of CH bonds. Additionally, the presence of hydrogen bonds is indicated by the peaks at 1658 cm⁻¹ to 1604 cm⁻¹. The characteristic peaks for LS are observed at 3252 cm⁻¹ and 2934 cm⁻¹, corresponding to the stretching vibration of -OH and the asymmetric stretching vibration of -CH, respectively. Moreover, peaks at 1046 cm⁻¹, 704 cm⁻¹, and 1023 cm⁻¹ indicate the presence of nano silver. Furthermore,

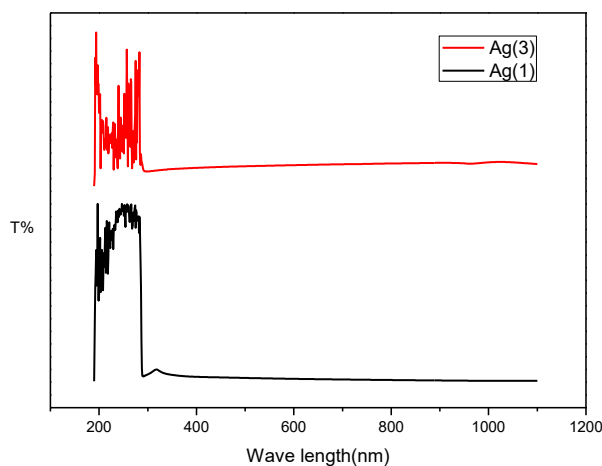
peaks at 617 cm and 482 cm suggest the formation of AgNPs through the –O-H bond between the oxygen atom in Ag₂O and H atom on the surface of nanoparticles been illustrated in Figure 1 [5].



[Figure 1.](#) The FTIR spectra of laboratory-ready silver Samples.

5.2.The UV-Vis

The UV-Vis optical properties of AgNPs were assessed through measurements taken within the 300 to 700 nm range. The nanoparticles' optical characteristics were analyzed using UV-Vis spectroscopy, and the peak absorption wavelength of Ag nanoparticles, demonstrated in Figure 2, was observed to be concentrated between 190 and 290 nm. These findings are in line with those presented been illustrated in Figure 2[6].



[Figure 2.](#) The UV spectra of laboratory-ready silver samples.

5.3 EDS

The presence of silver nanoparticles was verified through energy dispersive X-ray spectroscopy (EDS), as depicted in Figure 3 and Figure 4. The dominant Ag peak was observed at [3 keV], followed by the Ag peak at 69.98, as illustrated in Figure 3 and Figure 4. The silver content was determined to be 71.71% been illustrated in Figure 3 and Figure 4 [7].

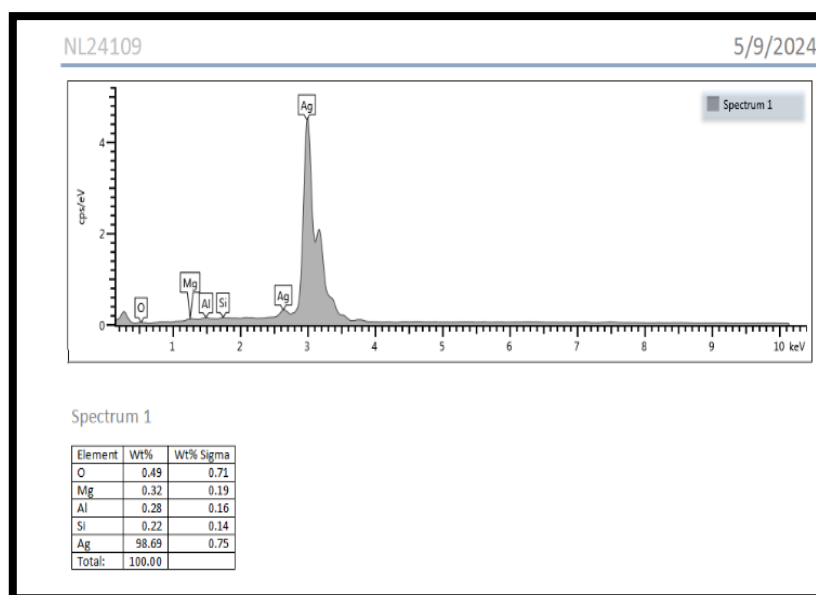


Figure 3. EDX spectra analysis of sample 1.

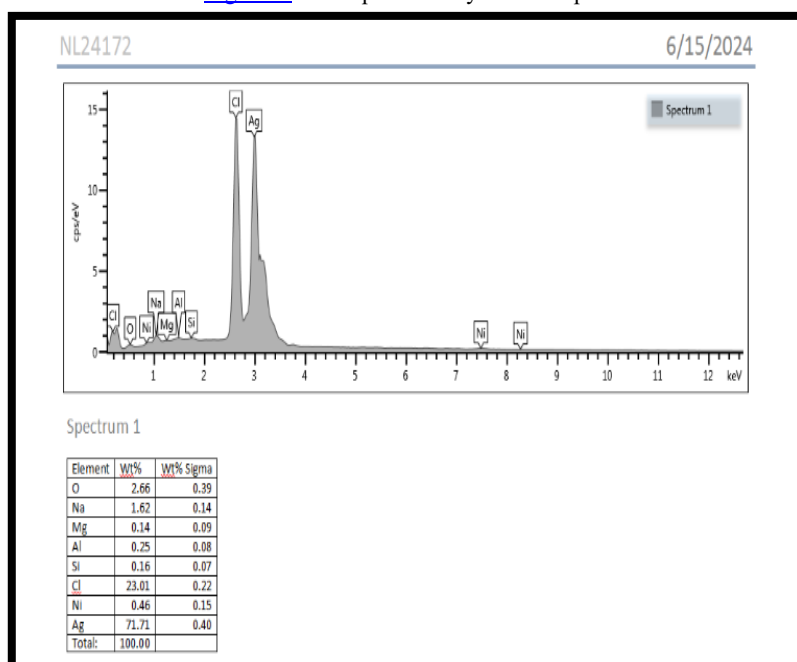


Figure 4. EDX spectra analysis of sample 3.

5.4. The Zeta potential (ZP) and Nano particle size (PS)

The Zeta potential and Nano particle size (PS) and zeta potential (ZP) can be analyzed using the Zeltzer to determine the size and charge of nanomaterials. The particle size distribution and zeta potential of core-shell AgNPs were examined in Figure 5 and Figure 6, indicating a concentration of colloidal AgNPs with a determined ZP value. The presence of hydroxyl groups from starch molecules covering the structure of the produced AgNPs results in a negative ZP, consistent with previous findings. Solutions with zeta potentials above +50 mV or below -50 mV are considered stable, as shown in the results from [10]. The average particle size of the obtained AgNPs was 500 nm based on Figure 5, with particles ranging from 30 nm to 400 nm. Zetasizer measurement in Figure 6 illustrates the average particle size of AgNPs synthesized using Zeta potential, which is an important property for determining their quantity and stability. The negative zeta potential indicates increased stability in the colloidal state, as presented in Figure 7 and Figure 8 [8], providing critical information about molecular stability.

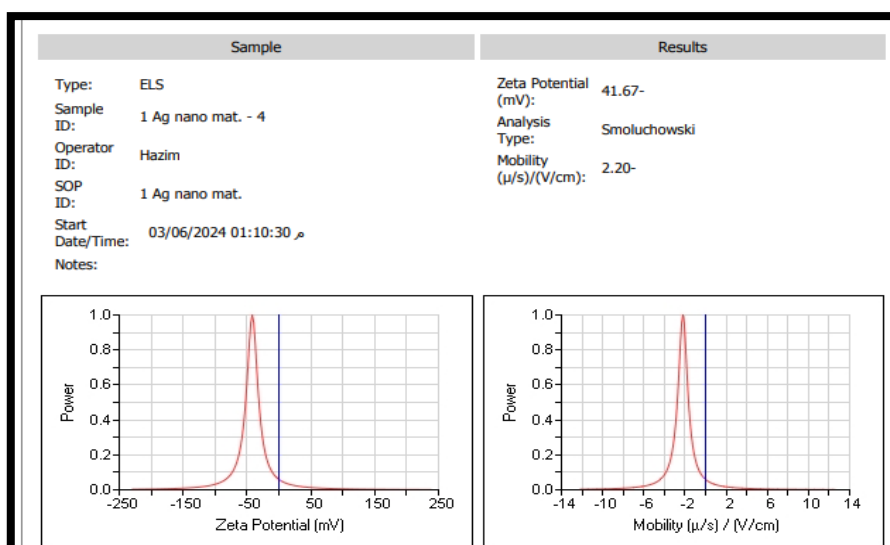


Figure 5. ELS the zeta potential of the first ready-made sample1.

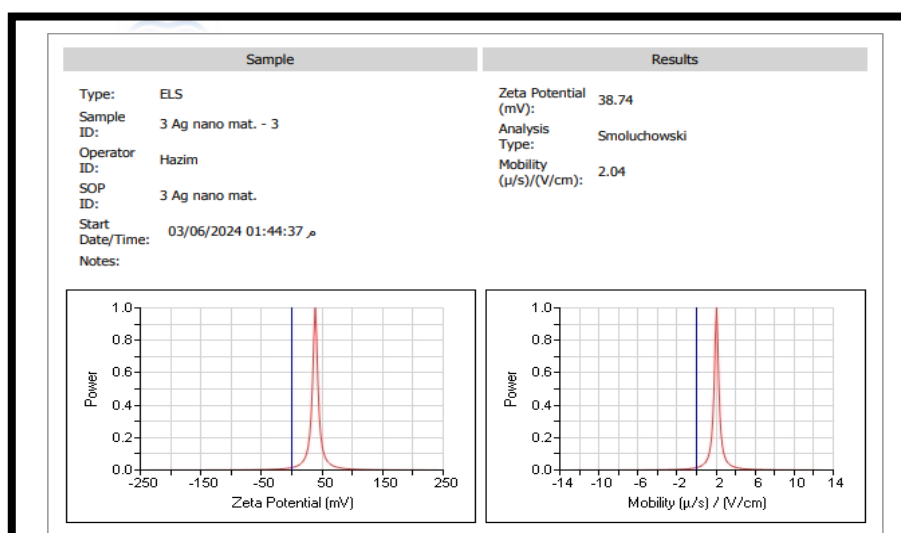


Figure 6. ELS the zeta potential of sample3 .

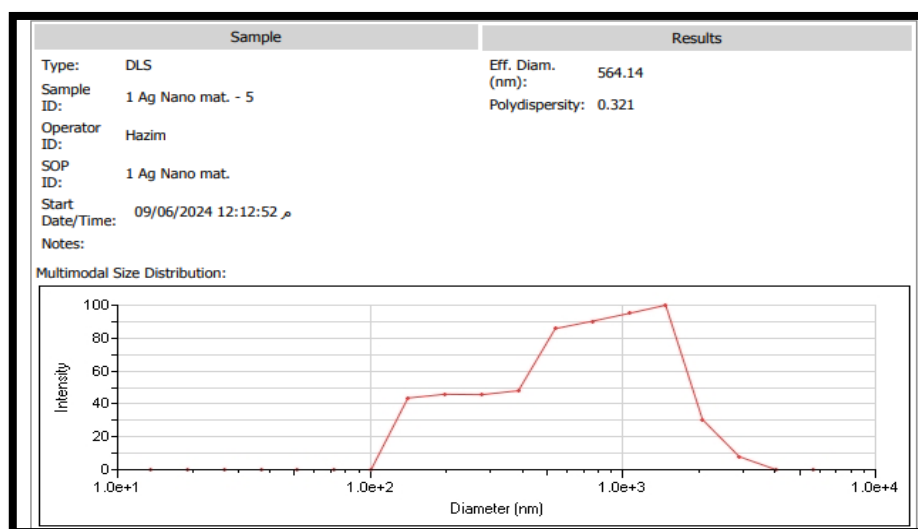


Figure 7. DLS the Nano partial of the first ready-made sample 1.

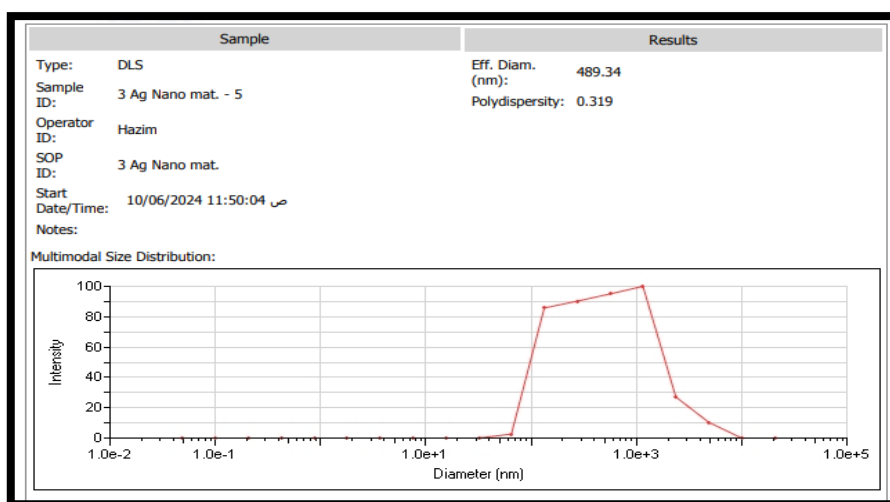


Figure 8. DLS Nano partial examination of sample 3 chemically prepared as a powder.

5.5.The photodegradation

The study examined the photodegradation process of Methylene Blue (MB) dye, a pollution model, on AgNPs samples under sunlight radiation [9]. The characteristic wavelength of 664.5 nm for MB dye was identified to analyze the photodegradation of industrial pollutants. The investigation of photocatalytic activity followed a specific procedure: a 1 mg/L MB dye solution was prepared under high stirring for 3 hours. Subsequently, a thin film of AgNPs (20 mg of powder deposited on a glass substrate at low temperature) was added to 50 ml of the MB dye solution [10]. To achieve desorption and adsorption equilibrium of MB dye on the photocatalyst surface, the solution was kept in darkness for 30 minutes. Then, 3 ml of the solution was extracted every 30 minutes to monitor the decrease in absorbance and concentration using UV-visible spectroscopy. The efficiency of MB dye degradation was calculated using a specific formula [11].

$$\text{Degradation\%} = [1 - C_t/C_0] \times 100$$

Where $[C_t]$ and $[C_0]$ are the absorbance of MB dye after and before exposure to Sunlight.

The degradation of MB dye through the use of AS-AgNP for photocatalysis was examined with the dyes RB-222A and RB-220. The decomposition rate was observed over a specific period, showing a consistent percentage decrease. The pigment colors exhibited a gradual decrease in intensity over time. Dye decolorization is primarily attributed to the action of hydroxyl and oxy radicals, which break down hazardous pollutants formed during the generation of electron-hole pairs. A comparison with a recent study utilizing NPs revealed that silver NPs were found to mediate and facilitate dye degradation in Figures 9, 10, 11, 12, 13, and Figure 14 and table 1 [12].

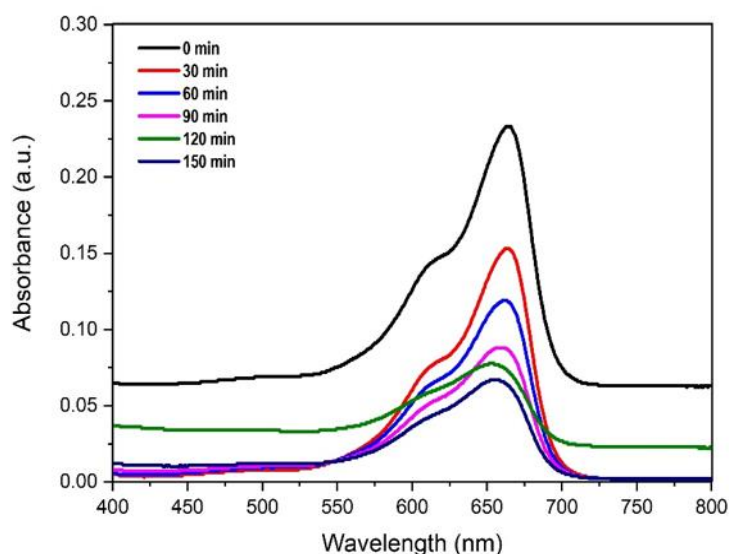


Figure 9. UV-visible spectra of methylene blue dye in the presence of biosynthesized AgNPs at different time intervals. Sample 1.

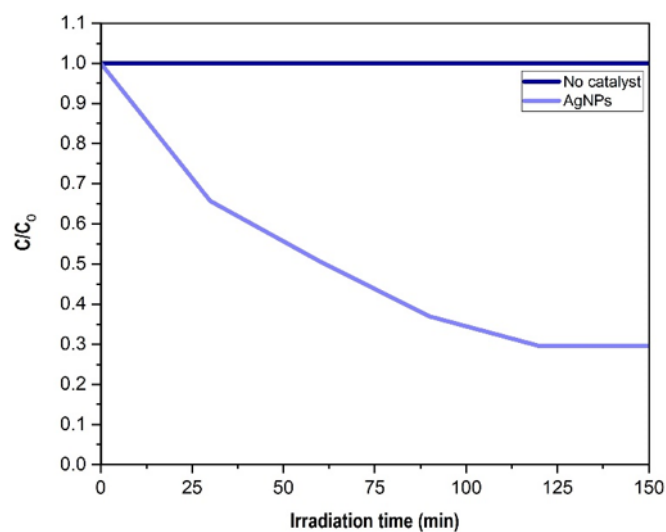


Figure 10. Plots of $[C/C_0]$ against irradiation time for AgNPs Sample1 .

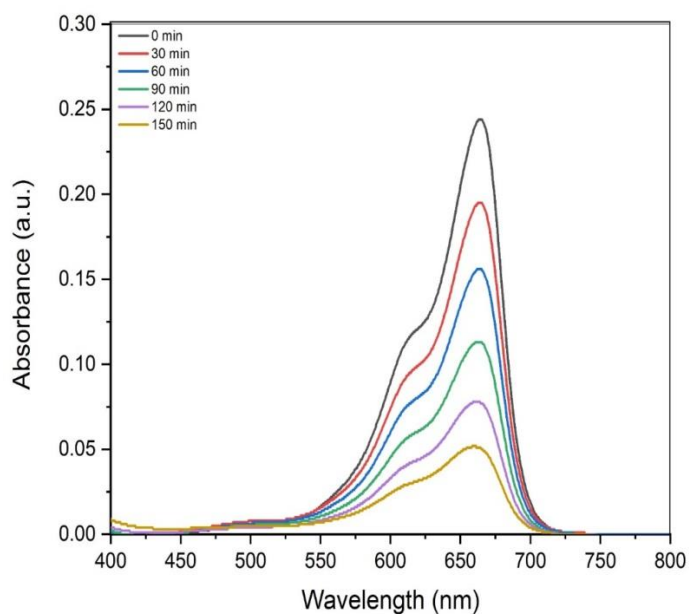


Figure 11. UV-visible spectra of MB dye in the presence of biosynthesized AgNPs at different time intervals Sample 3.

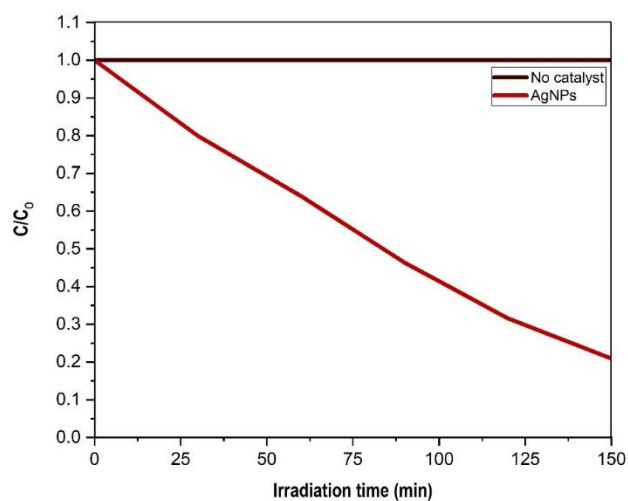
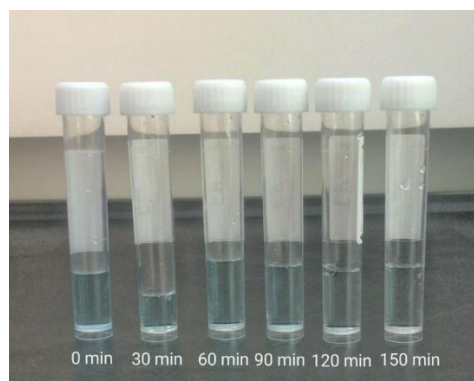
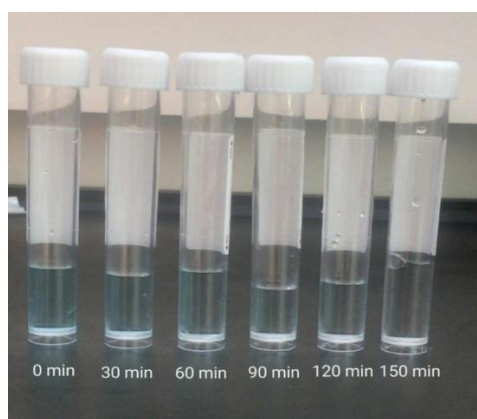


Figure 12. Plots of $[C/C_0]$ against irradiation time for AgNPs Sample3.

Table 1. Photo degradation efficiency of AgNPs.

Sample	Efficiency
1	70
3	79

**Figure 13.** Color change of M.B dye after add Ag NPs Sample 1.**Figure 14.** Color change of M.B dye after add Ag NPs Sample 3.

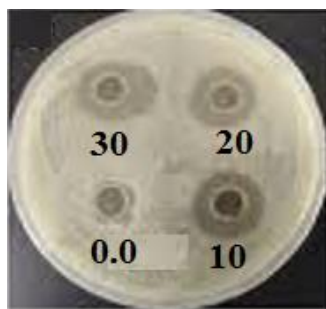
Investigating the impact of nano materials Two bacterial isolates were cultured on nutrient agar medium to examine the impact of the synthesized nano materials on their external isolates. Investigating the influence of nano materials on bacterial isolates The diffusion well technique was employed to assess the impact of silver nanoparticles produced at concentrations of [30, 20, 10 and 0.0] $\mu\text{g/ml}$ on the growth of Gram-negative *Escherichia coli* [25922 ATCC coli] [13]. Been illustrated in Figure 15 and Figure 16. And Table 3, Table 4, and Table 5.

Staphylococcus aureus strain 25923 ATCC, a Gram-positive bacterium, was activated using the following procedure. The bacterial cells were first cultured in brain and heart infusion broth medium for 24 hours at 37 °C with continuous agitation to activate them. Subsequently, the activated bacterial cells were cultivated in Hinton-Muller medium to investigate their antagonistic effect. To study this effect, 6 mm diameter wells were evenly spaced on the medium for the placement of Nano component solution at a volume of 100 μL per well. The plates were allowed to settle and absorb the nanocomponent solutions for fifteen minutes at room temperature before being transferred to a 37°C incubator for further incubation [14]- [15] .

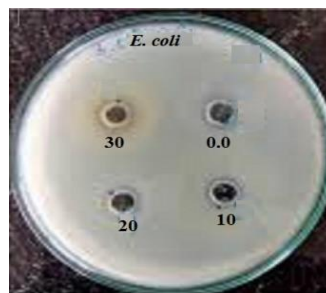
$$\text{Inhibition Ratio} = \text{Test Reading} / \text{Control Reading} \times 100 .$$

Example:

25 = Inhibition zone diameter in the presence of amoxicillin at a concentration of 250 $\mu\text{g/ml}$, table 2.



Escherichia coli ATCC 25922[1].



Escherichia coli ATCC 25922[3].

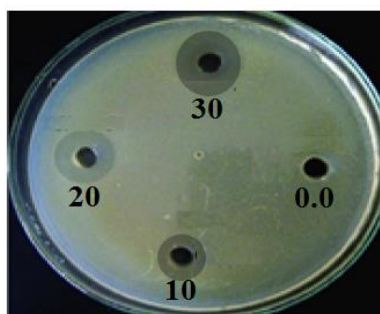
Figure 15. Zone of inhibition [mm] of gonococci with different concentrations of silver prepared by different methods for Escherichia coli ATCC.

Table 2. Inhibition zone diameter [mm] for gonococci with different concentrations of silver prepared by different methods Inhibition zone in [mm] for Escherichia coli ATCC 25922.

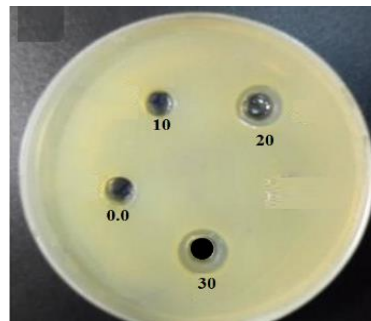
Concentration $\mu\text{g/mL}$	1	3
-Ve control	0.0	0.0
10	9.9	7.5
20	13.5	8.4
30	15.6	9.3
+Ve control	25.6	

Table 3. Inhibition rate [%] of gonococci with different concentrations of silver prepared by different methods shows the zone of inhibition in mm for Escherichia coli ATCC 25922.

Concentration $\mu\text{g/mL}$	1	3
-Ve control	0.0	0
10	38.67	29.30
20	52.73	32.81
30	60.93	36.33



Staphylococcus aureus ATCC 25923[1].



Staphylococcus aureus ATCC 25923[3].

Figure 16. Zone of inhibition [mm] of gonococci with different concentrations of silver prepared by different methods for Staphylococcus aureus ATCC 25923.

Table 4. Inhibition zone diameter [mm] for gonococci with different concentrations of silver prepared by different methods Inhibition zone in [mm] for Staphylococcus aureus ATCC 25923.

Concentration $\mu\text{g/mL}$	1	3
+Ve control	0.0	0.0
10	9.3	7.1
20	11.3	7.8
30	14.2	8.6
+Ve control	26.8	

Table 5. Inhibition rate [%] of gonococci with different concentrations of silver prepared by different methods shows the zone of inhibition in mm for *Staphylococcus aureus* ATCC 25923.

Concentration µg/mL	1	3
+Ve control	34.70	0
10	42.16	26.49
20	52.99	29.10
30	34.70	32.09

5.6. Evaluation of the Antibacterial Activity of Silver Nanoparticles Loaded onto Filter Papers against *E. coli* ATCC 25922

The study aimed to investigate the impact of silver nanoparticles loaded onto filter papers with varying manufacturing specifications on *E. coli* ATCC 25922. The experimental approach involved the utilization of the plate casting method to assess the influence of the prepared silver nanoparticles loaded onto filter papers with different manufacturing specifications on the *E. coli* ATCC 25922 isolate. Activate the bacterial cells by culturing them in brain infusion broth for 24 hours at 37C⁰ with continuous shaking.

1. Adjust the number of cells in the bacterial suspension to (1x10⁸) cells/ml .
2. Pass the water containing the bacterial cells through filter papers of different manufacturing specifications.
3. Take one milliliter of the treated water [filtrate] and mix with 25 ml of Muller Hinton medium in the liquid state and leave it to solidify at room temperature, then place it in the incubator for 24 hours at 37C⁰.
4. After 24 hours, remove the plates from the incubator containing the bacterial growth and count the colonies
5. Calculate the inhibition percentage based on the formula below Inhibition percentage [%] = 100 - number of test colonies / number of control colonies x 100%.

Two different types of filters were utilized in the study. The first was a rolled membrane paper, composed of three layers of specialized paper, intended for home filtration purposes. The second type was a 4.5-inch diameter cellulose paper, cut and used in conjunction with a biological clip to quantify bacterial growth within specific grid squares.

Table 6. Effect of silver nanoparticles loaded on filter papers with different manufacturing specifications on *E. coli* ATCC 25922 bacteria and shows the percentage of inhibition.

Treatment	Bacterial number	Removal rate (%)
Control	1x10 ⁸	0.0
1	47x10 ⁶	53
3	32x10 ⁶	68

The focus of this study was *Escherichia coli* ATCC 25922, a bacterium commonly found in water contaminated by fecal matter. Its presence indicates the presence of other pollutants, such as sewage and raw water, which can lead to intestinal infections. The study evaluated six filters based on their removal efficiency and the types of bacteria they allow to pass through. This assessment involved measuring the removal efficiency and identifying the bacteria present and their ability to penetrate the filters. From the figure 17 below it appears that the filter is 1, the removal rate is (53%), while the third filter 3, has a removal rate of 68% and illustrated table 6 [16].

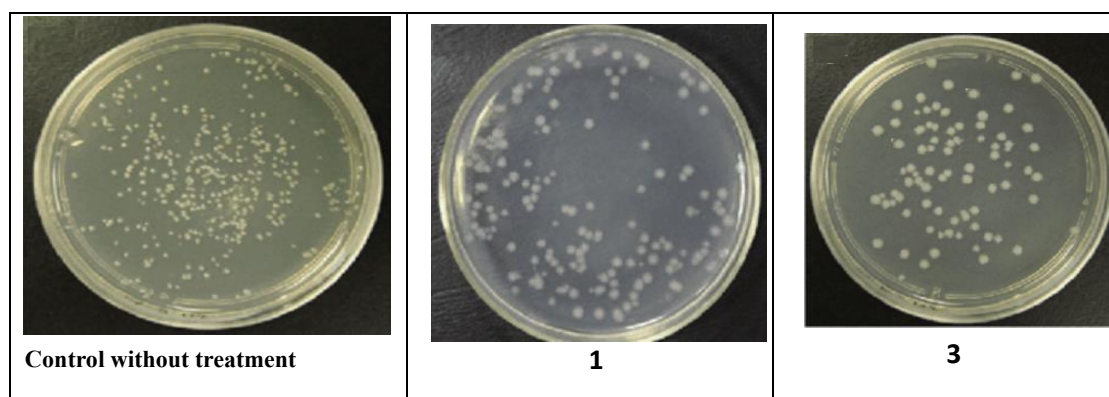


Figure 17. Colony count of Escherichia coli ATCC 25922 exposed to different concentration of Ag NPs and filtration.

6. CONCLUSION

The findings indicated that silver nanoparticles exhibit significant antimicrobial properties against various types of bacteria, including Gram-positive, Gram-negative, and other tested strains. This suggests a broad range of potential applications in water purification, where silver nanoparticles are utilized in filter systems and have been demonstrated to be effective. The antibacterial effectiveness of Ag-NPs is influenced by factors such as size, shape, morphology, and suspension stability. This study confirmed the stability and efficacy of the tested silver nanoparticle suspension. Additionally, it was found to be effective against the dye methyl blue but showed limited effectiveness against methyl yellow for dye removal. Furthermore, the nanoparticles were shown to be effective against both strong and weak types of fungi.

ACKNOWLEDGEMENTS

The author would like to express sincere gratitude to the University of Diyala, College of Science, Department of Physics, for providing the necessary scientific support and facilities and for allowing access to its laboratories to conduct the practical part of this research. The author also gratefully acknowledges the supervisors for their valuable guidance, scientific advice, and continuous support, as well as for their assistance in organizing the practical work and suggesting the appropriate procedures and experiments. Their contributions played an important role in the successful completion of this research. The author also extends sincere thanks to everyone who provided support and assistance throughout the various stages of this work.

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