

SYNTHESIS, CHARACTERIZATION AND BIOLOGICAL POTENTIAL OF SILVER NANOPARTICLES OF OLIGOMERIS LINIFOLIA

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ABSTRACT

The plant *Oligomerislinifolia* holds significant medicinal value, and this study focuses on the synthesis and biological potential of silver nanoparticles (AgNPs) derived from its flower extract. The plant was harvested during its flowering stage from the Karak district in Khyber Pakhtunkhwa, Pakistan. After collection, the plant material was air-dried for one week, following which it was dissolved in deionized (DI) water. After four days, the solution was filtered using a funnel and filter paper, and the resulting filtrate was utilized for the synthesis of AgNPs. UV-vis spectroscopy analysis revealed the formation of AgNPs with a strong absorption peak at 414 nm. During the synthesis process, a color change from yellow to light pink indicated the nanoparticles' excellent colorimetric sensing capability towards Cu^{2+} ions. The detection mechanism is thoroughly described in this paper, with the sensor showing a reliable linear response to Cu^{2+} concentrations ranging from 1 M to 50 M. This sensor

was effectively applied for detecting Cu^{2+} in tap water. Additionally, the AgNPs, combined with the plant extract, exhibited promising antibacterial activity. results

Keywords: Silver Nanoparticles, Green Synthesis; Plant-Mediated Biosynthesis; Phytochemical Reduction; Characterization; Uv-Vis Spectroscopy, Cytotoxicity; Biomedical Applications; Eco-Friendly Nanotechnology

Introduction

Nanotechnology has emerged as a transformative field, especially in the synthesis of nanoparticles that exhibit unique physical, chemical, and biological properties. Among various metal nanoparticles, silver nanoparticles (AgNPs) have garnered significant attention due to their versatile applications in areas such as medicine, catalysis, electronics, and environmental science (Hussain et al., 2023; Mumtaz et al., 2024). AgNPs are particularly renowned for their antimicrobial, antiviral, and anti-inflammatory properties, making them ideal candidates for biological and pharmaceutical applications (Mumtaz et al., 2024). The synthesis of these nanoparticles using green, eco-friendly approaches, such as plant extracts, offers several advantages over conventional chemical methods, including reduced toxicity, environmental sustainability, and cost-effectiveness (Ahmad et al., 2025; Shahid et al., 2024).

Oligomeris linifolia is a medicinal plant known for its broad range of therapeutic properties. Native to arid regions, particularly in Pakistan, it has been traditionally used for its antioxidant, antibacterial, and anti-inflammatory effects (Shahid et al., 2024). The plant's biochemical constituents, such as flavonoids, phenolic compounds, and alkaloids, play a crucial role in the reduction of silver ions during nanoparticle synthesis. These phytochemicals act as natural reducing/stabilizing agents and can modulate biological responses (Khan et al., 2023; Ahmad et al., 2025). This bio-reduction method not only facilitates the formation of silver nanoparticles but also enhances their stability, making plant-based synthesis an attractive alternative to chemical methods (Ahmad et al., 2025). The synthesis of silver nanoparticles using *Oligomeris linifolia* offers a dual advantage i.e., the nanoparticles inherit both the intrinsic biological activity of silver and the medicinal properties of the plant. This synergistic effect provides a promising avenue for developing novel therapeutic agents, especially in combating drug-resistant bacteria and in potential sensing applications (Khan et al., 2023; Hussain et al., 2023).

Plant extracts, abundant in various phytochemicals, are crucial in the environmentally friendly synthesis of nanoparticles, serving as natural reducing and stabilizing agents. These sustainable methods reduce reliance on toxic chemicals while utilizing bioactive plant compounds that can influence metabolic pathways, thereby improving nanoparticle production and functionality (Khan et al., 2023). Emerging approaches in sustainable agriculture and biotechnology further support greener production routes and integration with advanced tools (Nirmal & Ahmad, 2024; Ahmad et al., 2025).

Silver nanoparticles (AgNPs) are diminutive particles of silver, generally measuring between 1 and 100 nm, that have garnered considerable interest owing to their distinctive physicochemical and biological characteristics. They are extensively utilized across medical, electronic, and environmental applications because of their

superior antibacterial, antiviral, and anti-inflammatory behavior (Sidra Ahmad et al., 2023; Hussain et al., 2023). In clinical contexts, AgNPs are explored in wound dressings, device coatings, and targeted therapies. Nonetheless, concerns about potential toxicity and ecological effects persist, necessitating continued research into safe, effective application (Mumtaz et al., 2024). This study focuses on the synthesis, characterization, and biological potential of silver nanoparticles derived from the flower extract of *Oligomerislinifolia*. The plant extract acts as both a reducing and capping agent, facilitating the formation of stable silver nanoparticles. Additionally, the study explores the colorimetric sensing capabilities of AgNPs towards Cu^{2+} ions, a heavy metal contaminant, and their potential as antibacterial agents. The development of a green synthesis method for AgNPs not only contributes to the growing body of research on plant-mediated nanotechnology but also underscores the potential of *Oligomerislinifolia* in biomedicine and environmental applications (Ayesha et al., 2024).

In this paper, we aim to discuss the synthesis process in detail, characterize the resulting nanoparticles, and evaluate their biological activity. Special attention is given to their application in detecting copper ions (Cu^{2+}) in tap water, an important environmental concern, and to their antibacterial properties, which could offer an alternative solution to antibiotic resistance. Through this research, we hope to contribute to the field of green nanotechnology and open new possibilities for the use of medicinal plants in the synthesis of bioactive nanoparticles.

Methodology

Experimental

Materials

Various chemicals and instruments were employed in this work. All experimental procedures were conducted using deionised water. A silver nitrate solution was utilised to obtain silver ions, while a 0.1 M sodium hydroxide solution was employed to create a basic medium. Extract of *Oligomerislinifolia* flowers utilised as a reducing agent. All instruments utilised in this experiment were cleaned with aqua regia and deionised water before to use.

Methods

Collection

The plant was meticulously rinsed in distilled water to eliminate dirt and latex, and subsequently, it was dissected into segments using knives and scissors. The entire blossoms were meticulously detached from the branches using a knife and scissors. The flower fragments were thereafter arranged on the floor of the room above a clean sheet for shadow drying, for a duration of 3 to 4 days. The dried flowers were further dehydrated in the oven for approximately 30 minutes at 40°C prior to the extraction process to eliminate residual moisture and achieve a fine powder.

Extraction

The flowers of *Oligomerislinifolia*, after being dried in the shade for 3 to 4 days and subjected to oven treatment, yielded a fine powder. 0.2g of the dried powdered flower extract was incorporated into 100 ml of deionised water and stirred at room

temperature for approximately 36 hours, after which the solution was filtered through filter paper. Consequently, following filtration, a floral extract was procured for synthesis.

Synthesis of AgNPs

The extract derived from flowers was subsequently utilised for the production of silver nanoparticles. Ten millilitres of a solution containing 0.01M silver nitrate and 0.1M sodium hydroxide were mixed along with one millilitre of the aqueous extract of the flowers of *Oligomerislinifolia*. The solution was allowed to react at the temperature that was considered normal. As a consequence of this, the colour of the solution changed from a diluted state to a yellowish-brown hue, which is a sign that silver nanoparticles were present. As a result of the complete elimination of silver ions, the colour changed to a yellowish-brown colour. By obtaining spectra using ultraviolet visible spectroscopy, it was determined that the synthesis of silver nanoparticles from the flowers of *Oligomerislinifolia* was confirmed. The band that was observed occurred at 414 nm(Shah, Poinern, & Fawcett, 2016).

Detection of different metals with synthesized AgNPs

After being synthesised, the silver nanoparticles were condensed into a bulk solution that displayed an extraordinarily high level of absorption. As a blank solution, 8 millilitres of deionised water were added to 2 millilitres of silver nanoparticles (AgNPs) that were generated from the flowers of *Oligomerislinifolia*. This was done in order to achieve dilution. In following examinations, this blank solution was utilised for a variety of purposes, such as interference experiments, calibration studies, tests on tap water, and temporal studies. An initial interference research was carried out in order to evaluate the detection of different metals. This was accomplished by introducing a solution of multiple metal ions, which consisted of Cu^{2+} , Co^{2+} , Ni^{2+} , Cd^{2+} , Hg^{2+} , Cr^{3+} , Fe^{2+} , Pb^{2+} , and Zn^{2+} , in a concentration of 25 μM into a solution of AgNPs that was 5 ml in volume. Spectra were collected through the use of UV-visible spectroscopy, and a variety of colour changes were detected in each of the five millilitre solutions individually. A series of test tubes were used for the calibration research. First, 5 millilitres of a diluted solution of silver nanoparticles (AgNPs) was put into each of the test tubes. Next, different volumes (μl) of copper solutions were added to each of the test tubes. Spectra were then recorded for each solution after a period of time had passed(Annadhasan, Muthukumarasamyvel, Sankar Babu, & Rajendiran, 2014).

Detection of Cu^{+2} ions with tap water

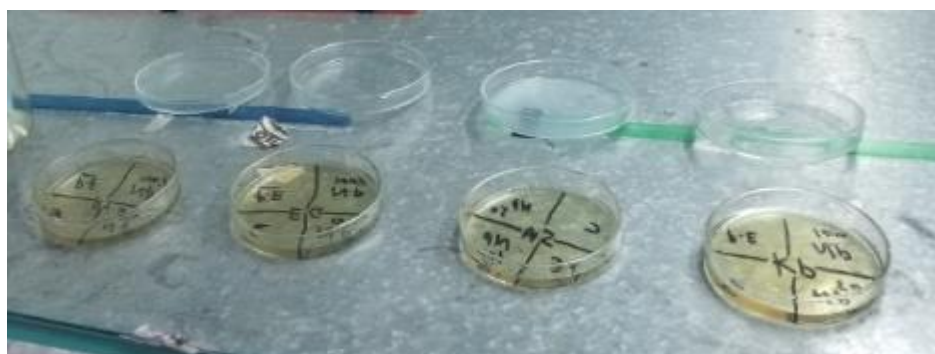
By combining 10 millilitres of tap water, 70 millilitres of deionised water, and 20 millilitres of concentrated silver nanoparticles, a solution that was similarly diluted was generated. Following this, a specific amount of copper ion (Cu^{2+}) was introduced into a set of three test tubes, and then the spectrum data for each sample was collected by means of ultraviolet-visible spectroscopy(Wang, Wang, Ren, & Chae, 2014).

Antibacterial Activity

The three bacterial strains were obtained from the Department of Botany at the

University of Science and Technology Bannu A complete washing and drying with tissue paper, which was then encased in large-sized paper for the sterilisation operation, was followed by the utilisation of three Petri plates, each of which was designated for a certain strain of bacteria Before being autoclaved at 121 degrees Celsius for thirty minutes, 1.58 g of powder were dissolved in sixty millilitres of deionised water. Immediately following the autoclaving process, the media was moved to a petri dish. After filling each Petri dish with 20 millilitres, the mixture was allowed to harden. After the mixture had been allowed to solidify, cotton swabs were used to perform the inoculation process. After that, four wells were prepared: one for the extract (100 percent), one for the concentrated nanoparticles (100 percent), one for the diluted nanoparticles (50 percent), and one for the control (erythromycin). After a period of twenty-four hours, the inhibition zone was assessed with the help of a transparent scale(Abboud et al., 2014).

Figure 1: Effect of AgNPs and extract against bacteria



Results and Discussion

UV analysis of Silver Nanoparticles

The creation of silver nanoparticles was demonstrated by the observation of an absorption band at 400 nm, which was obtained by the use of a spectrometer to confirm the presence of silver nanoparticles for the first time. Spectroscopic investigation, which revealed an absorption band at around 400 nm, provided evidence that the successful production of silver nanoparticles was validated. This absorption peak is indicative of the surface plasmon resonance (SPR) of silver nanoparticles, which is a one-of-a-kind optical phenomenon that occurs as a result of the collective oscillation of electrons on the surface of the nanoparticles when they are illuminated. The emergence of the absorption band at this wavelength clearly suggests the creation of silver nanoparticles, consistent with the normal range documented in the literature. The pronounced and clear peak not only validates the existence of silver nanoparticles but also indicates consistency in size and shape, which are essential for their biological and chemical efficacy. The spectroscopic results confirm the successful synthesis process and guarantee that the generated nanoparticles exhibit the requisite characteristics for later antibacterial and other functional applications.

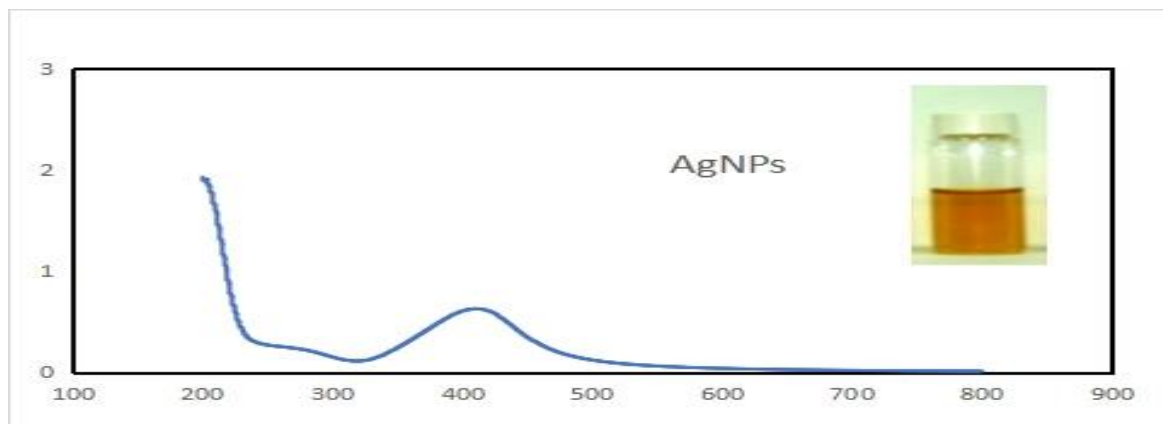


Figure 2: UV analysis of silver nanoparticles.

Effect of pH on synthesized AgNPs

It was explored how the volume of the base affected the synthesis of silver nanoparticles (AgNPs), with the volume varying from fifty to two hundred microlitres. In the beginning, it was seen that there was a rise in the strength of absorption up to a volume of 160 μ l. However, after this volume was exceeded, the absorption intensity began to decrease. Through the analysis of these data, it was determined that the ideal volume of base for the synthesis of silver nanoparticles at a pH of 10.5 was 160 μ l.

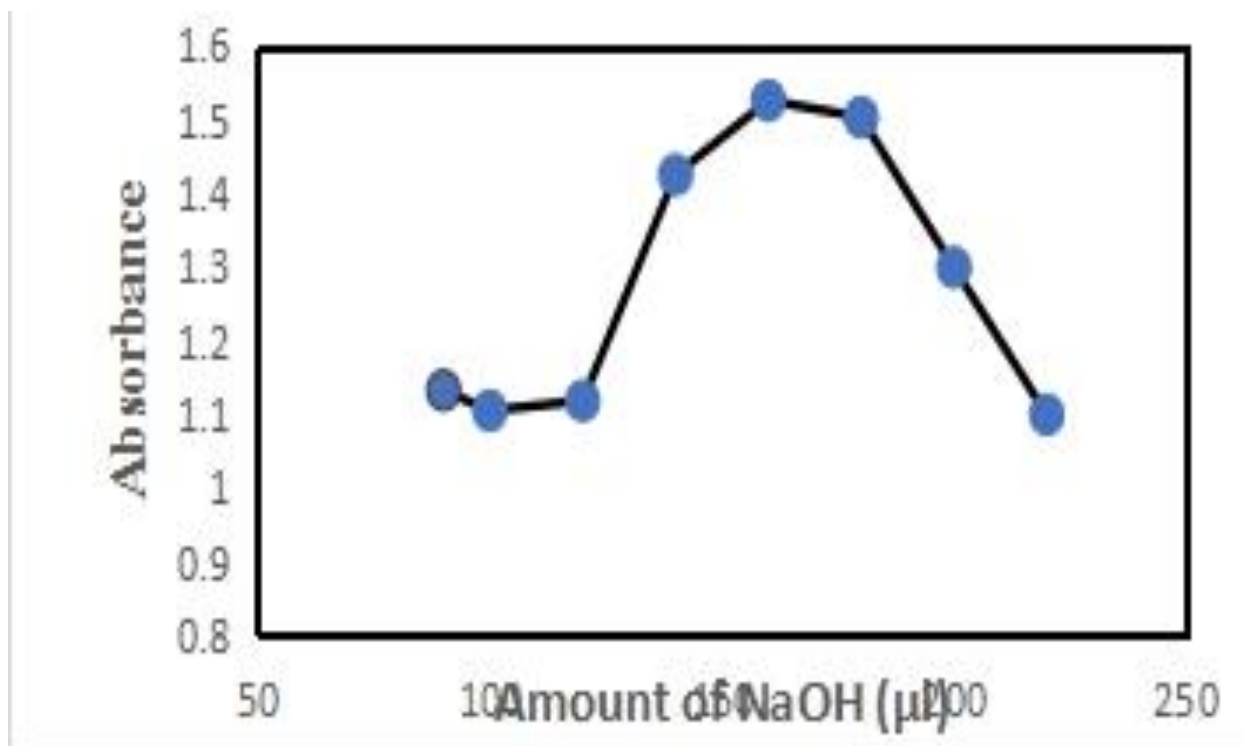


Figure 3: Effect of NaOH on the absorption intensity of AgNPs.

Effect of plant extract on synthesis of AgNPs

An important factor that had a substantial impact on the quality of AgNPs was the concentration of *Oligomerislinifolia* extract. When the amount of plant extract was increased from 0.1 millilitres to 0.5 millilitres, the strength of the absorption gradually increased as a consequence. There was a decrease in the amount of AgNPs that were absorbed when the volume of the extract was increased from 0.5 ml to 1.5 ml. Consequently, it has been established that all of the silver ions have been reduced and stabilised at a concentration of 0.5 millilitres of extract. The increased concentration of plant extract had a significant impact on the nanoparticles' size as well as their dispersion throughout the sample. The quantity of AgNO_3 was maintained at a constant level throughout all three of the tests. Similar results were also found by (Anigol, Charantimath, & Gurubasavaraj, 2017; Das et al., 2018).

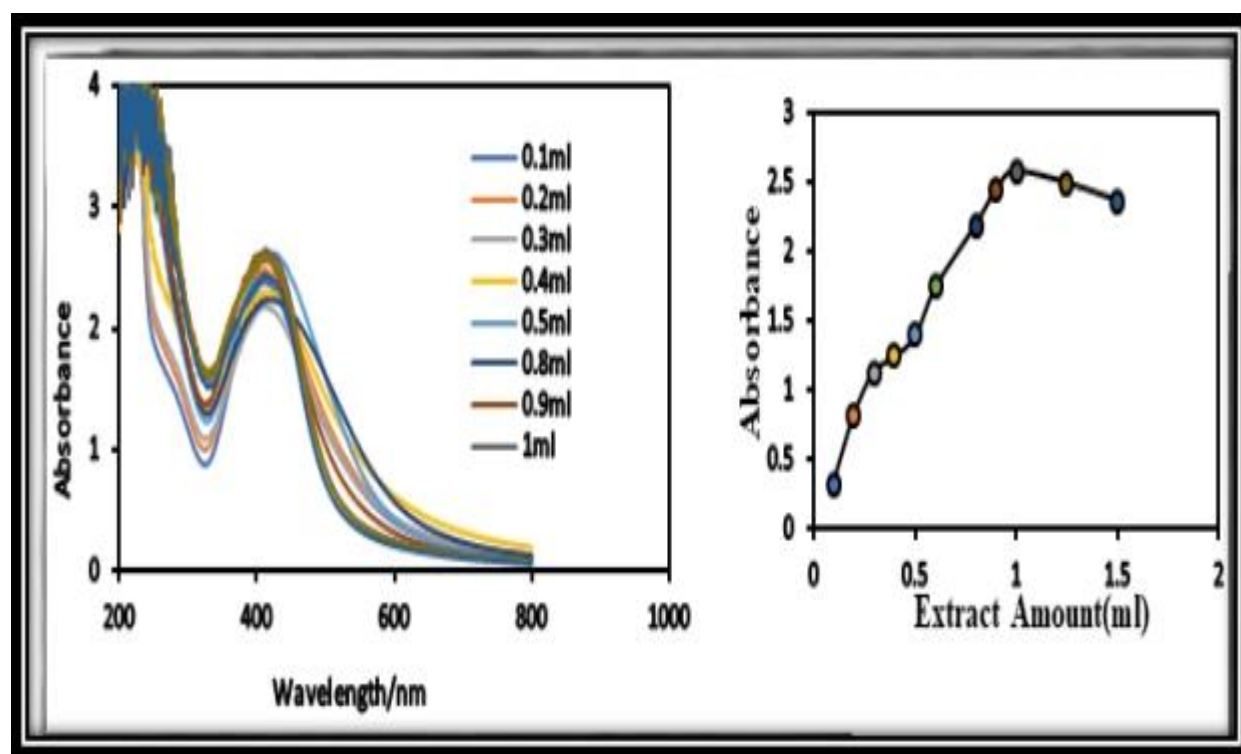


Figure 4: Effect of extract on synthesis of AgNPs

Selectivity

The selectivity of AgNPs derived from *Oligomerislinifolia* for the detection of Cu^{2+} was investigated. To evaluate the UV-Vis absorbance fluctuations of *Oligomerislinifolia*'s AgNPs, metal ions including Cu^{2+} , Cr^{2+} , Zn^{2+} , Hg, Co^{2+} , Mn, Fe^{2+} , Mg^{2+} , Ca^{2+} , Pb^{2+} , and Cd^{2+} were utilised at a concentration of 25 M. The metal ion Cu^{2+} significantly reduced absorption intensity, but other metal ions did not exhibit a noticeable effect on absorption. Furthermore, the solution's colour altered upon the addition of Cu^{2+} , transitioning from yellow to pinkish, a change discernible

to the human eye. A slight alteration in colour was noted upon the introduction of supplementary metal ions. This outcome showed unequivocally that the suggested colorimetric sensor can identify Cu^{2+} precisely (Kadam et al 1990).

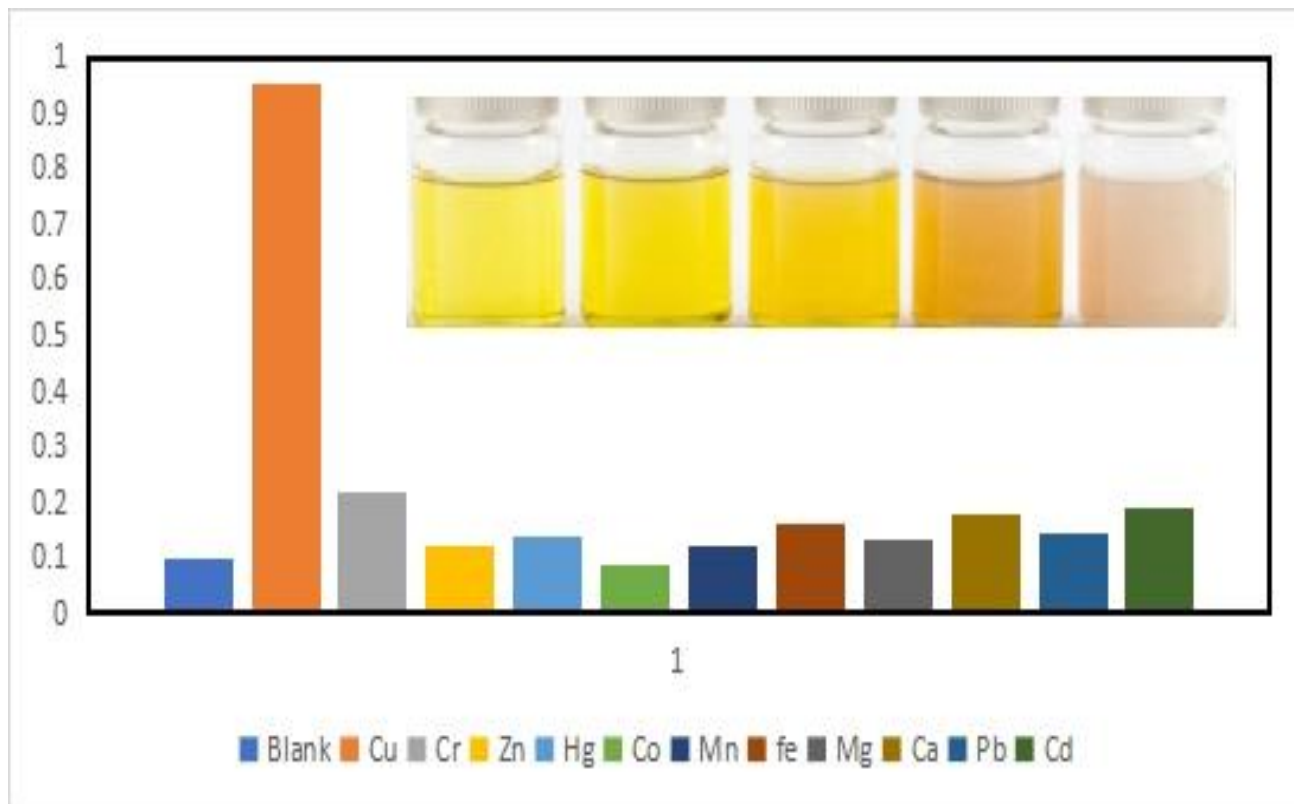


Figure 5: The colorimetric response of AgNPs of different metal ions.

Sensitivity

An experimental evaluation was conducted to determine the sensitivity of the proposed biosynthesised sensor to Cu^{2+} ions. The traditional UV-vis absorption peaks of AgNPs progressively decreased at 416 nm, whereas new absorption bands emerged at 502 nm as the concentrations of Cu rose from 1 μM to 50 μM , as depicted in Figure. The spectrum alterations induced a gradual transition in the colour of the AgNPs solutions from yellow to pink. The spectrum shifts were utilised to ascertain the absorption ratios (A_{502}/A_{416}), which were subsequently shown as a function of varying Cu^{2+} concentrations. A regression model represented by $Y=0.0154x + 0.1338$ exhibits a R^2 correlation coefficient of 0.9978, resulting in a linear calibration plot.

Figure 6: Effect of increase in concentration of Cu ions

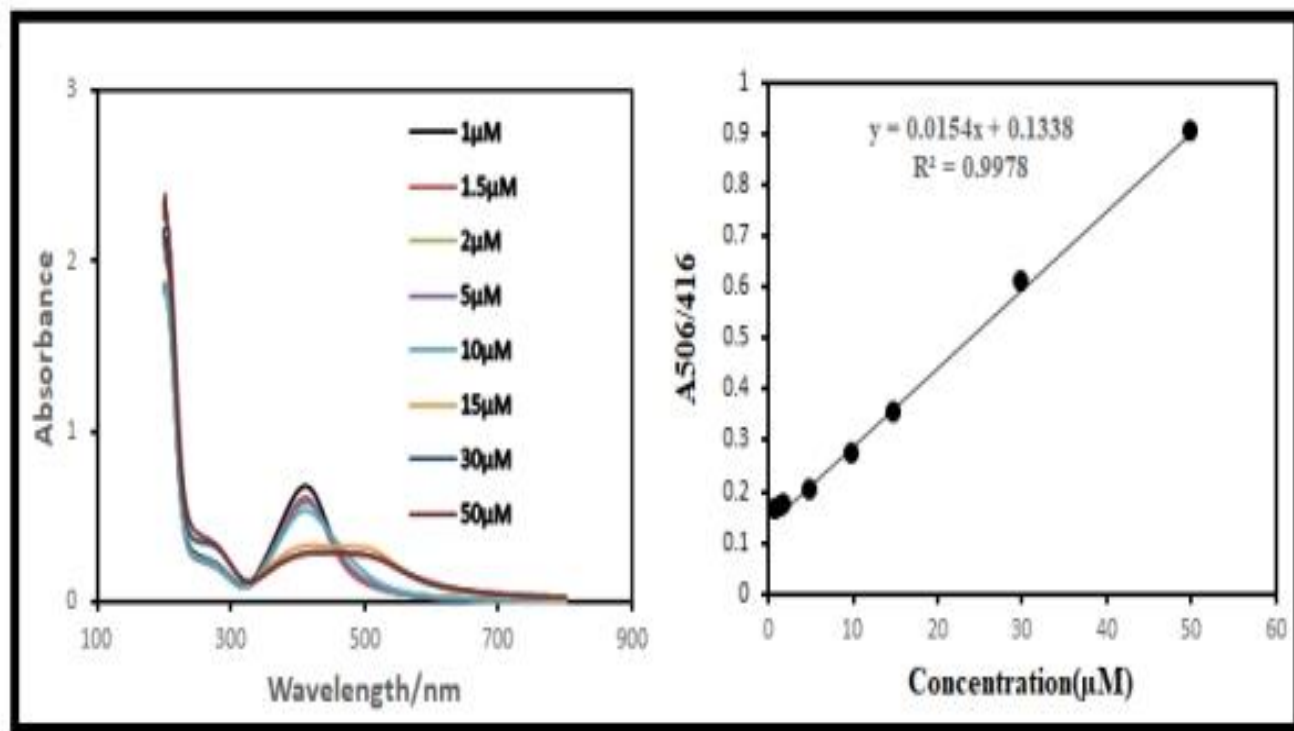


Figure 6: Effect of increase in concentration of Cu ions

Application to tap water

Copper concentrations were measured in a tap water sample to evaluate the biosensor's efficacy. To this end, several blanks were created by combining 10 ml of tap water with 90 ml of diluted AgNPs, followed by the addition of Cu at variable concentrations of 1.5 μM, 5 μM, 10 μM, and 50 μM. Acceptable recoveries for the tap water ranged from 98 to 102 percent, as indicated in Table 1. Similarly, the introduction of copper ions to the biosensor along with the tap water sample resulted in a noticeable alteration in colour and spectrum properties. This illustrates its accuracy and uniform applicability for tap water samples.

Table 1: Determination of copper in tap water

S. NO	Added (μM)	Found	Recovery (%)
1.	1.5	1.538	102.53
2.	2	2.123	106.5
3.	5	4.902	98.04
4.	10	9.538	95.38
5.	15	15.333	102.22
6.	30	29.846	99.48
7.	50	50.153	100.306

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Antibacterial activity

To test the antibacterial activity of *Oligomerislinifolia* three bacterial strains, one each of *E. coli*, *S. aureus* and *K. pneumonia* were examined. The antibacterial activity was assessed, by measuring the inhibitory zone that formed around the well. A typical and most common medication was Erythromycin. The *Oligomerislinifolia* extract and its nanoparticles showed good effectiveness against all of the tested bacteria, which is comparable to normal medication. Silver nanoparticles possess good antibacterial activities as evidenced by previous literature (Li et al., 2010; Prema & Raju, 2009).

The antibacterial efficacy of *Oligomerislinifolia* extract and its nanoparticles was evaluated against three bacterial strains: *Escherichia coli*, *Staphylococcus aureus*, and *Klebsiella pneumoniae*. The evaluation was conducted by quantifying the inhibitory zones surrounding the wells, which reflect the efficacy of the antimicrobial drugs. Erythromycin, a widely utilised antibiotic, functioned as the reference medicine for comparison. The findings indicated that the *Oligomerislinifolia* extract and its nanoparticles shown significant antibacterial activity against all examined microorganisms, exhibiting inhibitory effects to Erythromycin. This indicates that the plant extract and its nanoparticle formulations may function as viable replacements or complements to conventional antibiotics. The documented antibacterial efficacy corresponds with earlier research on the antimicrobial characteristics of silver nanoparticles, recognised for their capacity to compromise bacterial cell walls, produce reactive oxygen species, and disrupt critical microbial processes. The combination of *Oligomerislinifolia* with silver nanoparticles may augment the antibacterial efficacy of innovative medicinal drugs, providing a natural and efficient remedy against resistant bacterial strains.

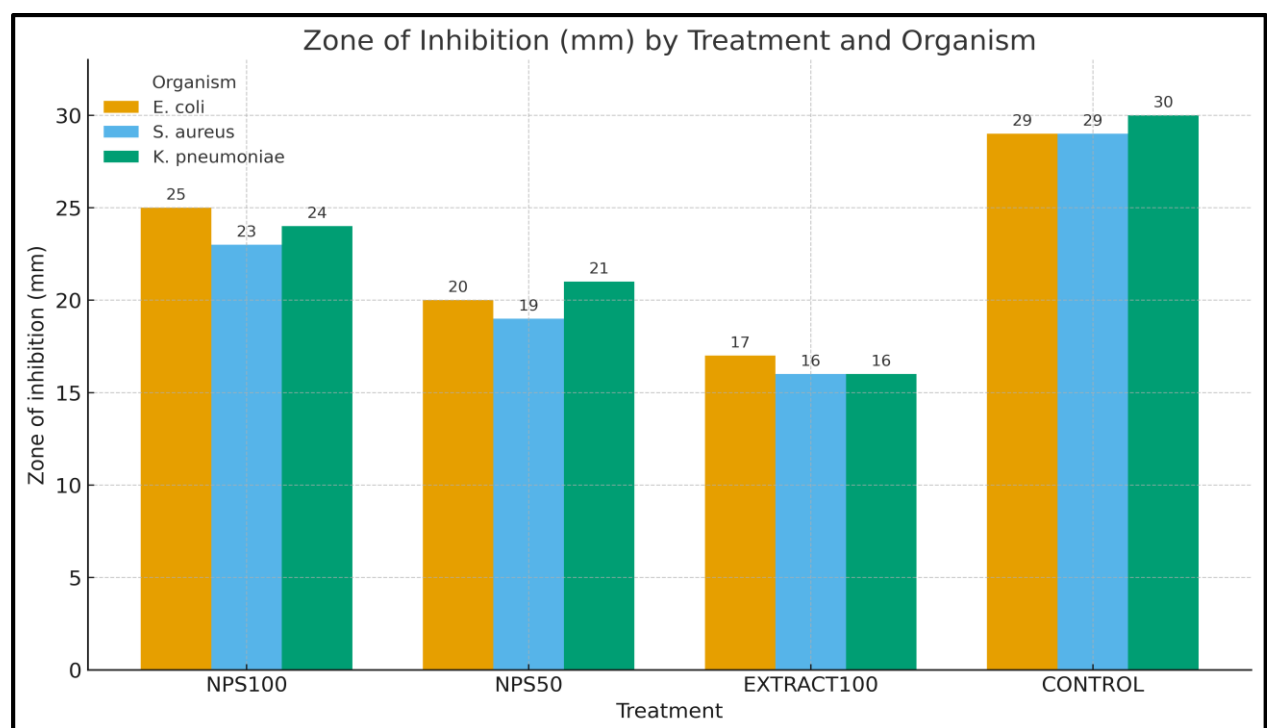


Figure 7 Grouped bar chart showing zones of inhibition (mm) for three test

organisms across four treatments: NPS100, NPS50, EXTRACT100, and CONTROL. Raw values (mm): *E. coli* — 25, 20, 17, 29; *S. aureus* — 23, 19, 16, 29; *K. pneumoniae* — 24, 21, 16, 30. Across organisms, the positive control yielded the largest zones (≈ 29 – 30 mm). Among silver nanoparticle doses, NPS100 consistently exceeded NPS50, and both were greater than the crude extract (EXTRACT100). Overall efficacy pattern: CONTROL > NPS100 > NPS50 > EXTRACT100; *K. pneumoniae* was marginally more susceptible than *S. aureus* at the same nanoparticle dose.

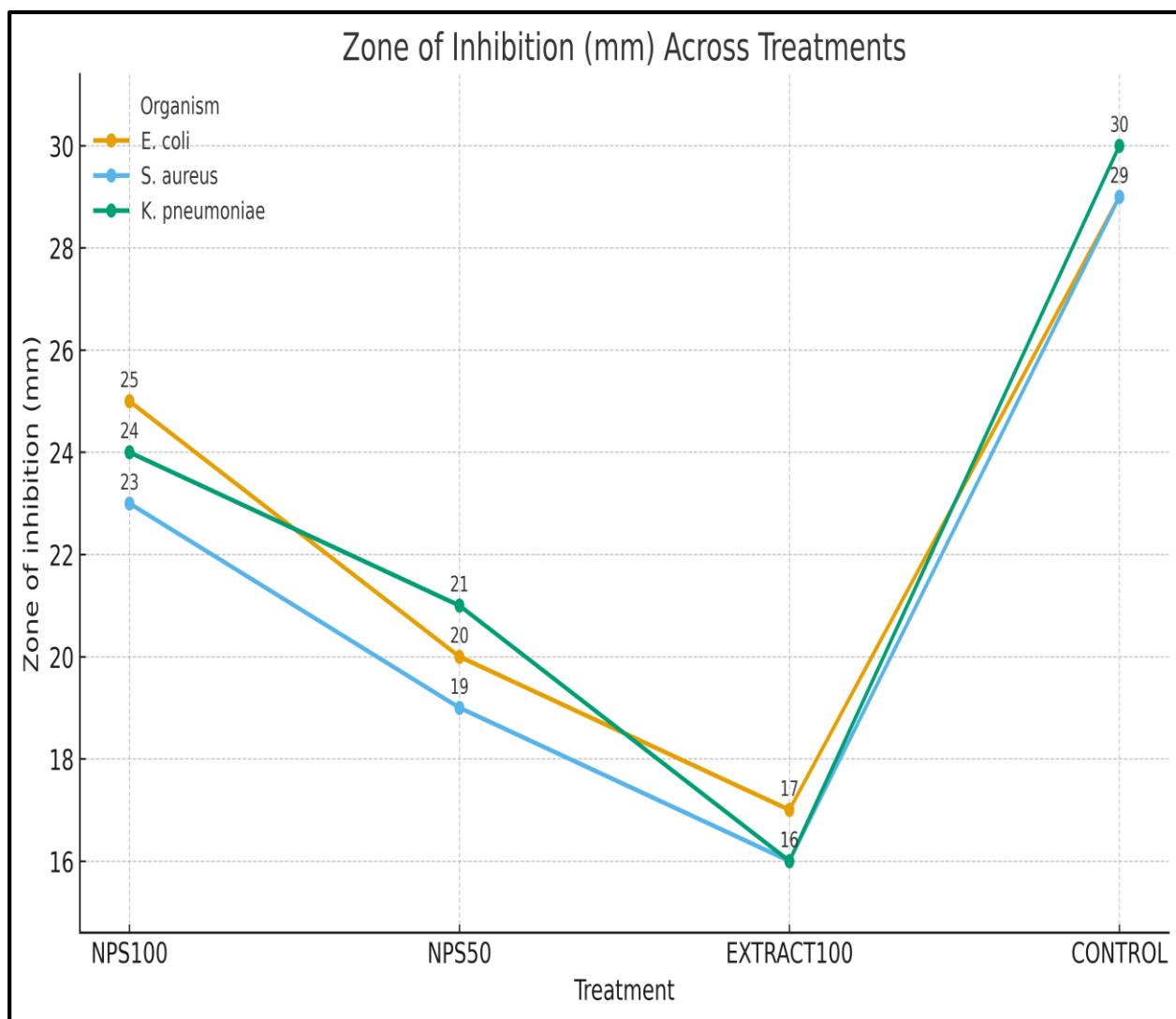


Figure 8. Connected scatter/line plot of zones of inhibition (mm) across treatments. Trajectories make dose–response differences evident: values rise from EXTRACT100 through NPS50 to NPS100 and peak at the CONTROL for all organisms. Data by organism (mm): *E. coli* — 25, 20, 17, 29; *S. aureus* — 23, 19, 16, 29; *K. pneumoniae* — 24, 21, 16, 30. The gap between NPS100 and NPS50 is ~ 1 – 2 mm for each organism, while the difference between nanoparticle treatments and EXTRACT100 is larger (~ 3 – 9 mm).

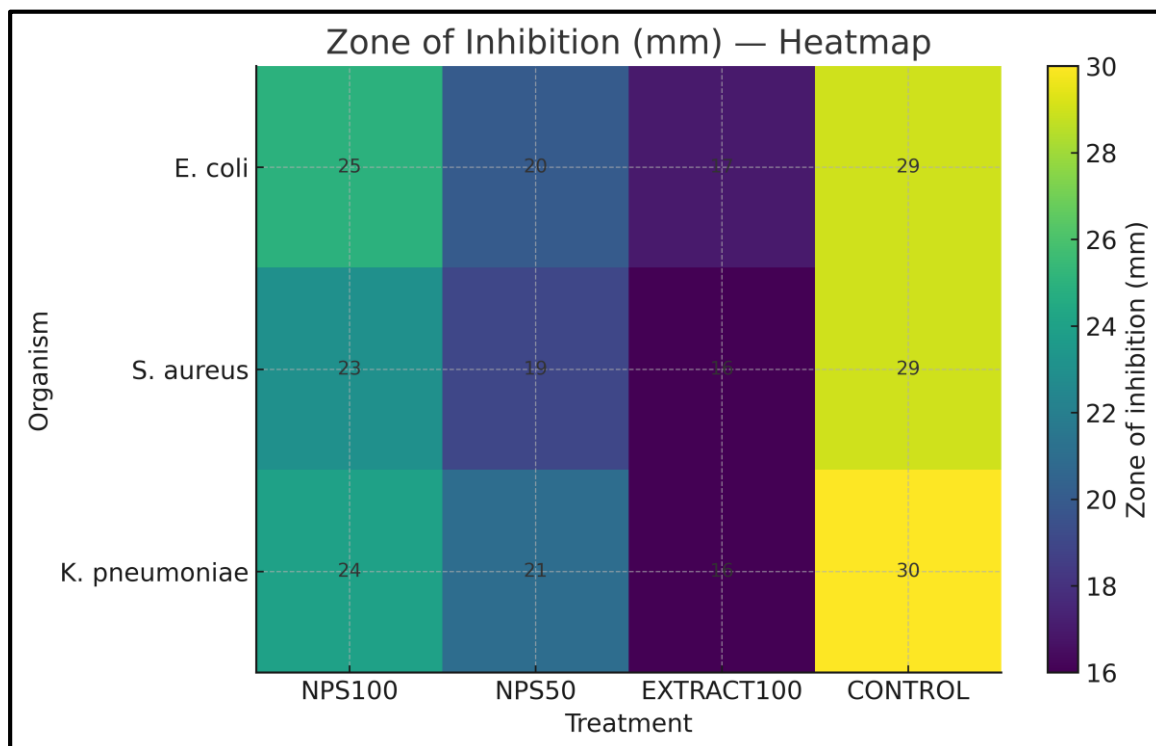


Figure 9. Heatmap representation of zones of inhibition (mm). Higher intensity corresponds to larger inhibition zones. Values are annotated in each cell for clarity: rows list organisms (*E. coli*, *S. aureus*, *K. pneumoniae*); columns list treatments (NPS100, NPS50, EXTRACT100, CONTROL). The highest inhibition appears in the CONTROL column (29–30 mm), followed by NPS100 (23–25 mm), NPS50 (19–21 mm), and EXTRACT100 (16–17 mm). This compact view reinforces the pattern observed in Figures 1 and 2.

Conclusion

Silver nanoparticles were synthesised utilising *Oligomerislinifolia* harvested during its flowering period from agricultural lands in Karak, Khyber Pakhtunkhwa. The synthesis process was conducted at several concentrations and pH levels, with the maximum synthesis occurring at a pH of 10.5. The highest effective synthesis occurred at a concentration of 1 ml. The synthesis of silver nanoparticles was validated via UV-visible spectroscopy and a distinct colour alteration. The colorimetric characteristics of the nanoparticles were further examined by injecting copper ions at varying quantities, leading to a colour transition from yellow-brown to light pink. The synthesised nanoparticles were evaluated for their efficacy in tap water treatment, successfully identifying and extracting copper ions, resulting in purification levels ranging from 100.36% to 102.53%. The antibacterial activity of the nanoparticles was assessed, revealing significant effectiveness. The results indicate that the extract from *Oligomerislinifolia* and its synthesised nanoparticles had considerable promise as an antibacterial agent and for water purification applications.

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