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Development of high-swelling double-network sliver nanocomposite reusable beads for environmental remediation

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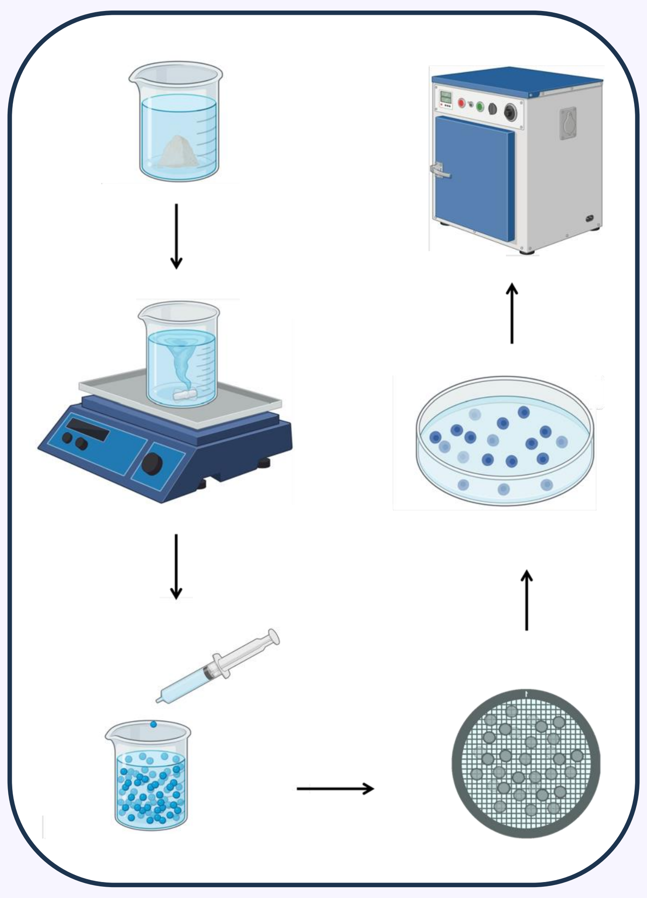
INTRODUCTION & AIM

Nanoremediation employs the nanotechnology of silver nanoparticles (AgNPs) to purify hospital waste and environmental treatment. Due to the high surface-to-volume ratio of AgNPs (1-100 nm), they can penetrate microbial cells, release silver ions (Ag^+), and disrupt pathogenic cellular processes. We used sodium alginate, which is a biocompatible polysaccharide from brown seaweed, in the synthesis of AgNP via cross-linking polymerization to form gelatinous beads with metal-ion binding properties. This technique is energy efficient and cost-efficient, and it is sustainable due to the reusability of the beads, which help detoxify toxic compounds and compete with drug-resistant bacteria like E. coli, S. aureus, and P. aeruginosa. For the nanocomposition characterization, we used UV-Vis and FTIR spectroscopy. We aim to develop sustainable antibacterial and catalytic materials for wastewater applications.

METHOD

- The silver alginate nanocomposite beads are synthesized by first dissolving sodium alginate (SA) in deionized water to create a uniform solution.
- Silver nitrate ($AgNO_3$) is then added to this solution, ensuring even dispersion of silver ions (Ag^+) throughout the alginate matrix.
- The pH is adjusted using sodium hydroxide (NaOH), with careful observation for a color change that indicates nanoparticle formation.
- The solution is covered and mixed overnight, after which ammonium persulfate (APS) is introduced to stimulate the polymerization process.
- A separate calcium chloride ($CaCl_2$) solution is prepared to facilitate gelation and subsequent bead formation as the SA mixture is drooped into it in the form of drops.
- An additional step was introduced for Alg-Ag beads reduction, immersing them in sodium borohydride ($NaBA_4$) to stabilise the reduced Ag^+ and prevent aggregation.
- The beads are rinsed thoroughly with deionized water and dried overnight in an oven to ensure stability.



component	Alg-0-Ag	Alg-Ag
SA (mL)	50	50
Sodium Acrylate (g)	2.075	1.0
MBA (g)	0.232	0.02
$AgNO_3$ (g)	N/A	0.094
APS (g)	0.244	0.0615
NaOH (drops)	N/A	2
Deionised Water (mL)	6.5	1.5

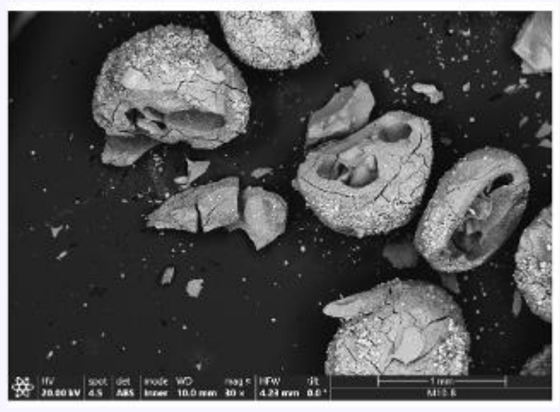


Fig 1. Scanning electron micrograph (SEM) of the silver nanocomposite beads.

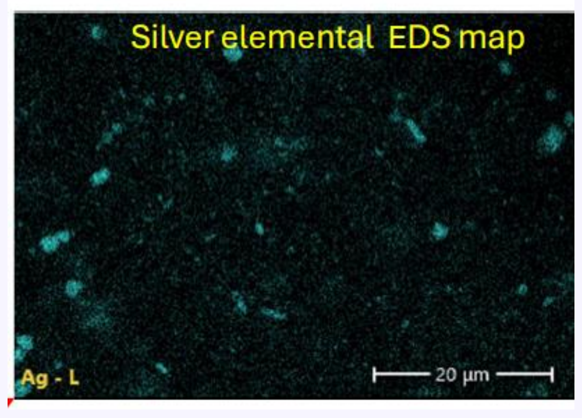


Fig 2. Energy dispersive elemental mapping of silver nanoparticles in the beads.

PRELIMINARY RESULTS

SWELLING BEHAVIOR

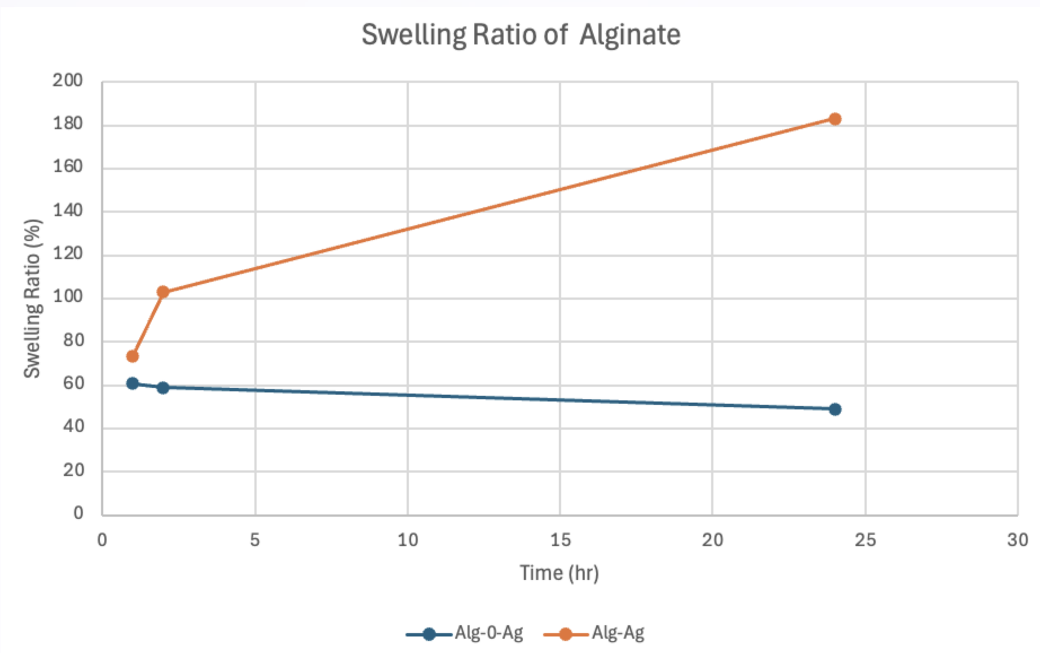
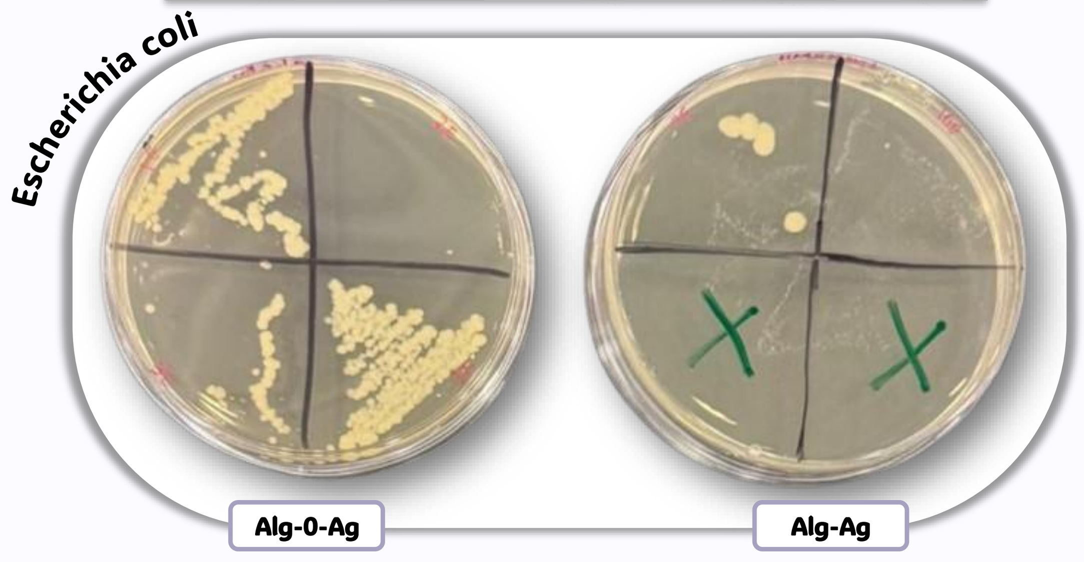


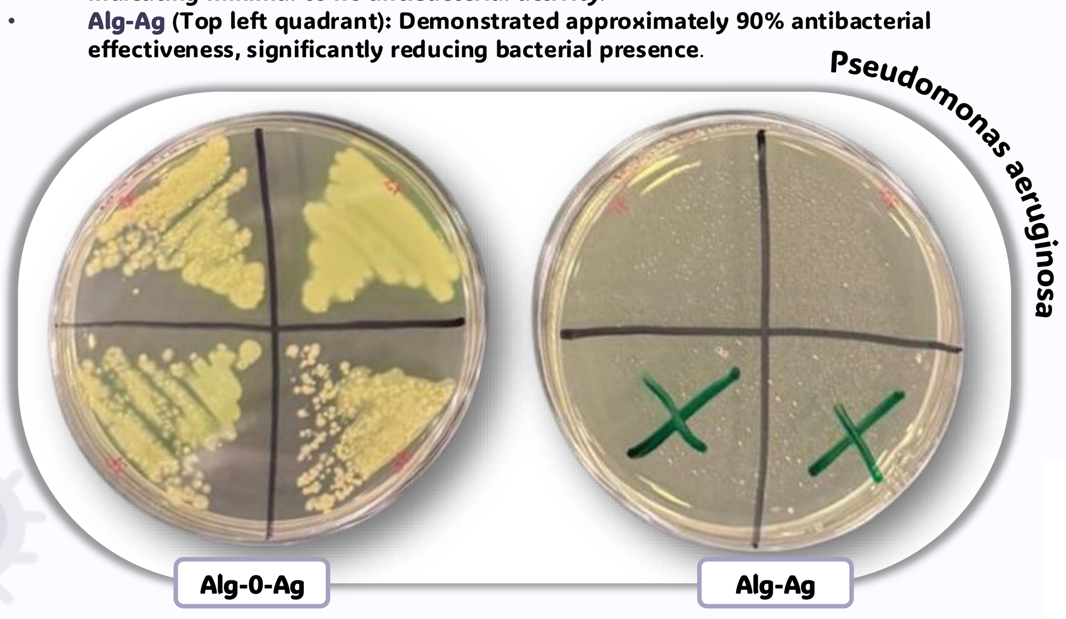
Fig 3. Alg-Ag demonstrates high swelling bahavior. Alg-0-Ag exhibits low porosity following the constant decrease in swelling ratio.

The produced nanocomposite beads were spherical, porous, and demonstrated a high swelling capacity, crucial for catalytic applications. The UV-Vis absorption spectrum displayed a distinct SPR peak around 400 nm, confirming the successful integration of silver nanoparticles into the polymer

ANTIBACTERIAL ACTIVITIES



After incubation, the two antibacterial plates were initially streaked with E. *coli*:
- **Alg-0-Ag** (Bottom right quadrant): Displayed persistent bacterial growth, indicating minimal to no antibacterial activity.
- **Alg-Ag** (Top left quadrant): Demonstrated approximately 90% antibacterial effectiveness, significantly reducing bacterial presence.



Similarly, two additional antibacterial plates were streaked with Pseudomonas aeruginosa
- Alg-0-Ag (Bottom right quadrant): Showed noticeable bacterial growth, confirming a lack of antibacterial activity.
- Alg-Ag (Top left quadrant): Exhibited outstanding results with 100% antibacterial effectiveness, completely inhibiting bacterial growth.

CATALYTIC DEGRADATION

The beads accomplished close to 100% degradation of Congo red and 2-nitrophenol in just 30 minutes, demonstrating their effectiveness in environmental detoxification. Their capacity to swiftly decompose toxic substances and be reused makes them strong candidates for tackling industrial and wastewater contaminants, with silver nanoparticles boosting their catalytic performance in purifying polluted water.

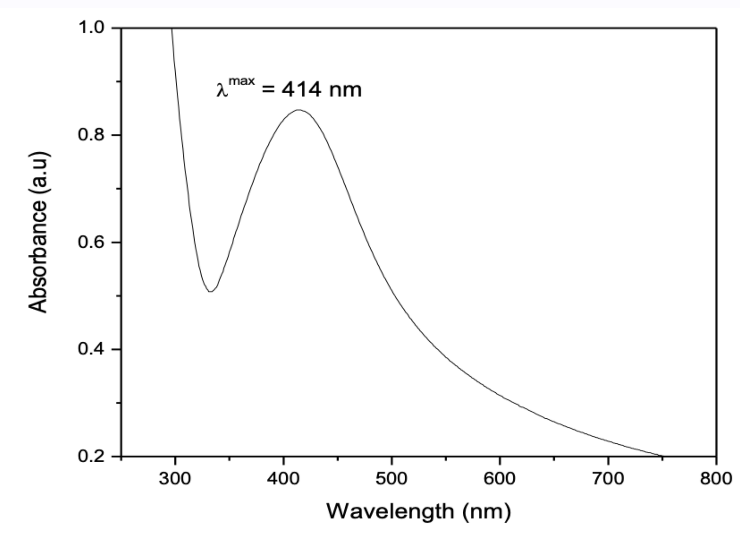
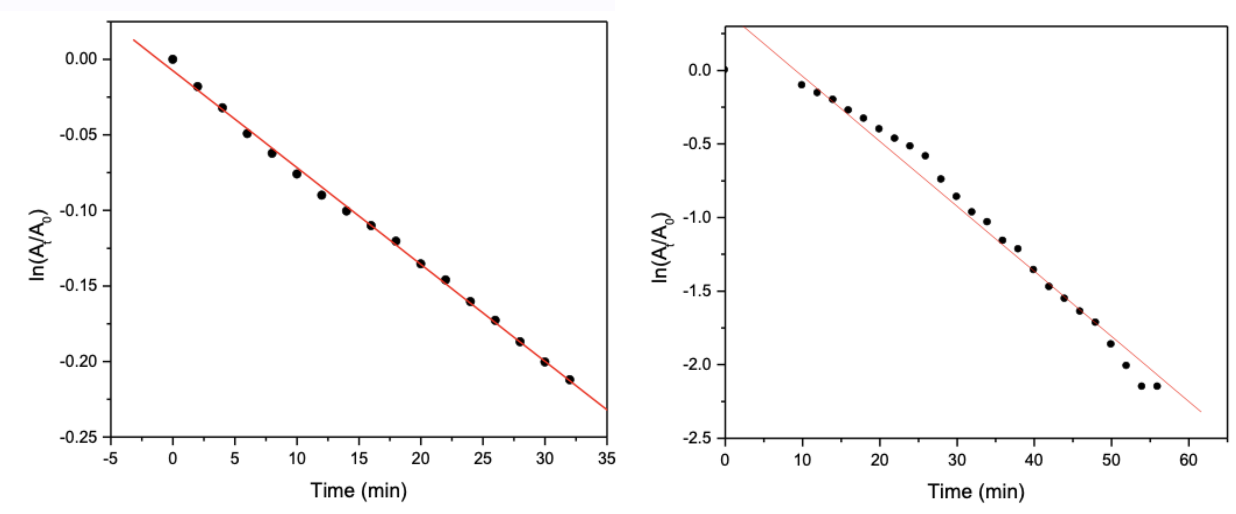


Fig 4. Absorption spectrum confirming the presence of Silver nanoparticles. The peak maxima at 414 nm is characteristic of silver nanoparticles. The symmetrical shape of the peak indicates that the nanoparticles are spherical in shape.



Figs 5-6. First-order kenetic model plot of Congo Red (left) and 2-Nitrophenol (right). The red line is a linear regression fit to the experimental data.

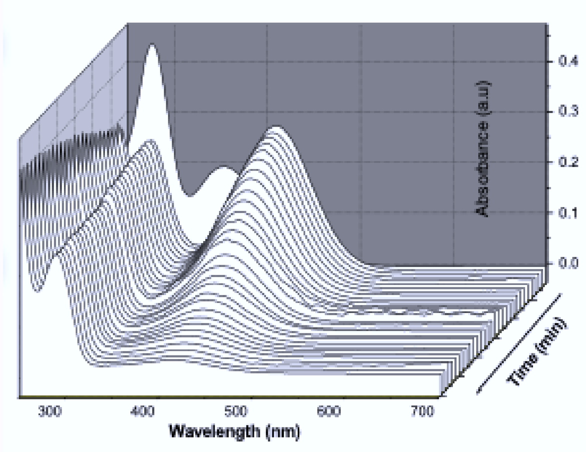


Fig 7. Absorption spectrum showing degradation of 2-Nitrophenol dye as function of time.

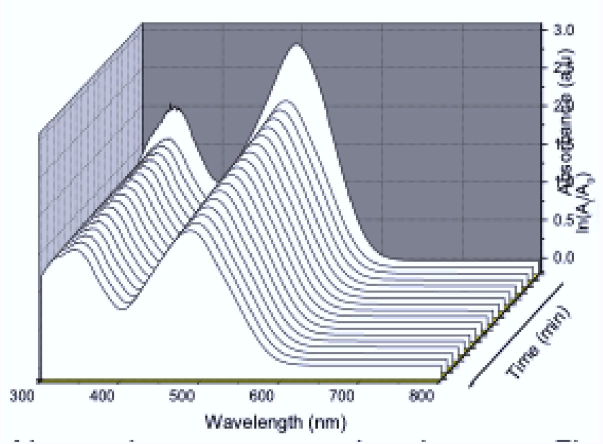


Fig 8. Absorption spectrum showing degradation of Congo Red dye as function of time.

Discussion and Significance of the Project

The antimicrobial properties of the beads allow them to penetrate biological substances and biofilms, thereby preventing the degradation of toxic compounds and disinfecting pathogens from healthcare infectious disposables. silver nanoparticles will continue to remain an essential tool for environmental detoxification and mitigating the effects of hospital pollutant particles.

In addition, the development and evaluation of sodium alginate-poly sodium acrylate silver nanocomposites underscored their promising application in wastewater treatment and antibacterial therapy. Current efforts are focused on testing the reusability of the beads and evaluating their performance with real-world wastewater samples.

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