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Development of Multifunctional High Swelling Alginate Silver Nanocomposite for Water Decontamination

Sirine Zamouri, Amal Abdulla, Farah Alhasan, Fatima Zabara, Noor Mahdi, Fatima Al-Hannan, Roshan Deen G*

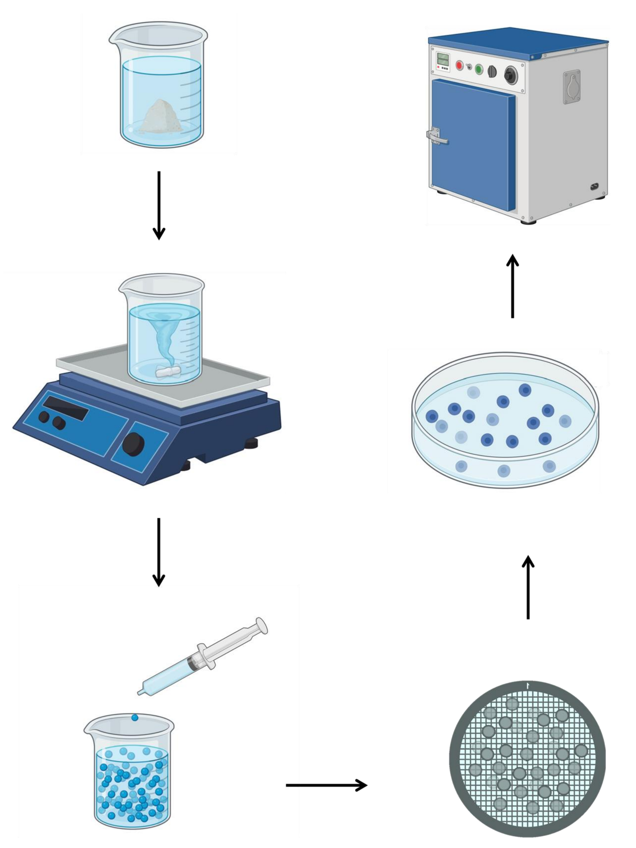
Materials for Medicine Research Group, School of Medicine, Royal College of Surgeons in Ireland, Medical University of Bahrain, Kingdom of Bahrain

Introduction

Nanoremediation utilizes the nanotechnology of silver nanoparticles (AgNPs) to detoxify hospital waste and environmental treatment. AgNPs (1-100 nm) exhibit antimicrobial properties due to their high surface-to-volume ratio, enabling them to penetrate microbial cells, release silver ions (Ag^{+}) and disrupt pathogenic cellular processes. Sodium alginate is a biocompatible polysaccharide from brown seaweed, used in AgNP synthesis via cross-linking polymerization to form gelatinous beads with metal ion-binding properties. The latter technique is cost-effective, energy-efficient, and reusable for detoxifying toxic organic compounds and combating drug-resistant bacteria like *E. coli*, *S. aureus*, and *P. aeruginosa*. The study also employes UV-Vis and FTIR spectroscopy for nanocomposite characterization, aiming 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

Table 1. The components of samples Alg-Ag-0 and Alg-Ag of Silver Alginate Solutions.

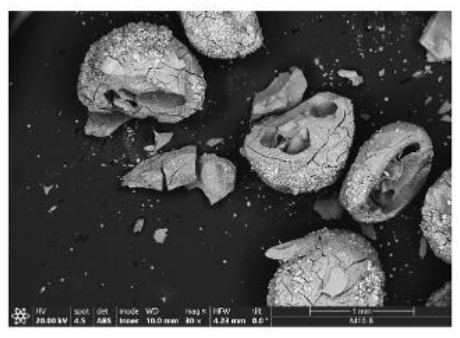


Fig 1. Scanning electron micrograph (SEM) of the silver nanocomposite beads.

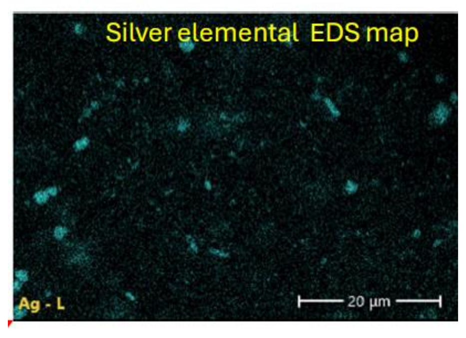


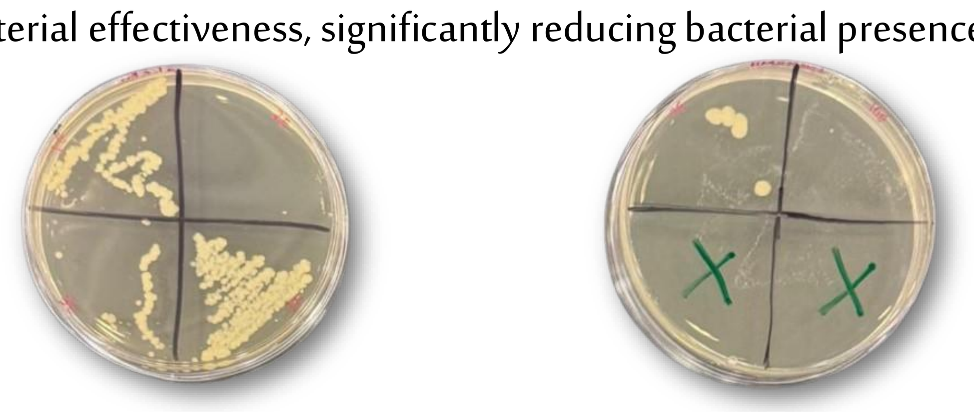
Fig 2. Energy dispersive elemental mapping of silver nanoparticles in the beads.

Preliminary Results

Antibacterial Acitivity

After incubation, the two antibacterial plates were initially streaked with *E. coli*:

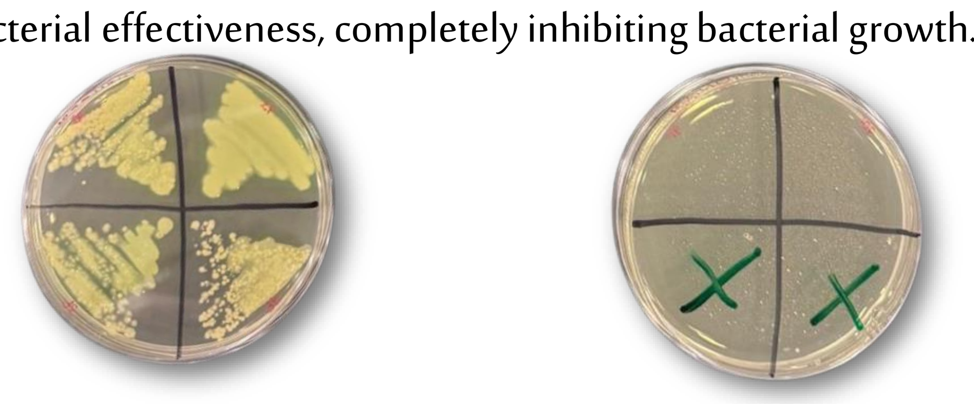
- **Alg-0-Ag** (Bottom right quadrant): Displayed persistent bacterial growth, indicating minimal to no antibacterial activity.
- **Alg-Ag** (Top left quadrant): Demonstrated approximately 90% antibacterial effectiveness, significantly reducing bacterial presence.



Alg-0-Ag **Alg-Ag**

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..



Alg-0-Ag **Alg-Ag**

Swelling Behavior

The synthesized 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 matrix.

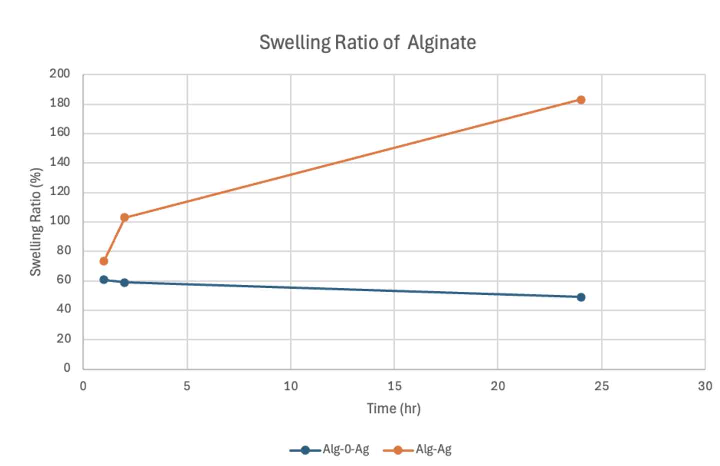


Fig 3. Alg-Ag demonstrates high swelling bahavior. Alg-0-Ag exhibits low porosity following the constant decrease in swelling ratio.

Discussion and Significance of the Project

The beads' antimicrobial activity enables them to penetrate biological substances and biofilms, thereby preventing the degradation of toxic compounds and disinfecting pathogens from healthcare infectious disposables. In light of research advances and the revolutionized field of nanotechnology, silver nanoparticles will continue to be a valuable tool in detoxifying the environment and mitigating the effects of hospital pollutant particles.

In addition, the development and evaluation of sodium alginate-poly sodium acrylate silver nanocomposites highlighted their potential applications 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.

Catalytic Degradation

The beads achieved nearly 100% degradation of Congo red and 2-nitrophenol within 30 minutes, showcasing their exceptional potential for environmental detoxification. Their ability to rapidly break down toxic compounds and be reused positions them as promising candidates for addressing industrial and wastewater pollutants, with silver nanoparticles enhancing their catalytic efficiency in treating contaminated water.

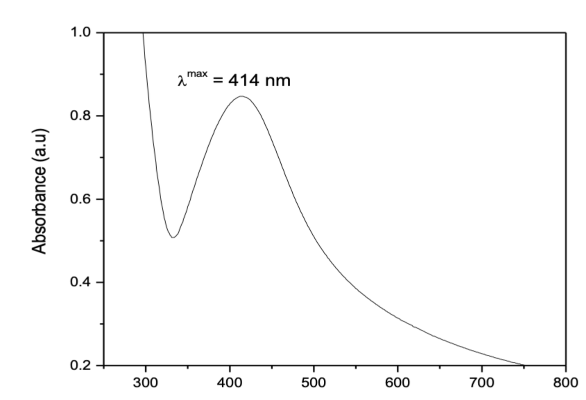
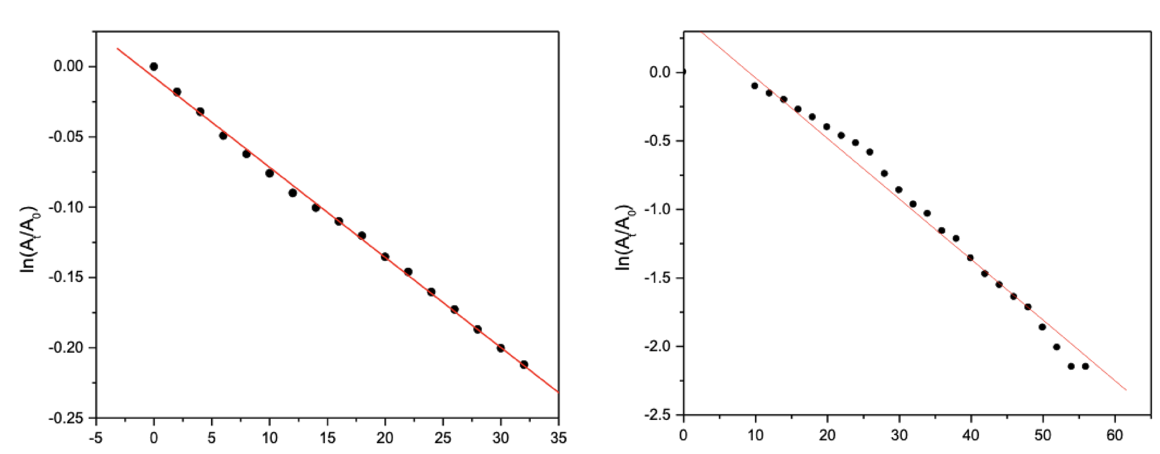


Fig 4. Absorption spectrum confirming the presence of Silver nanoparticles. The peak maxima at 414 nm is characteristic of silver nanoparticles. The symmetrical shape of the peak indicates that the nanoparticles are spherical in shape.



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.

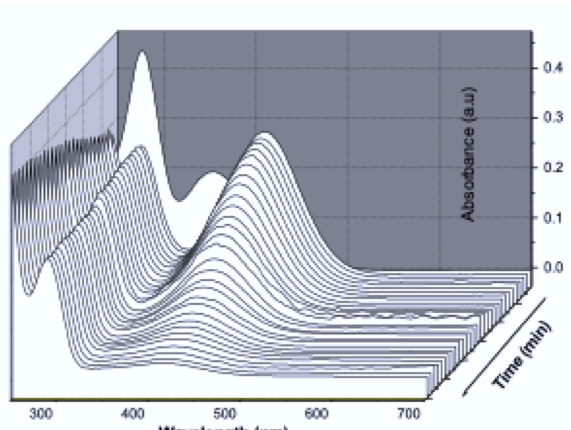


Fig 7. Absorption spectrum showing degradation of 2-Nitrophenol dye as function of time.

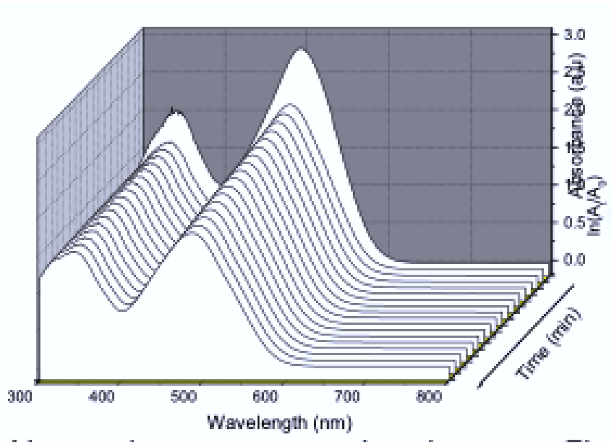


Fig 8. Absorption spectrum showing degradation of Congo Red dye as function of time.

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