# Spinach-Mediated Synthesis of Silver Nanoparticles/Nanoclusters and Fabrication of Reusable Polymer Beads and Membranes for Antimicrobial and Photocatalytic Applications

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## Abstract

In this study, we report a novel and eco-friendly approach for the green synthesis of silver nanoparticles (AgNPs) using spinach leaf extract as a reducing and stabilizing agent. The synthesized AgNPs were characterized using UV-vis spectrometry. To further enhance the applicability of the AgNPs, alginate beads were prepared using the extracted AgNPs. The AgNP-loaded alginate beads were then evaluated for their ability to degrade three common organic pollutants, 2-nitrophenol, methyl orange & Congo Red. The degradation efficiency was assessed by monitoring the absorbance changes of the dye solutions over time using UV-vis spectrometry. The results revealed that the AgNP-loaded alginate beads exhibited remarkable degradation activity for 2-nitrophenol, methyl orange & Congo Red. The enhanced degradation performance was attributed to the synergistic effects of AgNPs and alginate. AgNPs acted as catalytic sites for the degradation process, while alginate provided a stable matrix for the immobilization of AgNPs and facilitated mass transfer of the pollutants to the catalytic sites. The study highlights the effectiveness of AgNP-loaded alginate beads as a promising and eco-friendly material for medical treatment applications. The beads offer several advantages over conventional methods, including ease of preparation and enhanced degradation efficiency. This study paves the way for the development of sustainable and effective nanomaterial-based solutions for environmental remediation.

## Introduction and Research Questions

In the realm of nanotechnology, silver nanoparticles (AgNPs) have emerged as a class of materials with remarkable properties, holding immense promise for diverse applications. However, traditional methods of AgNP synthesis often rely on hazardous chemicals, raising concerns about environmental impact and human safety. Seeking an alternative, this research have turned to nature's bounty, exploring the green synthesis of AgNPs using plant extracts, particularly those derived from spinach leaves.

- Can silver nanoparticles (AgNPs) be effectively synthesized using spinach leaves as a reducing and stabilizing agent?
- Does green synthesis of silver nanoparticles (AgNPs) influence the dye degradation efficacy?

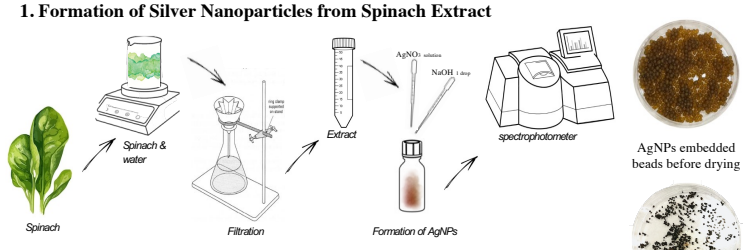
Addressing these research questions holds significant importance due to their implications for environmental sustainability, improved properties for medical applications, economic advantages, and promotion of sustainable practices.

## Aim of the Research Project

1. To synthesize silver nanoparticles using spinach leaves.
2. To evaluate the catalytic activity and antibacterial activity of silver nanoparticles

## Approach & Methodology

### 1. Formation of Silver Nanoparticles from Spinach Extract



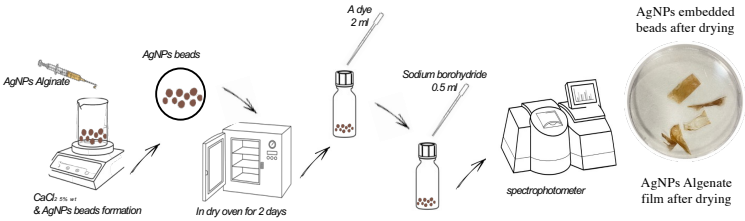



AgNPs embedded beads before drying



AgNPs embedded beads after drying

### 2. Syntheses of Silver Nanoparticle-Embedded Alginate Beads



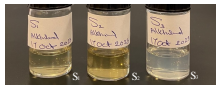



AgNPs Algenate film after drying

### *Effect of Silver salt and Extract on the Synthesis*

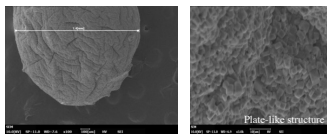
| | *Extract (in water)* | *AgNO3 (in water)* | *Before adding 1 drop of NaOH* | *After adding 1 drop of NaOH* |
|---|---|---|---|---|
| *Sample 1* | 3 ml | 3 ml | Pale yellow | Dark Green |
| *Sample 2* | 5 ml | 1 ml | yellow | Brown |
| *Sample 3* | 1 ml | 5 ml | Pale yellow | Dark Green |

- Before adding 1 drop of NaOH



- After adding 1 drop of NaOH

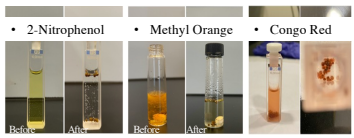
### *Silver nanoparticle-embedded beads visualized by SEM*




Silver nanoparticle beads synthesized using a physical crosslinking method with calcium chloride

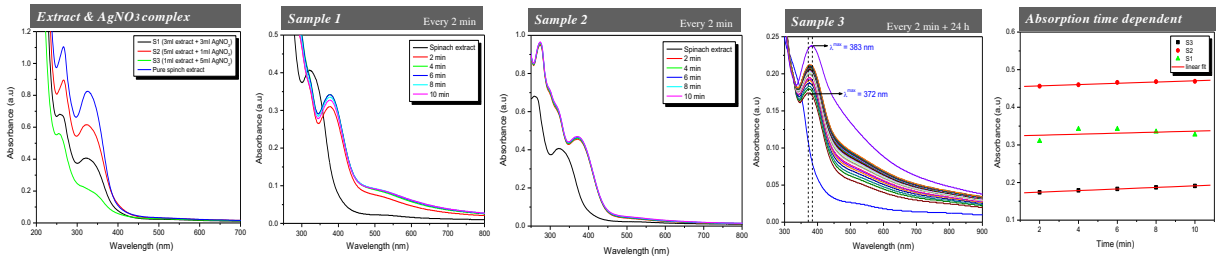
### *Catalytic Properties of Nanoparticle Embedded Beads*

- 2-Nitrophenol
- Methyl Orange
- Congo Red



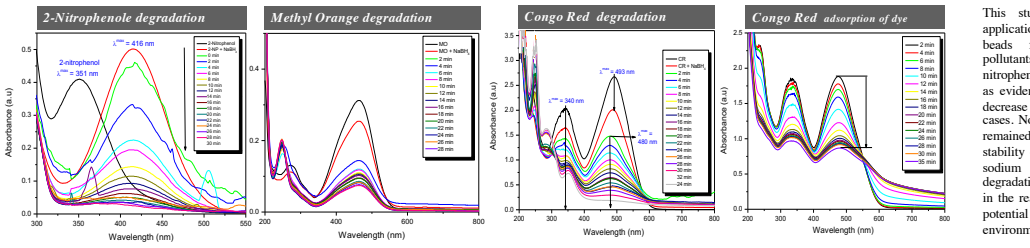

## Highlights of Results

### 1. Formation of Silver nanoparticles (AgNPs) using spinach extract & Time-dependent change in absorbance




This study reports the successful synthesis of silver nanoparticles (AgNPs) using spinach extract in three samples. UV-Vis spectra analysis confirmed the formation of AgNPs, evidenced by a characteristic peak around 400 nm. Interestingly, sample 2 exhibited the highest absorbance peak, indicating a greater concentration of AgNPs. This observation suggests that increased spinach extract content, relative to the silver salt precursor, promotes enhanced AgNP formation.

### 2. Degradation of 2-Nitrophenol, Methyl range & Congo Red after adding AgNPs beads & Time-dependent changes in absorbance




This study demonstrates the successful application of silver nanoparticle-embedded beads for biodegradation of various pollutants. The beads effectively degraded 2-nitrophenol, methyl orange, and Congo red, as evidenced by visual color change and a decrease in absorbance values in all three cases. Notably, the initial color of the beads remained unchanged, indicating their stability during the process. The addition of sodium borohydride further enhanced the degradation rate, suggesting its catalytic role in the reaction. These findings highlight the potential of these beads for efficient and environmentally friendly pollutant removal.

While Figure "Congo Red: Absorption of Dye" initially indicated degradation without sodium borohydride, further analysis revealed dye adsorption onto the bead surface rather than true biodegradation. This was confirmed by post-treatment with sodium borohydride, which desorbed the dye and restored the original black color of the beads. This finding underscores the importance of complementary analyses to differentiate between adsorption and degradation mechanisms.

## Conclusions

- ✓ The synthesis of AgNPs using spinach extract was successfully accomplished, as demonstrated by the emergence of a peak in the spectrometry at approximately 400 nm. Moreover, the peak intensity exhibited a gradual increase over time, confirming the ongoing production of AgNPs.
- ✓ The UV-Vis spectra clearly demonstrate the successful degradation of 2-nitrophenol, methyl orange & Congo Red dye by green synthesized AgNPs. The absorbance steadily decreased over time, reaching a minimal value, indicating the effective removal of the dye.

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