# Layered Double Hydroxides as Nitrate Adsorbents in Water and Their Incorporation into Alginate Hydrogels Using Various Techniques

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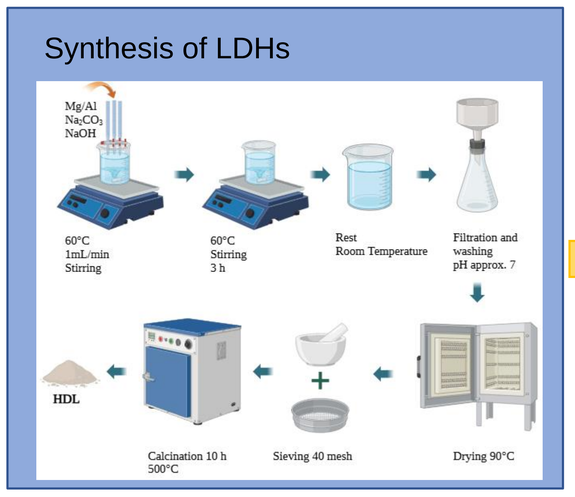
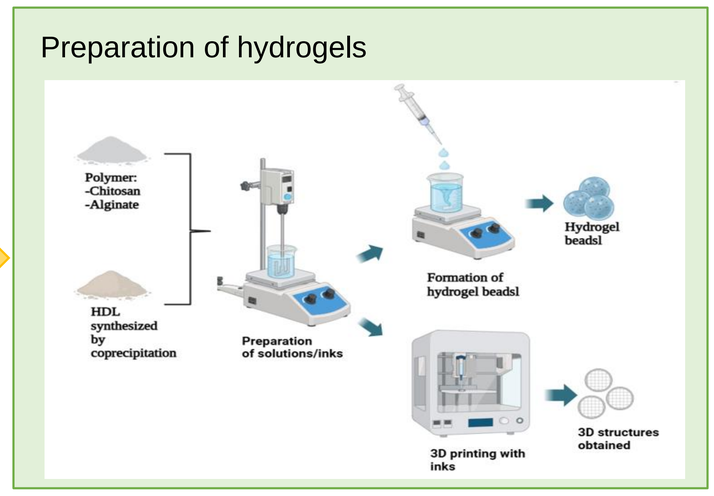
## Introduction

Nitrate contamination of water is a growing issue due to agricultural practices, industrial activities, and the natural characteristics of water sources. Hydrotalcites, or layered double hydroxides (LDHs), are effective adsorbents for contaminants such as nitrates. In this study, hydrogels incorporating LDHs were developed to create filters for water remediation. Synthesis, characterization, and nitrate removal tests were performed, achieving good results in both simulated and real water. Subsequently, a composite material of LDHs and biopolymers (alginate) was fabricated into spheres and 3D structures, which were tested as adsorbent materials.

## Experimental procedure

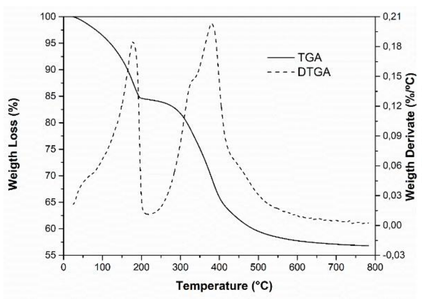


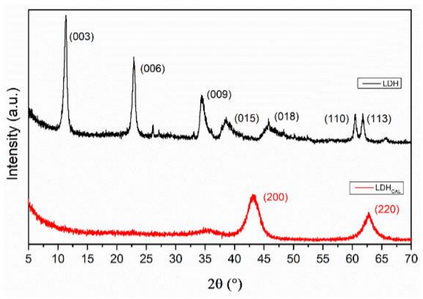

## Results

- *LDHs*

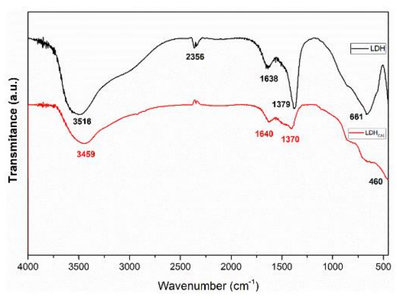
*-TGA*




*-XRD*



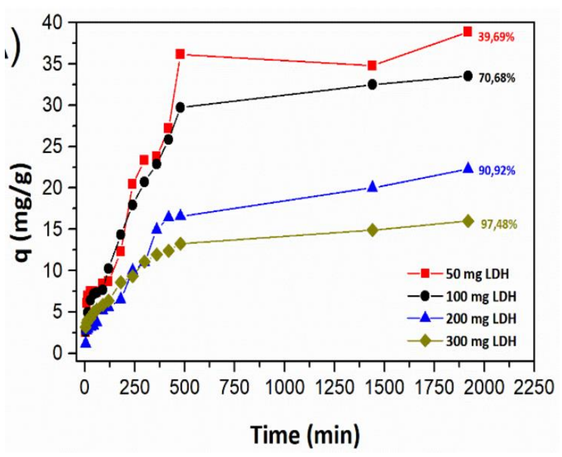

*-IR*




✓ The curve TGA shows two main stages: 1) between 20.0 °C and 200.0 °C, a 15.6% mass loss, due to the removal of physisorbed and interlaminar water, indicated by a peak at 178.9 °C in the DTG. 2) between 200.0 °C and 500.0 °C, a 24.6% mass loss related to CO3 elimination and dehydroxylation of HDL layers.

✓ XRD and IR spectra reveal the characteristic signals for HDL, which disappear after calcination, transitioning to mixed oxides. The IR spectrum shows a new band at 460 cm-1, corresponding to the vibrations of magnesium and aluminum oxides.

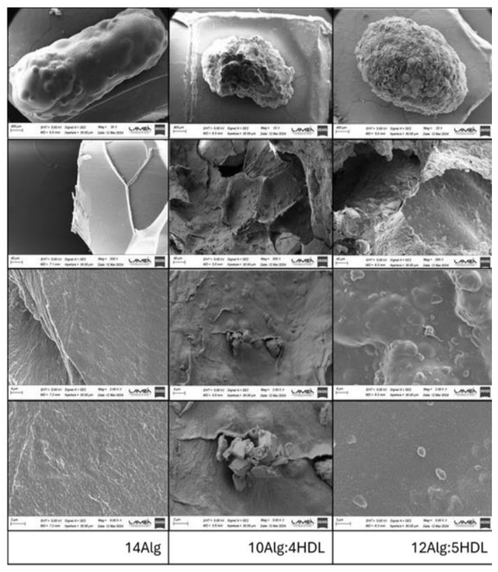
*-Nitrate removal*




✓ The optimal dose for the removal test was 100 mg of LDH in 50 ml of water (2 g/L), providing a balance between adsorption capacity (qe) and removal efficiency, achieving a qe of 33.5 mg/g and a removal percentage of 70.68%.

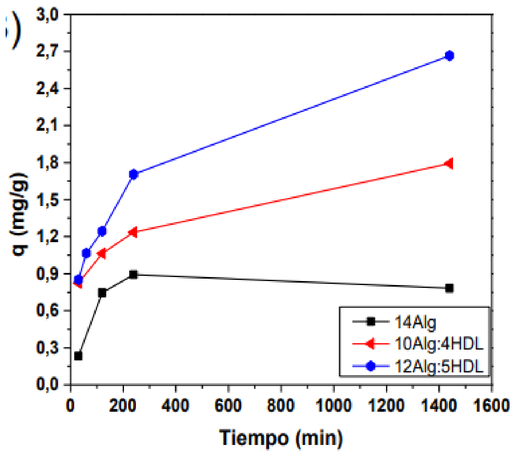
- *Hydrogels Alginate - LDH*

*-SEM*




✓ Ellipsoidal structures, which increase their porosity as HDL is added to the formulation.

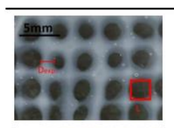
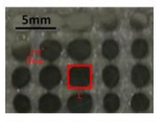
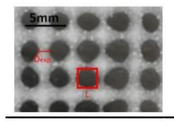
*-Nitrate removal*



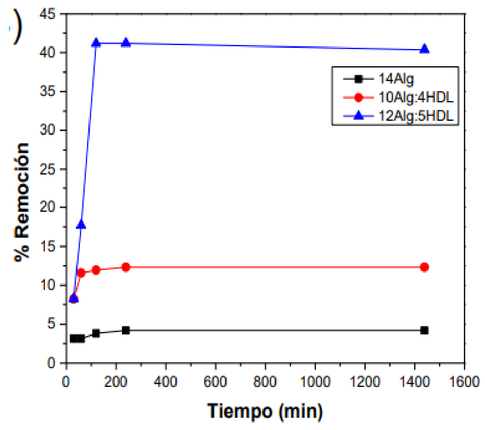

✓ La remoción de nitratos es mayor en sistemas con más HDL. El alginato solo tiene baja adsorción (0,89 mg/g), mientras que el sistema 12Alg:5HDL, con más arcilla, alcanza una adsorción de 2,66 mg/g y 27,90% de remoción.

- *3D printing of alginate and HDL hydrogels*

*-SEM*

| | | Pore Printability | Strand Printability |
|---|---|---|---|
| | | $P.Pr = L^2/16A$ | $S.Pr = 1 - \frac{Ds-Dexp}{Ds}$ |
|  | 14Alg | 0,902 | 1,00 |
|  | 10Alg:4HDL | 0,952 | 1,02 |
|  | 12Alg:5HDL | 0,914 | 1,10 |

*-Nitrate removal*




✓ The prepared biotinks were optimal for 3D printing, producing pieces with good precision, showing Pore Printability values between 0.9 and 1.0 and Strand Printability values between 1,0 and 1,1.

✓ Los sistemas con más HDL muestran mayor adsorción, ya que la capacidad de remoción depende de la arcilla agregada. El sistema 12Alg:5HDL, con mayor contenido de arcilla, presenta la mayor adsorción.

## Conclusion

The layered double hydroxides were successfully synthesized using the co-precipitation technique, demonstrating high efficiency in nitrate removal in both simulated and real water. Additionally, new nanocomposite materials were obtained by incorporating these hydroxides into alginate spherical hydrogels, and 3D-printed pieces were fabricated using this material. Nitrate removal tests showed higher efficiency in the Alg12:HDL5 systems. Furthermore, hydrogels prepared with 3D printing bioinks showed outstanding results in nitrate removal.

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