The REMEDIATE Project: bioestimulation for inducing in-situ denitrification in the aquifer area discharging to the Mar Menor lagoon (Campo de Cartagena, SE Spain)

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Introduction

The **REMEDIATE project** (***Groundwater pollution and induced in-situ remediation of aquifers discharging to coastal lagoons***) aims to reduce the concentration of target pollutants (nitrate and emerging contaminants, ECs) in an aquifer polluted from agricultural activities, that discharges into a coastal lagoon. To that end, bioestimulation is proposed to induce in-situ denitrification by adding agri-food industry by-products that serve as electron donors for heterotrophic microbial denitrification.

This research focuses on Campo de Cartagena Quaternary aquifer (SE Spain), which discharges into the Mar Menor lagoon. Groundwater flow is one of the main nitrogen carriers and has caused eutrophication of the lagoon since 2015, leading to a severe ecological harm.

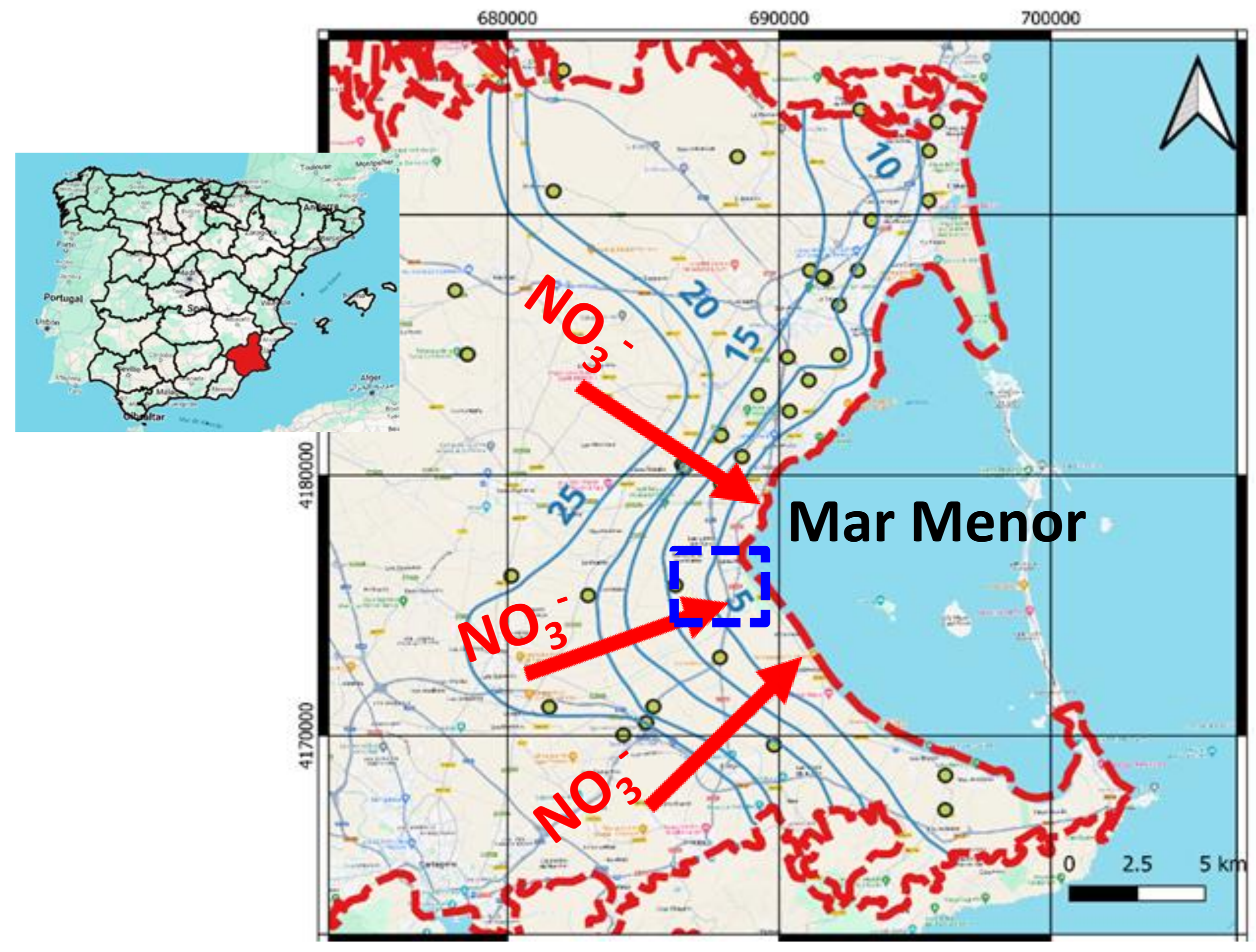
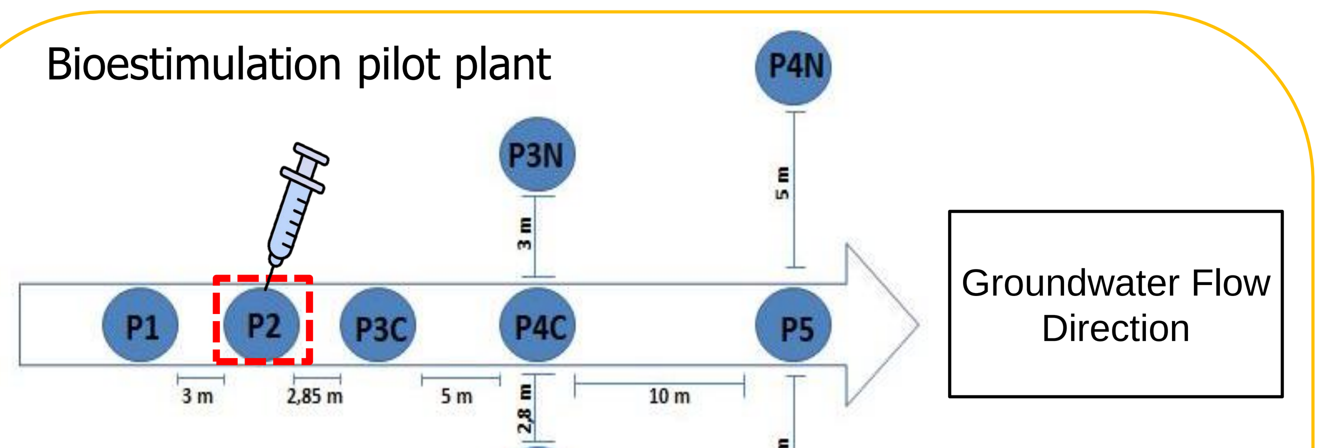


Figure 1. Piezometric map (March 2024) and flux of nitrates discharging by groundwater into the Mar Menor lagoon. Nitrates mainly are related to the agricultural activity in Campo de Cartagena. The blue square indicates the location of the pilot monitoring wells for denitrification of groundwater.

Methodology: preliminary field work

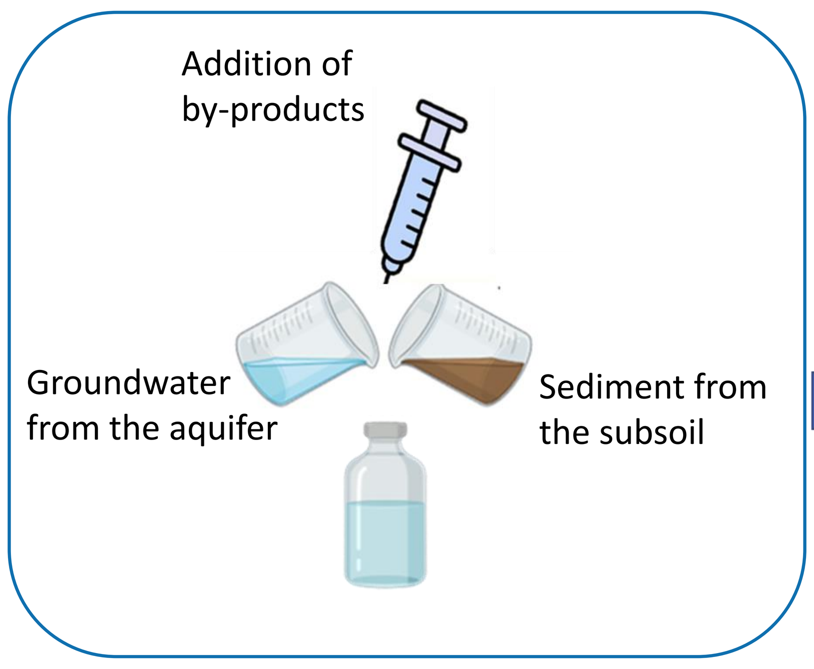
Drilling works at Campo de Cartagena aquifer during the installation of the pilot monitoring and injection wells.

- Soil sampling and groundwater sampling for the batch experiments
- Hydrogeological characterization of the aquifer:
- boreholes correlation to determine the variability in the hydraulic conductivity
- pumping tests and tracer tests

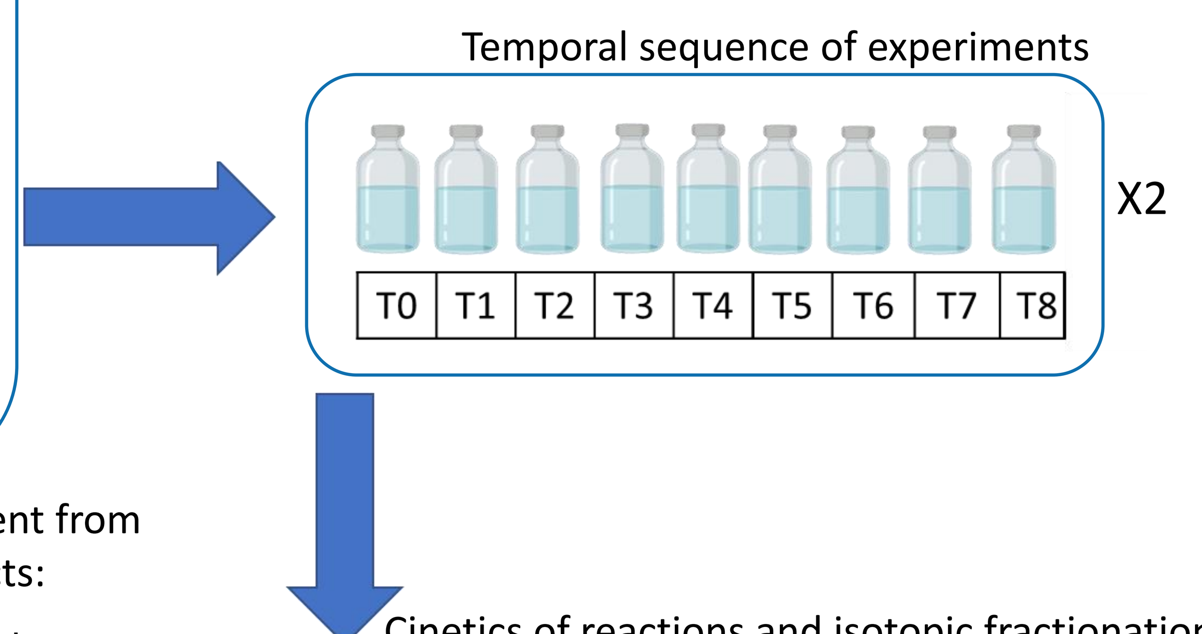


- P2 is the proposed injection point to add the by-product

Methodology: batch experiments (laboratory)

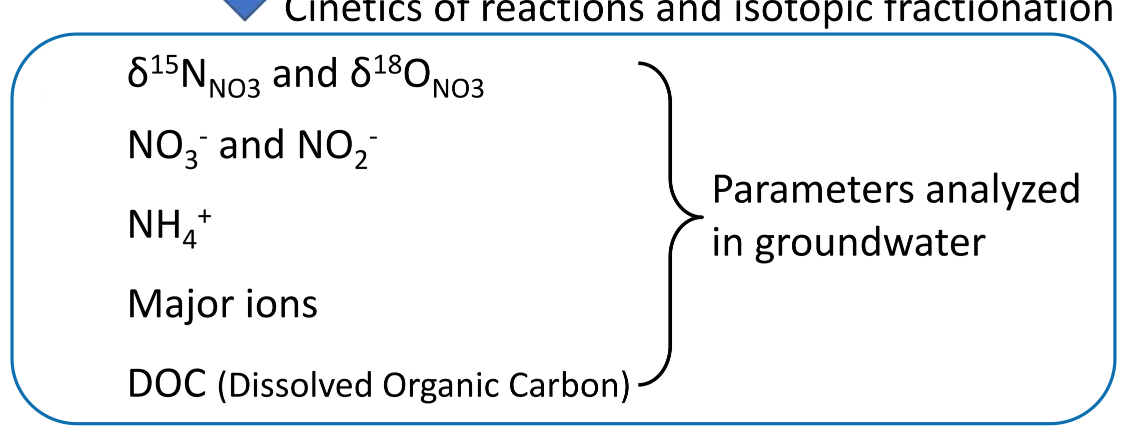


The aim is to assess the viability of using a specific electron donor to promote denitrification while avoiding adverse effects.



Batch experiments using water and sediment from the aquifer and adding different by-products:

- Four by-products were evaluated: S1 and S2 (dairy) and E1 and E2 (sweetener)
- Several depths were assessed in the subsoil (8,4-9,3 m, 11,2-11,7 m and 20,7-21,0 m) according to Loss-on-ignition (LOI)



Results

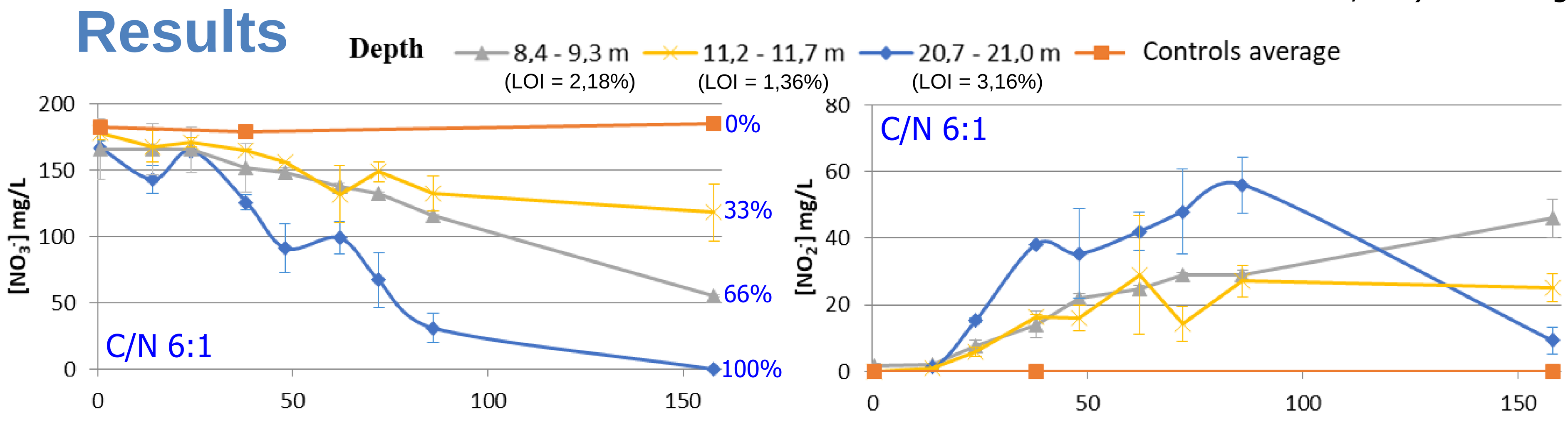


Figure 2. Evolution of Nitrate and Nitrite concentrations adding by-product E1 (3 depths).

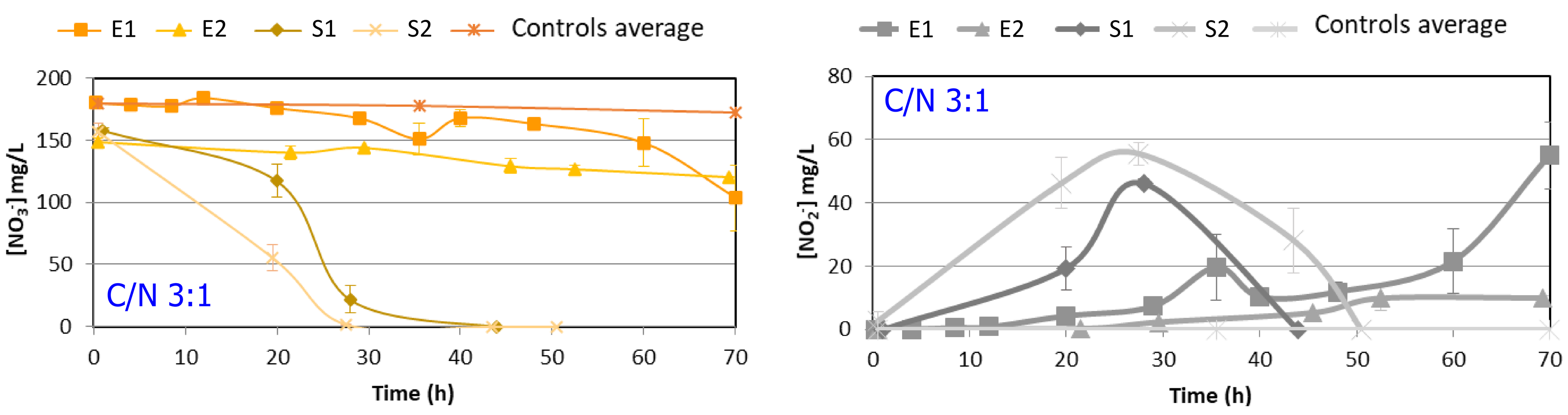


Figure 3. Evolution of Nitrate and Nitrite concentrations adding by-products S1, S2, E1 and E2 (at 11,2-11,7 m).

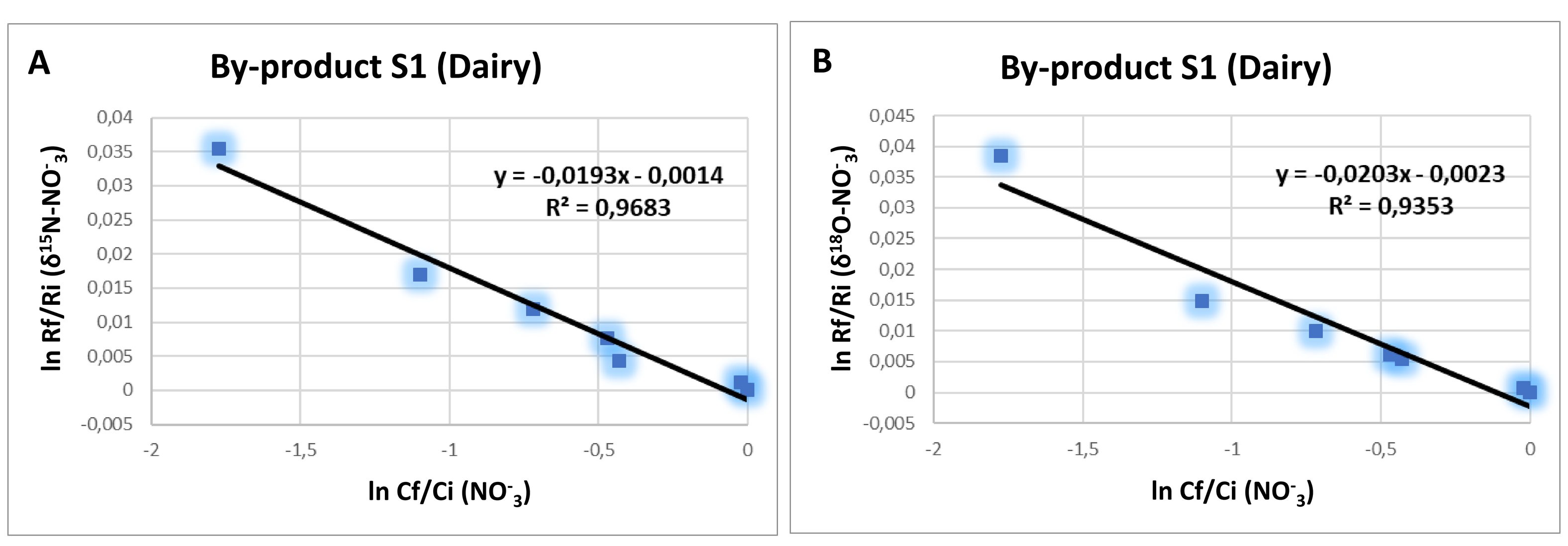


Figure 4. NO_3^- and NO_2^- ε calculation. A and B show the fractionation for the $\delta^{15}N\text{-}NO_3^-$ and $\delta^{18}O\text{-}NO_3^-$, respectively. $\varepsilon^{15}N_{NO3}$ is −19,3‰ and $\varepsilon^{18}O_{NO3}$ is −20,3‰.

Conclusions

- Dairy by-products (S1 and S2) showed the highest efficiency to promote denitrification in groundwater.
- The highest levels of organic matter in soil are also associated with the highest efficiency.
- Harmful intermediate compounds were not detected at the end of the chemical reactions, such as Nitrite, Nitrous Oxide, or Ammonium.
- Denitrification triggers fractionation of $^{15}N_{NO3}$ and $^{18}O_{NO3}$.
- The isotopic fractionation of Nitrate decomposition has a value of $\varepsilon^{15}N_{NO3}$ = -19,3 ‰, and $\varepsilon^{18}O_{NO3}$ = -20,3 ‰.
- This isotopic fractionation will be used to evaluate the efficiency of bioremediation at a pilot-scale test.
- To promote both a cost-effective strategy and the circular economy, the nearest dairy by-product will be selected.

Future actions

- Perform a column experiment in the laboratory (ongoing) in order to determine the C/N ratio and the optimal frequency of injections.
- Perform the in-situ bioestimulation at a pilot-scale test.
- Evaluate the efficiency of the in-situ denitrification according to the isotopic fractionation.
- Assess the influence of the injection on the microbiological community and the ECs.
- Conduct a geochemical modelling.

Acknowledgments

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